Long-run Determinants of Technological Progress in Nigeria

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Abstract

Growth economists established that sustainable economic growth depends considerably on the level of technological progress in an economy. Using growth accounting model, economic researchers were able to estimate a measure of technological progress in any economy which has been known as Total Factor Productivity (TFP). Several research works have been carried out on the determinants of TFP in different countries using different methodologies. This study utilized time series data sets on TFP constructed based on purchasing power parity covering from 1960-2010 to estimate long run determinants of technological progress in Nigeria using Vector Error Correction Mode(VECM)l. The co-integration result shows evidence of two co-integrating equations while the Fully Modified Ordinary Least Squares (FMOLS) shows that the chosen variables are significantly linearly correlated with TFP. The estimated VECM reveals that 0.025 percent of disequilibrium in the TFP model is corrected within a year while imports, domestic credit and exchange rate are favourable for TFP growth whereas trade and degree of openness are negatively related to TFP. Policies that will strengthen the financial sector, improve our trade and encourage investment in new capital are bound to engender growth of TFP.

Keywords: Total Factor Productivity, Technological,VECM.

Introduction

The attainment of sustainable economic growth and development has been the main objective of government and policy makers of any nation. To a very large extent, the standard of living of the citizens of any country is determined by the level of output produced by the respective factors of production owned and employed by the economy. To achieve a sustainable level of output growth, the respective factors of production should be employed efficiently. Countries that share homogenous levels of capital stock and active labour force but different levels of output growth are found to have disparate measures of the efficiency parameter in their respective production function. The efficiency of factor employment has several interpretations in economic literature but it has been universally referred to as technical change and innovation. However, the economics of innovation and technical change in an economy depends on the level of technology available to that economy. Generally, the disparity amongst nations in terms of output growth is traceable to technological progress or Total factor productivity. Economic historians have argued that long-term growth of an economy is to a great extent attributable to the growth of the Total Factor Productivity (TFP) or technological progress rather than growth in factor accumulation. Following neoclassical assumption of exogenous technological change and New

Growth Theorists (NGT), endogenous technological change, output growth can be sustained through technological progress. Countries that have experienced sustained economic growth over time are found to have invested both in physical factor accumulation and growth in labor efficiency [1]. Due to the important role of technological progress in economic growth, economic researchers have been investigating its determinants using time series, panel and cross-sectional data. Based on growth accounting framework, data on TFP is constructed as the residual of a typical production function after taking into account of any factor contribution. Research works on technological progress in Nigeria have been very sparse and factor prices in such works are based on the local currency. In this study, we decided to change the direction of TFP determinants by employing data sets constructed from purchasing power parity since most technologies employed in the production of goods and services are imported. More so, output are better compared among nations based on the "law of one price". The objective of this study therefore is to investigate the long-run determinants of technological progress in Nigeria using time series data sets constructed from purchasing power parity while deploying a multivariate cointegration analysis. The result of this study should be a good comparison to other similar works in the western countries from where we import our technologies and indication of policy direction from international viewpoint.

Growth Accounting

Growth accounting model developed by Solow [2] is usually a point of reference to explain what is meant by technological progress (TFP). Growth accounting is viewed as an empirical methodology that allows economic researchers to decompose the observed growth in GDP into different components that are associated with changes in factor inputs and in the production technologies [3]. Because technological progress is difficult to measure directly with the growth rate of the GDP, economists resorted to taking the part of growth that is not accounted for by observable growth of inputs to be a measure of technological progress. That is, residual of growth not accounted for by capital and labour (given the interaction with other observable inputs). Even though this exercise can be extended to explain elements such as government policies, human capital, initial levels of physical capital and natural resources, growth accounting generally measures the fundamental determinants of economic growth without analyzing factors that drive the growth rate of each input or factor share. Following a typical aggregate production function, TFP can be estimated as follows:

$$Q = A(t) f(K, L) \qquad (1)$$

Where

Q represent aggregate output

$A(t)$ is a function of time that allows for neutral technological change

$f(K, L)$ Is a function of capital and labour

The above production function can be treated as an identity. Differentiating the LHS and RHS with respect to time and dividing by Q we obtain the following expression

$$\frac{\dot{Q}}{Q} = \frac{\dot{A}}{Q} f(K, L) + \frac{A}{Q}\frac{\partial f}{\partial K}\dot{K} + \frac{A}{Q}\frac{\partial f}{\partial L}\dot{L} = \frac{A}{A} + \frac{A}{Q}\frac{\partial f}{\partial K}\dot{K} + \frac{A}{Q}\frac{\partial f}{\partial L}\dot{L} \qquad (2)$$

In the neoclassical analysis of technological progress, factors are paid their marginal products. Thus wage and rent are derived as follows:

$$w = A\frac{\partial f}{\partial L} \text{ and } r = A\frac{\partial f}{\partial K}$$

Substituting these factor shares into equation (2), we obtain

$$\frac{\dot{Q}}{Q} = \frac{\dot{A}}{A} + \frac{r}{Q}\dot{K} + \frac{w}{Q}\dot{L} \qquad (3)$$

Which can be expressed as

$$\frac{\dot{Q}}{Q} = \frac{\dot{A}}{A} + \frac{rK}{Q}\frac{\dot{K}}{K} + \frac{wL}{Q}\frac{\dot{L}}{L}$$

where wL is aggregate labour income and rK is aggregate capital income)

To derive technological progress as a residual , we have

$$\frac{\dot{Q}}{Q} = \frac{\dot{A}}{A} + \alpha\frac{\dot{K}}{K} + \beta\frac{\dot{L}}{L} \qquad (4)$$

Where $\beta = \frac{wL}{Q}$ (labour`s share of GDP), $\alpha = \frac{rK}{Q}$ (capital`s share of GDP)

Both α and β can be computed from output (GDP) data. Rearranging equation (4) to account for contribution of each factor to aggregate output, we obtain the residual referred to as Total Factor Productivity. Thus we have

$$\frac{\dot{A}}{A} = \frac{\dot{Q}}{Q} - \alpha\frac{\dot{K}}{K} - \beta\frac{\dot{L}}{L} \qquad (5)$$

Therefore $\frac{\dot{A}}{A}$ can be determined as the residual from output which cannot be explained by adjustments on capital and labour.

Total factor productivity, however, is conventionally seen as the increase in output that is not traceable to factor inputs (capital and labor). Put differently, TFP is a measure of improvement in technology and efficiency in an economy [4]. Even though there is general acknowledgement amongst economists of the influence of TFP on growth, there is lack of theoretical framework for the analysis of TFP [5]. This may be as a result of the divergent views with regard to the actual measurement of TFP. Economists generally align their definitions of TFP to three main conceptualizations:

i. The conventional view-TFP is a measure of technological progress
ii. TFP is technical change associated with externalities and scale effect (disembodied technical change)
iii. TFP is a measure of our ignorance (like manna from heaven)

This study adopted the conventional definition of total factor productivity as a measure of technological progress.

A review of some of the growth accounting literature reveal that adjustments can be made to the basic growth accounting equation in order to include human capital variable or labor quality variable. It can be showed that the Solow model can be augmented to include a measure of human capital index [6]. Even though there is no consensus among economic scholars whether human capital should be treated as separate factor of production in growth accounting model, [7] argues that human capital can influence growth through its effects on TFP. In this case, [1] suggest that human capital is labor-augmenting. Similarly, it can be showed that education and better health improve the quality of the labor force which can translate to growth in output [8].

Neoclassical Model of Technological Progress (Solow-Swan Model)

In this fundamental neoclassical growth model, output growth depends on change in capital stock. Mathematically, the per capita equation of this model is given as:

$$\dot{k} = s.f(k) - (n+\delta).k \qquad (6)$$

Equation (6) is the fundamental differential equation of Solow-Swan model where $s.f(k)$gross investment is and $(n+\delta).k$ is effective depreciation rate of capital. If the saving rate, s, were 0, capital per person would decline partly due to depreciation of capital at the rate δ and partly due to the increase in population at the rate n.

We can equally show that over time, the steady state of the economy is given by

$$s.f(k^*) = (n+\delta).k^* \qquad (7)$$

The steady state occurs when the various quantities grow at constant (perhaps zero) rates. In the Solow-Swan model, the steady state is identical to $\dot{k}$ =0 in equations (6)

In equations (6) and (7) of the Solow-Swan model, we assumed that the level of technology is constant overtime which is unrealistic in the long run. This is so because diminishing returns would set in and per capita growth cannot be maintained if we continue to accumulate more capital per worker. The neoclassical models recognize that technological progress is needed if per capita growth is to be sustained. In other words, improvement in technology will take care of the problem of diminishing return [3]. According to this model, technological progress is exogenous and can only be capital-saving or labor-saving. Otherwise, it is said to be neutral or unbiased when it is neither capital-saving nor labor-saving technological progress. Similarly, technological progress can be capital augmenting or labor augmenting. In the Solow-Swan model, technological progress is labor augmenting. If we assume only constant rates of capital growth and constant rate of population growth, it then follows that only labor augmenting technological change will be consistent with the existence of a steady state.

We can include labor-augmenting technological progress in the aggregate production function by introducing the technology term T(t). Now the condition for the change in the capital stock is

$$\dot{K} = s.F[K, L.T(k)] - \delta K \qquad (8)$$

Where T(t) is a multiple of L.
The change in k over time is derived by dividing both sides of equation (6) by L. which gives the following expression

$$\dot{k} = s.F[k, T(t)] - (n+\delta).k \qquad (9)$$

Equation (9) indicates that output per person is now dependent on the level of technology, T(t).

Dividing both sides of equation (9) by k gives the growth rate of technology:

$$\dot{k}/k = s.F[k, T(t)]/k - (n+\delta) \qquad (10)$$

Using the Cobb-Douglas production function [$(\dot{\hat{k}}/\hat{k} = sA.(\hat{k})^{-(1-\alpha)} - (x+n+\delta)$] we can derive the speed of convergence to the steady state level of technology given as:

$$\beta^* = (1-\alpha).(x+n+\delta) \qquad (11)$$

Endogenous model of Technological Progress

The neoclassical growth model came under serious criticism by some new growth theorists on the grounds that in the long run the assumptions underlying the model fail to hold [3]. The assumptions of the neoclassical model are as follows:

- Technological progress in the model is exogenous.
- Existence of diminishing returns to capital
- Non-rival nature of technological ideas
- Constant returns to scale
- Perfect competition

These assumptions of the model led to the advancement of the Endogenous growth model of technological progress. It has been established that technological progress can be endogenous which is as a result of purposeful activity (such as R&D investment) which makes technological ideas not to be non-rival under the imperfect competition[9][10]. It is not assumed to take place on its own accord like “manna from heaven” type in the neoclassical model. The AK Model was advanced which endogenized technological progress. The distinct characteristic of endogenous growth model is that diminishing return to capital is absent. This has been shown to be true contrary to the assumption of the neoclassical model. Here, the production function is given as:

$$Y = AK \quad (10)$$

Where A is a positive constant that reflects the level of technology and K may be used in broad sense as capital which incorporates human capital. Output per capita is then given as $y = Ak$ and the average and marginal products of capital are constant at the level $A > 0$ [3]. Substituting $f(k)/k = A$ in equation (4) we obtain

$$\dot{k}/k = sA - (n + \delta) \quad (11)$$

The steady state growth rate of k is therefore given as:

$$(\dot{k}/k)^{*} = sA - (n + \delta) \quad (12)$$

And the per capita variables grows at the same constant rate by the following equation

$$y^{*} = sA - (n + \delta) \quad (13)$$

For a full explanation and understanding of the endogenous model of technological progress and its transitional dynamics the reader is referred to [3].

Selected Literature Review

Research works on technological progress in Nigeria is scanty. However, the following works is worthy of mention. [11] Studied the macroeconomic determinants of technological progress in Nigeria and concluded that macroeconomic instability, the level of financial development, and the level of human development are significant determinants of technological progress. He obtained a time varying TFP by employing Kalman filter model to determine the evolution of Solow residual from a perpetual inventory method while assuming the level of capital depreciation to be twenty percent. However , there is evidence supporting the fact that depreciation rate of fixed capital tends to be higher in developed countries than in developing countries.

An analysis was done on TFP in the Nigerian manufacturing industries with emphasis on the trend, causal factors and the policies that promote it [12]. He employed the approach of the trend analysis of TFP over the period 1980-1998. A major implication of his result is that the economic situation prevalent in Nigeria is an indication of the industry performance. Consequently, production improvements in an economy stimulates investment which in turn generates jobs and higher standards of living which translates to improved firm performance.

Similarly, Total Factor Productivity Growth (TFPG) was calculated for the aggregate manufacturing sector of Nigeria and across the various subsectors and correlates these with specific indexes of trade policy for the period covering 1962 to 1985 [13]. They employed both parametric and non-parametric approach for the analysis. Based on the non-parametric approach, strong assumptions of competitive equilibrium and constant returns to scale were imposed while the parametric approach relaxed the constraints of perfect competition and allows for the assumption of constant returns to scale to be empirically validated. They concluded that trade liberalization is a strong determinant of output growth through its influence on improved production.

Other determinants of technological progress from empirical work include degree of openness of the economy to international trade. One argument in support of TFP growth as a result of openness of the economy rests on the notion of static or dynamic gains from trade. Reallocation of resources to the production of goods for which a country possess comparative advantage can yield static gains from trade. This means that the economy produce at a lower opportunity cost than other countries and its consumption possibilities expands. On the other hand, dynamic gains from trade is said to occur when there is improvement in the production possibilities of an economy. That is, an outward shift of the production possibility frontier as result of improvement in technology. Since the country`s products sale in the competitive international market, it is important that such a country should strive to produce its exports at a low cost. [14] Maintained that international competition pressures different economies to operate in an efficient manner, producing high quality products and relentlessly seek improvements in its products. This follows that such countries should carry out enormous research and development in order to bring about cost saving innovations and equally hire highly skilled managers to manage their firms. This is likely to induce improvement in TFP of that economy. It has been argued that certain goods being imported from other countries may embody technological know-how [15]. This will have effect on the level of TFP in the economy as these goods can only be used effectively with the attached technology. In other words, importation of advanced goods can potentially increase the stock of knowledge which is also a measure of TFP (labour efficiency).

Most studies on TFP are related to human capital development because of its role in enhancing labor efficiency and productivity. It has been argued that qualified and highly skilled labor is needed in order to implement innovations brought about by technological improvement within the economy. This effectively improves the marginal productivity of the work force. Human capital development involves education of the labor force. Research show that countries with high school enrollment ratios tend to possess improved TFP when compared to others. [15] suggest that a country`s ability to absorb new knowledge through trade or FDI depends on the level of human capital development. He argued that R&D activities can trigger growth domestically when countries interact but this will only be benefited by countries that possess absorptive capacity in terms of human capital. One of the advantages of FDI to the recipient country has been that of establishment of backward and forward linkages with the country of origin. FDI to developing countries is viewed as one of the ways through which advanced technology can be transferred from the highly industrialized economies. In some instance, the government can deliberately create opportunities that attract FDI to the country because FDI produce positive externalities in the form of knowledge spillovers to the domestic economy through learning from nearby foreign firms and employee training programmes . Even though FDI has been seen as producing negative externalities, however, several empirical studies show that it helps domestic economies to grow in terms of their technology (TFP).

Capital stock needed to be upgraded periodically in terms of quality if firms are to remain competitive. New machines are more productive than older ones and such embodied technology are usually costly. Well developed financial system implies ease of assessing credit to finance technological change. Huge resources need to be invested in order to take advantage and master imported technologies. Financial development affects growth mainly through TFP growth rather than capital accumulation. Studies have shown that financial development and productivity growth is related as firms take advantage of growth opportunities by investing in new technologies.

Model Building, Variables and Data Sources

The current study focused on the long run determinants of technological progress in Nigeria using variables based on theoretical and empirical considerations. Other determinants exist and can equally be added to the model where there is data and Data Generating Process (DGP) can be modeled without difficulty. Here, we present the parsimonious model of TFP based on statistical plausibility, model selection criteria and model adequacy. Following the standard endogenous growth production function, we model the Nigerian technological progress (TFP) as follows.

$$Y = [(1 - a_k)K^{\alpha} A(1 - a_L)L]^{1-a}$$

$$A = B[a_k K]^{\beta}[a_L L]^{\lambda} A^{\theta}$$

Therefore,

$$A = tfp = f(docre_t, dpcre_t, exch_t, impt, openk_t, trade_t)$$

Where the exact econometric model is specified as follows

$$TFP = \phi + \beta_1 DOCRE_t + \beta_2 DPCRE_t + \beta_3 EXCH_t + \beta_4 IMP_t + \beta_5 OPENK_t + \beta_6 TRADE_t + u_t$$

Where

TFP	=	Measure of technological progress
$DOCRE_t$	=	Domestic credit provided by banking sector (% of GDP)
$DPCRE_t$	=	Domestic credit to private sector (% of GDP)
IMP_t	=	Imports of goods and services (% of GDP)
$EXCH_t$	=	Official exchange rate (LCU per US$, period average)
$OPENK_t$	=	Measure of degree of openness to international trade (at 2005 constant prices (%))
$TRADE_t$	=	Trade (% of GDP)
ϕ	=	intercept
β_s	=	slope coefficients
u_t	=	error term

All the data used for this study were sourced from the World Bank country-database on Nigeria and Penn World Table version 8.0 constructed by [16]. The data covered the period between 1960 and 2010. This study adopted these data sets to minimize subjectivity associated with author-computed errors and bias from other previous work on TFP and to allow the model to fit as close as possible to the data generating process(DGP). It is important to note that all the variables were constructed based on Purchasing Power Parity (PPP).

Econometric Methodology

To begin this analysis, we first explored the time series property of the variables. It is required that the variables used in the study be integrated of the same order before a vector error correction mechanism can be estimated. To achieve this, we carried out a test for the stationarity on all the variables (TFP, DOCRE, DPCRE, EXCH,IMP, OPENK and TRADE). A stochastic variable is said to be stationary if its first and second moments are time-invariant. In other words, the members of stationary stochastic process must possess constant mean while the variance is expected not to vary with time. However, time series variables can be tested to confirm if they are stationary or non-stationary (unit root process) and to ascertain the order of integration. For the purpose of this study, it is expected that the variables are integrated of order one [i.e. I (1) process] before co-integration and VECM can be deployed. To test the order of integration, we deployed the Augmented Dickey-Fuller (ADF) unit root test proposed by Dickey and Fuller [17] with null hypothesis that the series are non-stationary.

If a group of time series variables are distributed as *I(1)* stochastic processes and share a common trend, a linear combination of some of the variables might be distributed as *I(0)* process. In that case, they are said to be cointegrated. We carried out the maximum likelihood multivariate co-integration test to check for the existence of a long-run relationship among the variables as the problem of spurious regression has been addressed for *I(1)* stochastic processes.

This test reveals the number of co-integrating relationship amongst the variables based on VAR estimation procedure. Following Johansen approach to co-integration, there can be a maximum of n-1 co-integrating vectors each of which forms a long-run equilibrium relationship amongst the selected variables. According to this framework, a long-run solution exists where there is full rank, r, of n independent equations for an nxn matrix of parameters which may depend on the restrictions imposed on the VAR. Unlike the Dickey-Fuller test, all the variables in a vector X_t must be stationary. Generally, the rank of the parameter matrix indicates the co-integrating vectors.

Johansen and Julius [18] proposed two tests to confirm the number of co-integration vectors by checking the significance of the characteristic root of the matrix. The two tests are as presented below:

$$\textit{Trace Statistics} = \lambda_{trace}(r) = -T \sum_{i=r+1}^{n} ln$$

and

$$\textit{Maximum Eigenvalue} = \lambda_{max}(r, r+1$$

Where $\hat{\lambda}_i$ is the estimated values of the characteristics roots and T is the number of observations. The trace statistics test the null hypothesis that the co-integrating rank is equal to r against the alternative that co-integrating rank is equal k while the maximum Eigen-value tests the null hypothesis that the co-integrating rank is equal to r against the alternative that co-integrating rank is equal $r+1$.

Having established co-integrating relationship between the variables, the Granger Representation Theorem proposed by Engle and Granger [19] state that an Error Correction Model (ECM) can be estimated that describes the short-run dynamics or how the co-integrating variables return back to equilibrium when there is deviation from its long-run equilibrium value. In this study, we estimated Vector Error Correction Model (VECM) based on the VAR estimation procedure. The VAR used in this study has the following reduced form representation:.

$$y_t = \nu + A_1 y_{t-1} + A_2 y_{t-2} + \cdots A_p y_{t-p} + \varepsilon_t \quad (2)$$

Where this is a VAR with p lags. y_t is Kx1 vector of variables, ν is a Kx1 vector of parameters, $A_1 - A_p$ are KxK matrices of parameters and ε_t is Kx1 vector of disturbances with zero mean. Since the variables in the model of equation (2) are *I(1)* processes and are linked together by a common stochastic trend, according to Granger Representation Theorem (GRT), the linear combination of these variables should be an *I(0)* process. This condition implies that the variables are co-integrated and the residual is stationary. In this case where some of the variables are trended, a reduced form VECM with deterministic components, can be modeled as follows

$$\Delta \boldsymbol{y}_t = \prod \boldsymbol{y}_{t-1} + \boldsymbol{\Gamma}_1 \Delta \boldsymbol{y}_{t-1} + \cdots + \boldsymbol{\Gamma}_{p-1} \Delta \boldsymbol{y}_{t-p+1} + CD_t + \boldsymbol{u}_t \qquad (3)$$

Where $\prod = -(\boldsymbol{I}_k - \boldsymbol{A}_1 - \cdots - \boldsymbol{A}_p)$ and $\boldsymbol{\Gamma}_i(\boldsymbol{A}_{i+1} + \cdots + \boldsymbol{A}_p)$ for $i = 1,...,p-1$, D_t contains the regressors related to the deterministic components and C is the parameter matrix. By subtracting y_{t-1} from both sides and rearranging terms based on the VAR of equation (2) above, a VECM is obtained. Since Δy_{t-1} is devoid of any stochastic trend, $\prod y_{t-1}$ is the only term that contains I(1) variables and hence are equally devoid of stochastic trend (i.e. the variable are stationary). Thus, the co-integration relationships between the variables are contained in $\prod y_{t-1}$. From the above specification, the $\Gamma_j s(j = 1,...,p-1)$ are the short-run adjustment parameters while $\prod y_{t-1}$ are the long-run equilibrium parameters.

Following the estimation of a VECM, Granger causality test is deployed to ascertain if there is causal relationship amongst the variables. According to the Granger Representation Theorem, variables that are individually *I (1)* processes and are co-integrated, past lags of each variable may contain useful information for the forecast of other variables in the system. For a two variable case, X_t and Y_t that are integrated of order one and are co-integrated, X_t is said to Granger-cause Y_t if lags of X_t can be useful in the prediction of Y_t and vice versa. Following the causality analysis, we estimated the Impulse Response Function (IRF) in order to trace out the current and future response of an exogenous shock or innovation in one variable in the VAR on some or all of the other variables.

Results

Table 1 below present the result for ADF unit root test of the series

Table 1: ADF Unit Root Test Result

Variables	Deterministic Terms	Test Value	Critical Values 1%	5%	10%	Result
TFP	Constant	-2.22	-3.56	-2.91	-2.59	I(1)
ΔTFP	Constant	-5.70	-3.56	-2.91	-2.59	I(0)
DOCRE	Constant	-1.96	-3.56	-2.91	-2.59	I(1)
ΔDOCRE	Constant	-6.49	-3.56	-2.91	-2.59	I(0)
DPCRE	Constant	-1.80	-3.56	-2.91	-2.59	I(1)
ΔDPCRE	Constant	-6.60	-3.56	-2.91	-2.59	I(0)
EXCH	Constant,Trend	-1.18	-4.14	-3.49	-3.17	I(1)
ΔEXCH	Constant	-6.55	-3.56	-2.91	-2.59	I(0)
IMP	Constant	-1.82	-3.56	-2.91	-2.59	I(1)

ΔIMP	Constant	-8.49	-3.56	-2.91	-2.59	I(0)
OPENK	Constant	-2.8	-3.56	-2.91	-2.59	I(1)
ΔOPENK	Constant	-7.45	-3.56	-2.91	-2.59	I(0)
TRADE	Constant	-1.29	-3.56	-2.91	-2.59	I(1)
ΔTRADE	Constant	-8.48	-3.56	-2.91	-2.59	I(0)

The ADF result show that all the series are all integrated of order one. The graph of all the series are presented in the Appendix

.

Table 2 :Johansen Cointegration Test for the series

H_0	Trace Statistics	5% Critical Value	P-value	Max-Eigen Stat	5% Critical Value	P-value
r=0	199.647*	150.558	0.0000	66.931*	50.599	0.0005
r=1	132.716*	117.708	0.0040	51.926*	44.497	0.0065
r=2	80.789	88.803	0.1647	37.036	38.331	0.0699
r=3	43.753	63.876	0.7034	16.986	32.118	0.8624
r=4	26.767	42.915	0.6945	11.564	25.823	0.8981
r=5	15.202	25.872	0.5577	9.5923	19.387	0.6624
r=6	5.6103	12.517	0.5113	5.6103	12.517	0.5113

Note: Deterministic Terms include constant and linear trend and lag order of two.

The Johansen Cointegration Test result using maximum eignvalue and trace statistics indicate the existence of two cointegrating equation. At 0.05 critical value, we reject the null hypothesis of no cointegration in the system of equations as there is at most two cointegrating vectors. This implies that a long-run equilibrium relationship exists and we proceed with the estimation of the short-run equilibrium dynamics through the VECM.

Table 3 Lag Length Selection Criteria

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-1002.005	NA	1.05e+10	42.93640	43.21195	43.04009
1	-766.7118	390.4871	3864318.	35.00901	37.21344*	35.83856*
2	-715.0882	70.29591	3968652.	34.89737	39.03068	36.45276
3	-650.4375	68.77741*	3016676.	34.23138	40.29357	36.51262
4	-570.3365	61.35398	1957205.*	32.90793*	40.89900	35.91502

* indicates lag order selected by the criterion

Based on the lag order used in the cointegration test, we selected two lag lengths for the VECM analysis. This Minimizes information criteria for Schwarz Information Criteria and Hann-Quinn Information Criteria

.

Table 4. FMOLS Long-run Result

Variable	Coefficient	Std. Error	t-Statistic	Prob.
DOCRE	-0.0121	0.001722	-7.026658	0000.0
DPCRE	0.010131	0.004187	2.419451	0.0197
EXCH	-0.000157	0.000511	-0.307202	0.7601
IMP	0.01311	0.004533	2.891791	0.0059
OPENK	-0.002748	0.001441	-1.907815	0.0630
TRADE	-0.00708	0.002142	-3.305589	0.0019
C	5.06879	0.060843	83.30913	0.0000
R-squared 0.73		Adjusted R-squared 0.69	D.W 1.9	F-Stat 20.43

Table 4 reports the Fully Modified OLS method proposed by Philips and Hansen [20]. The essence is to estimate regression of TFP on the six regressors that is independent of long run innovations on the cointegrating equations and stochastic regressors and to ascertain the contemporaneous effect on TFP as a result of a change in any of the chosen independent variables. With the exception of EXCH, all other variables are statistically significant and different from zero which signifies that they constitute determinants of TFP. Even though some of the independent variables returned negative signs, it is worthy of note that they should be regarded as being favourable for immediate policy target if TFP is to be improved upon.

Vector Error Correction short run Results.

Table 5 (See Appendix) presents the result of the unrestricted Vector Error Correction Model. Standard errors are in parentheses while the t-statistics are in brackets. The model utilized two lag lengths where SIC and HQ information criteria are at minimum. All the variables are in their first difference and are stationary. According to the Granger Representation Theorem, the error correction terms should be negative and statistically significant to ensure short run adjustment to equilibrium. In our VAR model, all the error correction terms are negative and statistically significant at 5 and 10 percent alpha levels. For the TFP equation, the error correction term of -0.00025 is statistically significant at 0.05 percent and reveals that 0.025 percent of disequilibrium is corrected within a year. First lag of DOCRE is negative in the TFP equation and statistically significant showing that domestic credit is not favourable for technological progress at that period while its second lag positively impacts on technological progress. With the exception of EXCH and IMP, first lag of other variables negatively impact on TFP while the second lag of all the variables positively impact upon TFP. The reason might not be unconnected to recent reforms in the financial sector which led to stricter risk management policies in the banking sector and where it has become more difficult to obtain credit facilities. Closer examination of the other equations and variable reveal that they are correlated with TFP while some are statistically significant.

Table 6 (See Appendix) reveal that TRADE and IMP granger-causes TFP at 10 percent level of significance while there is independence between TFP and other variables. IMP, OPENK and TRADE are found to granger-cause DOCRE and DPCRE while IMP and TRADE granger-causes EXCH. DOCRE and TRADE are found to granger-cause IMP whereas DPCRE, EXCH and IMP granger-causes TRADE. At all reasonable levels of significance, OPENK is found to be independent of all other variables.

The impulse response function shown in Figure 1. (See Appendix) is the response of the respective variables to a shock in the system. Based on the estimated model, TFP responds negatively to shocks in DOCRE, IMP and OPENK from the first year of innovation through to ten years and beyond as TFP remained below its equilibrium value through out. However, an initial shock to DPCRE has a positive influence on TFP of about 2 percent and increases to about 4.5 percent around the fifth year and remained higher that its equilibrium value beyond ten year period. Shocks on EXCH will have a negligible impact on TFP in the first year but increases to about 2 percent around the third year and remained so assuming there were no further shocks. Expectedly, TFP`s response to its own shock is about 6 percent in the first year and averaged about 5.5 percent throughout the ten year period. Finally, any innovation on TRADE, will lead to fluctuation of TFP around its equilibrium value for a long period of time assuming there are no further shocks in the system.

Discussion and Policy Implications

This study investigated long run determinants of technological progress in Nigeria while relying on data sets constructed from purchasing power parity. The essence is to verify whether such data sets aid in better understanding and prediction of our technological progress since the few empirical works on the subject matter were done based on decomposition of the output (here GDP) by the authors and to obtain a measure of TFP which they estimated against selected variables. In this study, we adopted a cross-country measure of TFP constructed by experts after due consideration of the respective country-specific characteristics as contained in the Penn World Table. In the end, the TFP data represents each country`s relative position in comparison to other countries of the world.

The current study reveals a mixed result. Research shows that an economy`s interaction with the outside world is favourable for technological progress. In this study, trade and openness variables which represent interaction with the international community impact on our TFP negatively. This might be an indication that apart from oil, trade does not contribute significantly to the making of our GDP and TFP growth. Trade reforms will be vital for ensuring technological progress. However, import is highly favourable for TFP growth particularly through its influence on technology-embodied capital goods. Similarly, domestic credit is found to be favourable for technological progress and financial reforms that will ease credit for investment in new technologies by firms and industries should be encouraged. Generally, policies that will improve the quality of capital should be encouraged. To this end, we recommend policies that will ensure stability in the financial sector. Reforms that will increase savings, generate credit and better allocation to investment will improve our TFP

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APPENDICES

Table 5. Vector Error Correction Result

Independent Variables	D(DOCRE)	D(DPCRE)	D(EXCH) Dependent Variables	D(IMP)	D(OPENK)	D(TFP)	D(TRADE)
ECT(-1)	-0.042027	-0.016703	-0.005301	-0.04327	-0.00061	-0.00025	-0.04445
	(0.01046)	(0.00582)	(0.02201)	(0.00669)	(0.01514)	(0.00014)	(0.01259)
	[-4.01946]	[-2.87105]	[-0.24080]	[-6.46795]	[-0.04042]	[-1.69969]	[-3.52954]
D(DOCRE(-1))	0.462243	-0.052244	-0.730774	0.179267	0.072571	-0.00259	-0.30391
	(0.26094)	(0.14519)	(0.54935)	(0.16696)	(0.37780)	(0.00359)	(0.31429)
	[1.77147]	[-0.35984]	[-1.33026]	[1.07370]	[0.19209]	[-0.72039]	[-0.96699]
D(DOCRE(-2))	0.443239	0.310346	-0.300536	0.337106	-0.61344	0.000802	0.618264
	(0.27130)	(0.15095)	(0.57117)	(0.17359)	(0.39281)	(0.00374)	(0.32677)
	[1.63375]	[2.05592]	[-0.52618]	[1.94193]	[-1.56167]	[0.21456]	[1.89205]
D(DPCRE(-1))	-0.146601	0.517568	0.977644	0.334288	-0.21923	-0.00025	1.004173
	(0.52014)	(0.28941)	(1.09504)	(0.33281)	(0.75310)	(0.00717)	(0.62648)
	[-0.28185]	[1.78838]	[0.89279]	[1.00443]	[-0.29111]	[-0.03474]	[1.60287]
D(DPCRE(-2))	0.551053	-0.445839	1.130463	-0.59539	-0.34753	0.005600	-2.00247
	(0.49634)	(0.27616)	(1.04492)	(0.31758)	(0.71863)	(0.00684)	(0.59781)
	[1.11024]	[-1.61442]	[1.08186]	[-1.87475]	[-0.48360]	[0.81911]	[-3.34966]
D(EXCH(-1))	0.065501	0.019489	-0.06009	0.088704	-0.07371	0.000216	0.253382
	(0.09123)	(0.05076)	(0.19207)	(0.05837)	(0.13209)	(0.00126)	(0.10988)
	[0.71797]	[0.38393]	[-0.31286]	[1.51956]	[-0.55803]	[0.17161]	[2.30591]
D(EXCH(-2))	0.167392	0.052992	0.386807	0.003463	-0.08809	0.000552	-0.12282
	(0.08988)	(0.05001)	(0.18923)	(0.05751)	(0.13014)	(0.00124)	(0.10826)
	[1.86234]	[1.05962]	[2.04413]	[0.06021]	[-0.67686]	[0.44572]	[-1.13448]

D(IMP(-1))	1.565357	0.566432	1.906617	1.501341	-0.1605	0.014294	2.134391
	(0.48264)	(0.26854)	(1.01609)	(0.30882)	(0.69880)	(0.00665)	(0.58131)
	[3.24334]	[2.10931]	[1.87643]	[4.86159]	[-0.22968]	[2.14998]	[3.67168]
D(IMP(-2))	0.607032	0.313185	1.376820	1.025126	0.237311	0.005357	1.936868
	(0.32207)	(0.17920)	(0.67806)	(0.20608)	(0.46632)	(0.00444)	(0.38792)
	[1.88476]	[1.74766]	[2.03054]	[4.97440]	[0.50890]	[1.20750]	[4.99292]
D(OPENK(-1))	0.509599	0.292188	-0.074442	0.021595	-0.26916	-0.0029	-0.11242
	(0.12843)	(0.07146)	(0.27038)	(0.08217)	(0.18595)	(0.00177)	(0.15468)
	[3.96798]	[4.08898]	[-0.27533]	[0.26279]	[-1.44750]	[-1.63669]	[-0.72679]
D(OPENK(-2))	0.185453	0.082483	0.151021	-0.04311	-0.23322	-0.00235	-0.13574
	(0.15636)	(0.08700)	(0.32917)	(0.10004)	(0.22638)	(0.00215)	(0.18832)
	[1.18610]	[0.94812]	[0.45879]	[-0.43092]	[-1.03020]	[-1.08947]	[-0.72079]
D(TFP(-1))	-10.17551	-6.548022	10.19890	4.316155	-10.7777	0.184413	-7.99712
	(11.4284)	(6.35874)	(24.0599)	(7.31248)	(16.5469)	(0.15743)	(13.7649)
	[-0.89037]	[-1.02977]	[0.42390]	[0.59025]	[-0.65134]	[1.17142]	[-0.58098]
D(TFP(-2))	-5.186317	-3.215725	-17.44628	5.544732	-21.9177	-0.10244	12.65529
	(12.2716)	(6.82792)	(25.8352)	(7.85203)	(17.7678)	(0.16904)	(14.7805)
	[-0.42263]	[-0.47097]	[-0.67529]	[0.70615]	[-1.23357]	[-0.60599]	[0.85621]
D(TRADE(-1))	-0.741552	-0.287413	-1.116985	-0.82152	0.082931	-0.00742	-1.24581
	(0.24683)	(0.13734)	(0.51964)	(0.15793)	(0.35738)	(0.00340)	(0.29729)
	[-3.00433]	[-2.09279]	[-2.14953]	[-5.20168]	[0.23205]	[-2.18073]	[-4.19051]
D(TRADE(-2))	-0.260517	-0.179596	-0.575568	-0.37971	-0.24562	-0.00379	-0.88125
	(0.18484)	(0.10285)	(0.38914)	(0.11827)	(0.26763)	(0.00255)	(0.22263)
	[-1.40942]	[-1.74628]	[-1.47907]	[-3.21055]	[-0.91778]	[-1.48928]	[-3.95834]
C	-1.218066	-0.160422	1.957277	0.294023	1.646132	0.001284	1.832896
	(0.92401)	(0.51412)	(1.94530)	(0.59123)	(1.33785)	(0.01273)	(1.11292)
	[-1.31824]	[-0.31203]	[1.00616]	[0.49731]	[1.23043]	[0.10085]	[1.64692]
R-squared	0.580287	0.543741	0.350357	0.717449	0.390977	0.390908	0.598064

Dependent variable: D(TRADE)			
Excluded	Chi-sq	df	Prob.

Adj.R-squared	0.383546	0.329870	0.045837	0.585004	0.105498	0.105395	0.409656
F-statistic	2.949501	2.542377	1.150523	5.416938	1.369546	1.369145	3.174305

Table 6 .VEC Granger Causality/Block Exogeneity Wald Tests Result

Dependent variable: D(TFP)				Dependent variable: D(DOCRE)			
Excluded	Chi-sq	df	Prob.	Excluded	Chi-sq	df	Prob.
D(DOCRE)	0.55860	2	0.7563	D(DPCRE)	1.30294	2	0.5213
D(DPCRE)	0.82403	2	0.6623	D(EXCH)	4.27653	2	0.1179
D(EXCH)	0.24486	2	0.8848	D(IMP)	10.5493	2	0.0051
D(IMP)	4.62669	2	0.0989	D(OPENK)	16.1887	2	0.0003
D(OPENK)	3.45383	2	0.1778	D(TFP)	1.24984	2	0.5353
D(TRADE)	5.01491	2	0.0815	D(TRADE)	9.02684	2	0.0110
All	16.27688	12	0.1789	All	35.29055	12	0.0004

Dependent variable: D(DPCRE)				Dependent variable: D(EXCH)			
Excluded	Chi-sq	df	Prob.	Excluded	Chi-sq	df	Prob.
D(DOCRE)	4.326415	2	0.1150	D(DOCRE)	2.077577	2	0.3539
D(EXCH)	1.359796	2	0.5067	D(DPCRE)	3.658118	2	0.1606
D(IMP)	4.983571	2	0.0828	D(IMP)	4.994606	2	0.0823
D(OPENK)	16.88790	2	0.0002	D(OPENK)	0.325480	2	0.8498
D(TFP)	1.643301	2	0.4397	D(TFP)	0.522544	2	0.7701
D(TRADE)	5.101632	2	0.0780	D(TRADE)	4.885286	2	0.0869
All	29.60814	12	0.0032	All	12.76990	12	0.3860

Dependent variable: D(IMP)				Dependent variable: D(OPENK)			
Excluded	Chi-sq	df	Prob.	Excluded	Chi-sq	df	Prob.
D(DOCRE)	5.016068	2	0.0814	D(DOCRE)	2.463939	2	0.2917
D(DPCRE)	3.537006	2	0.1706	D(DPCRE)	0.573817	2	0.7506
D(EXCH)	2.351300	2	0.3086	D(EXCH)	0.848991	2	0.6541
D(OPENK)	0.289848	2	0.8651	D(IMP)	0.613151	2	0.7360
D(TFP)	1.139053	2	0.5658	D(TFP)	2.531314	2	0.2821
D(TRADE)	27.73913	2	0.0000	D(TRADE)	1.424971	2	0.4904
All	47.81151	12	0.0000	All	13.15211	12	0.3581

D(DOCRE)	4.438154	2	0.1087
D(DPCRE)	11.22275	2	0.0037

D(EXCH)	6.162751	2	0.0459
D(IMP)	26.32018	2	0.0000
D(OPENK)	0.925193	2	0.6296
D(TFP)	0.871541	2	0.6468
All	43.35900	12	0.0000

Figure 1. Impulse Response Function to Cholesky one Standard Deviation Innovations

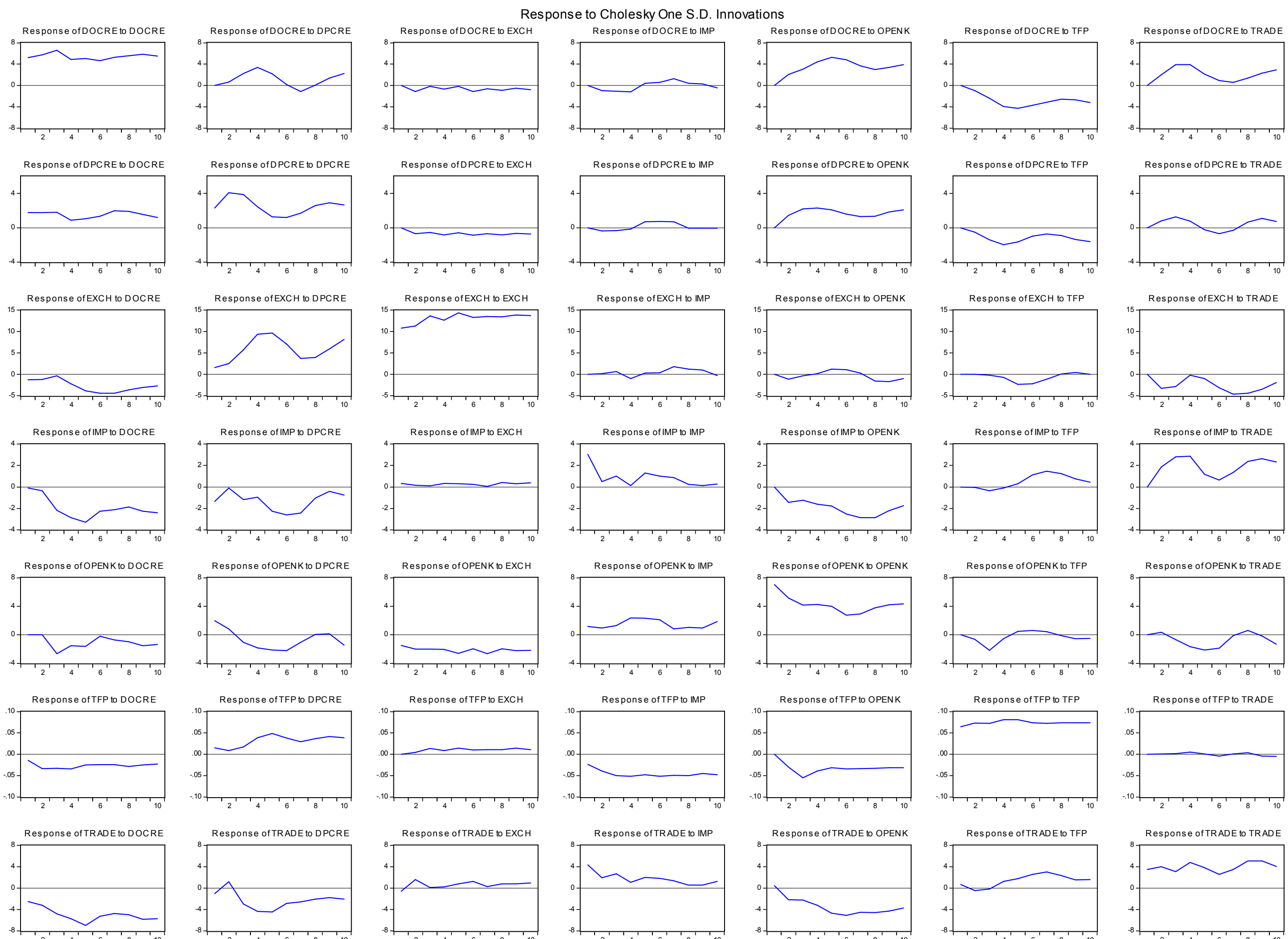
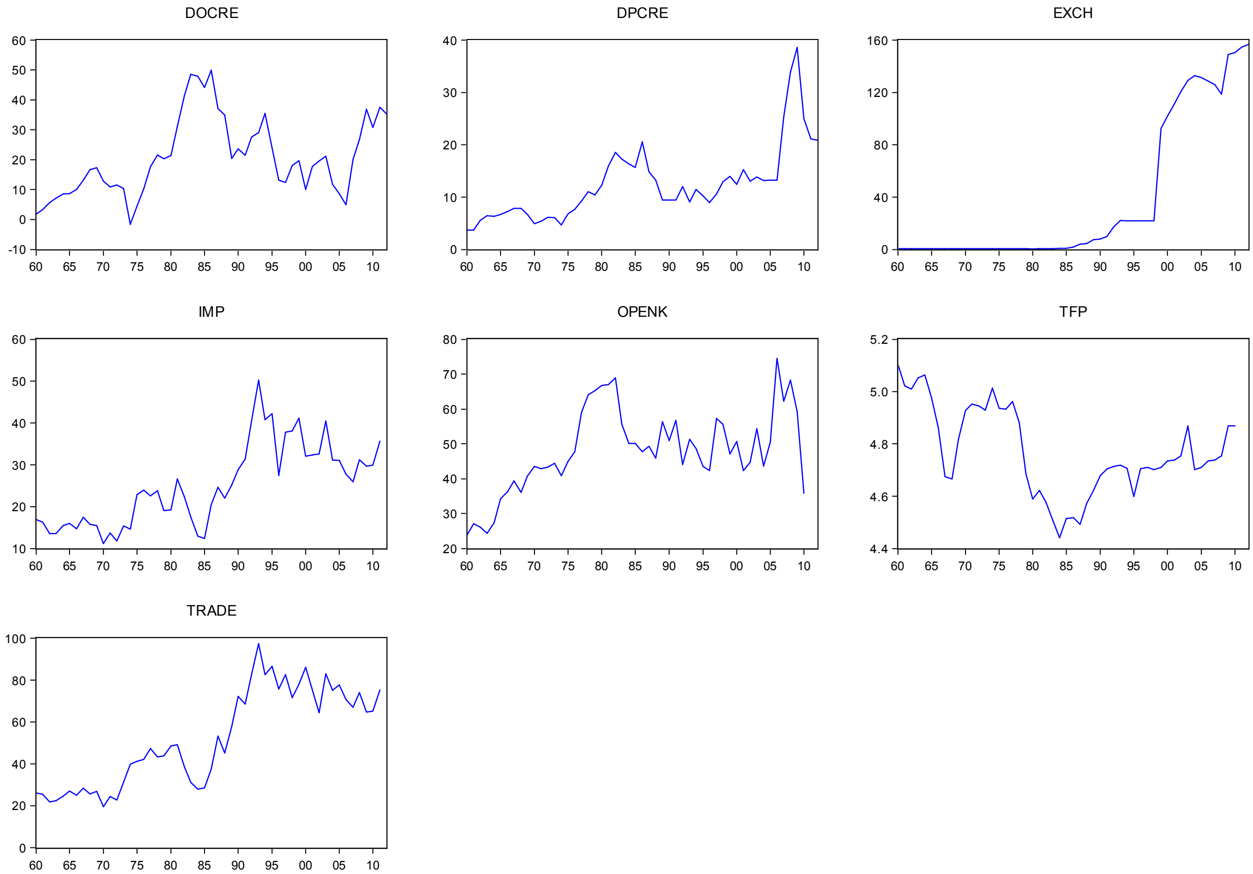


Figure 2. Graph of the series


DOCRE
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EXCH
IMP
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60 65 70 75 80 85 90 95 00 05 10