
ASEKUNOWO, V.O.
Department of Entrepreneurship Management Technology, Federal University of Technology, Akure, Nigeria.

ABSTRACT: Some strands of the growth accounting literature have suggested that apart from the traditional factors’ contribution to growth, some residuals may contribute more to it. These Total Factor Productivity (TFP) residuals may be embedded in imported technology (exogenous) or can be home-grown (endogenous). This paper seeks to determine if the TFP variables contributed to real growth in the Nigerian economy from 1986 to 2010. Secondary data on these macroeconomic variables were fitted into two econometric models. In the Solow-type model, the OLS regression performed showed that HC (human capital) and RFDI (real foreign direct investment) were statistically significant. REMI (real expenditures on machinery imports) was also significant but was wrongly signed. This suggests that the exogenous growth model may not be applicable to Nigeria. In the Romer – type model, HC was allowed to interact with REMI. The OLS regression performed showed that HC [REMI] (the interaction variable), RFDI and RRDE (real research and development expenditures) were statistically significant. This hints at the fact that the endogenous growth model may be applicable to Nigeria. This therefore suggests that the country has the potential of becoming a successful technology adopter or imitator. The paper concludes by making recommendations as to how Nigeria can attain this status and possibly transit to the status of a technology inventor.

Keywords: Real Economic Growth, Technology Innovator, Technology Adopter, Technology Inventor, Total Factor Productivity, Total Factor Productivity Variables, Nigeria, Africa.

INTRODUCTION

The growth literature is replete with the positive contribution that technology can make to economic growth and possibly economic development. Available literature suggests that the nations of the world can be divided into two main groups: nations that are technology innovators (in which case, they acquire technology endogenously at home) and nations that are technology adopters (in which case, they “bring in” technology exogenously from the outside world). Examples of nations in the former category are nations that have developed economies, notably the United States of America, Canada, Europe and Japan; while the nations that belong to the latter category include some East Asian countries like Hong Kong, Singapore and China (Sachs and McArthur, 2008). Technology adoption occurs usually through a process called diffusion; whereby exchange of ideas and goods between innovator and adopter economies may spur adoption by the adopters among the trading partners (Sachs and McArthur, 2008).

It has been suggested that successful adopters usually become innovators eventually (Sachs and McArthur, 2008). Consequently, most
developing and emerging economies around the world strive to be very successful adopters so that they would have a good chance of transiting to enviable positions of innovators. Nigeria, as a developing country, nurses the ambition of perhaps, first becoming a successful adopter and then becoming an innovator so that she can provide her citizens with a comparable level of income per capita through real economic growth that many of the innovators have been able to provide their citizens. In pursuance of this, Nigeria’s economic managers have deemed it worthwhile to institute some programmes to actualise this ultimate goal of becoming a technology innovator in the 21st century. For instance, the Structural Adjustment Programme (SAP) was initiated in 1986 and many reforms in the real and financial sectors have also been instituted after SAP in a bid to “open up” the economy; thereby creating avenues for the inflow of ideas and goods. But since these programmes have been instituted, one is forced to query if the country has been able to, through technology adoption or diffusion or imitation, record any measure of real economic growth? For instance, Mayer (2001) submitted that although technological integration of developing countries has increased, this increase can be ascribed to only the efforts of comparatively few individual countries. Is Nigeria one of the few individual countries?

This paper seeks to evaluate whether there has been any measure of technology inflow into Nigeria since the institution of these programmes and the advent of globalisation. Also, it attempts to determine if these inflows have, through adoption or diffusion, been effectively translated into real economic growth. Efforts are also made to identify the macroeconomic variables that may have made the attainment of this growth possible. The paper concludes by making recommendations.

**LITERATURE REVIEW**

The literature review section is divided into 3 sub-sections: a brief review of Nigeria’s technology policy, the theoretical review of literature and the empirical review of literature.

**A Brief Review of Nigeria’s Science and Technology Policy**

In discussing Nigeria’s S&T policy, perhaps such discussion would be clearer if viewed from three periods: the pre-independence period, the 1960s to the 1980s and the 1990s to the present. The S&T policy pursued by the colonial masters was designed purely to serve their own interests. They created research institutions mainly in the area of agriculture in order to boost agricultural products’ output for use in their industries in Europe. The 1960s to the 1980s was a period dominated by military rule. It was during this period that it can be arguably said that the present S&T infrastructure of Nigeria was built. This was because during the period, there was a growing concern on the part of some military and civilian authorities to build up the S&T competence as part of a broader project of national growth and self-sufficiency (Abdullahi, 2004). However, this effort was for the most part confined to the segments of the state bureaucracy and academia. Infact, it was during this period that specialised Universities (Universities of Technology) were established in the country. The period also witnessed most firms including the multinationals and state-owned corporations being more interested in their costs and the reliability of the equipment used and less with the origin of the technologies they used in their productive activities. So, the important linkage between the research institutions and the productive sector was missing. In the 1990s, there was a renewed effort to resuscitate the S&T infrastructure but with a new focus. The new focus was to make it more directly relevant to industrial competitiveness. Consequently, the ideas of Technology Business
Incubators, Science Parks, Agencies for Engineering Infrastructure, Raw Materials Research and Development Council among others were introduced as part of the S & T Technology policy. These efforts however are yet to yield the desired results. The National Economic Empowerment and Development Strategy (NEEDS) document saw the Nigerian economy as “lacking effective linkages between industry, research institutes and universities” (CBN, 2005; p. 70) and that “the country’s industrial development strategy would be to encourage forward and backward linkages and an emphasis on increases in total factor productivity by pursuing knowledge and skill-intensive production on the basis of best practices” (CBN, 2005; p. 71). The vision 20: 2020 document observed that “successive governments have put in place several measures and policies aimed at expanding the country’s capacity in science, technology and innovation (STI) by establishing STI institutions especially under the 3rd and 4th Development Plans (1975-1985) to promote Research and Development (R&D) to ensure sustainable growth” (National Planning Commission, 2010; p. 236).

The document further noted that “the Nigerian economy has remained structurally rigid over the years and the impact of the STI institutions is yet to be felt in terms of R&D output, innovation, patents, commercialisation of research findings, scientific publications in international journals, new knowledge intensive products, total factor productivity enhancement and general improvement in the quality of life of Nigerians” (National Planning Commission, 2010; p. 236). It also blamed these poor outcomes on the fact that these institutions are poorly funded and as a way out, recommended the “private sector participation in R&D activities through the instrumentality of a tripartite partnership between government, industry and research institutions” (National Planning Commission, 2010; p. 237).

Theoretical Review of Literature

Adam Smith and his classicists colleagues did not acknowledge the critical role that technology may play in economic growth. They can be forgiven this oversight given the fact that those economists of their persuasion did much of their writings before the advent of the industrial revolution. The recognition of the role of technology as a possible engine of long-term economic growth also did not appear in the writings of Keynesians such as Roy Harrod (1939), Evsey Domar (1946) who both emphasised the role played by savings, investment and capital accumulation as the key drivers of Gross National Products and growth. Neoclassist Solow (1956) model suggested the source of temporary, short-term economic growth to be savings, investment and capital accumulation and the importance of increases in capital per worker (capital deepening). He however, attributed the source of post-steady state long-term economic growth to an exogenous rate of improvement in factors’ productivity caused by technological advancement. In testing his model, Solow (1956) discovered that most of the growth of the US economy over the past 100 years could not be explained by increased use of labour and capital. He therefore attributed the unexplained “residual” to technological progress. To him, technology was a free good and no attempt was made to explain where it came from and at what cost.

Since the early 1980s, growth and development theories have increasingly analysed the process of technological innovations as a central feature of growth rather than as something that was simply “brought in” from the outside. Major contributions were made by the likes of Lucas (1988) Romer (1990a), Grossman and Helpman (1991a) and Aghion and Howitt (1992). Much of the writings of these contributors have centred on attempting to understand the transition from technological change as an “exogenous” feature.
of an economy to technological change as an “endogenous” feature. In an attempt to explain technology advancement, Sachs and McArthur (2008) stressed two basic models. In the models, they referred to the former (exogenous feature) as adoption which means introducing technologies that have been devised elsewhere and referred to the latter (endogenous feature) as innovation which means developing one’s own technologies.

The first and still in many ways the most influential theory of technological change in economic growth was undoubtedly Schumpeter’s (1942) theory of innovation as the engine of capitalist development. His theory of innovation was based on his definition of the entrepreneur as that individual (or group of individuals) responsible for the business decisions which lead to the introduction of new products, processes and systems or the opening up of new markets and new sources of supply (Hanel and Niosi, 1998).

How then can a positive change in technology occur and by inference an increase in innovative activities in an economy? A change in technology and the fostering of innovativeness among the agents in an economy is knowledge-content based. In the 1960s, important contributions were made by Uzawa (1965), Phelps (1966), Conlisk (1967, 1969) and Shell (1967), which related technology growth to some specifications based on labour resources devoted to the development of new technologies and ideas i.e. Research and Development (R&D). More recent literature by Grossman and Helpman (1991a, 1991b) and Aghion and Howitt (1992) all shared the characteristic that a continued increase in the level of resources spent on the creation of new technologies lead to a continued increase in economic growth. Jones (1995a, 1995b) held a somewhat dissenting view of this position though. He queried why the number of scientists engaged in R & D (a generally believed proxy of the state of technology) in advanced countries rose substantially over about 4 decades while economic growth hardly rose at all.

Jones (1995a) gave several explanations for the contrasting relationship between the state of technology and productivity growth (which is usually spurred by R&D) known in the literature as productivity paradox. In explaining this phenomenon, he submitted that there were either some offsetting effects occurring in the movement of other variables that permanently affect economic growth or that persistent changes in policy measures which should have permanent effects on economic growth did not. After some empirical analysis, Jones concluded that these explanations cannot be endorsed and that the endogenous growth models are therefore inconsistent with time series evidence.

Be that as it may, through which mechanism though, can technology imitation or adoption or diffusion and technology innovation via R&D efforts be manifested in an economy? It is through Total Factor Productivity (TFP) which Easterly and Levine (2000) have described as a salient feature of countries’ growth experience that cannot be explained by factor accumulation alone. According to Ranis (2011), both neo-classical and new growth theorists agree that TFP represents the best measure of technology change and exercises a dominant influence on a country’s growth performance. Inspite of the fact that the residual includes economies of scale, terms of trade effects in addition to pure technology change, the TFP is generally accepted as the best yardstick of a country’s innovative capacity (Ranis, 2011). So what are the factors that we may say can influence TFP itself? Ranis (2011) excluded geography, institutions and the extent of democracy but included exports and/or tariffs, foreign direct investment (FDI), R & D and patents as factors that can influence growth through TFP. Commenting further on openness (exports and/or tariffs), he cited Keller (2004) who pointed
out that technology change is determined in large part by technology diffusion carried in traded goods as well as FDI across borders. Imported R&D especially if adapted to domestic conditions are usually assumed to substantially raise domestic TFP while trade with countries operating close to the international technology frontier might be especially beneficial to developing countries thereby avoiding the need to invest a great deal of time and resources into the development of such technologies on their own. The key of course is the extent to which such frontier technologies are modified and adapted to local conditions.

FDI facilitates the use and exploitation of local raw materials, introduces modern techniques of management, eases access to new technologies, allows financing current account deficits, does not generate repayment of principal and interest (as opposed to external debt), increases the stock of human capital via on the job training and stimulates investment in R & D (Hassan, 2003). According to Hermes and Lensink (2003), there are different channels through which positive externalities associated with FDI can occur. First, there is the competition channel in which competition may lead to increased productivity, efficiency and investment in human and/or physical capital and increased competition may lead to changes in the industrial structure towards more competitiveness and export-oriented activities. Second, there is the training channel in which there would be increased training of labour and management. Third, there exists the linkages channel in which foreign investment is often accompanied by technology transfers and these transfers are only achievable through transactions with foreign firms. Fourth, there is the demonstration channel in which domestic firms imitate the more advanced technologies used by foreign firms. However, Hassan (2003) outlined some criticisms of FDI as including domestic savings and investment crowding-out, external balance destabilising because of profit repatriation, enclave investment, sweatshop employment, income inequality and high external dependency promoting.

Human capital has also been seen to be a leading factor in explaining economic growth (Hassan, 2003). Habib and Spiegel (1994) have found evidence that human capital affects Total Factor Productivity growth through its impact on the capacity of a country to innovate and capacity of using and adapting foreign technology. Sachs and Warner (1997) also noted that a rapid increase in human capital development results in rapid transitional growth. Furthermore, Becker et al. (1990) stated that higher rates of investment and human and physical capital would lead to higher per capita growth. The reason being that well-developed human capital leads to an improvement in productivity and an increase in growth rate and investment ratio. In a similar vein, Barro (1997) put it that human capital in form of secondary and higher education are highly significant in their effects on potential rates of growth. This implies that the better and more highly trained workforce, the more productive it will be in helping to enhance the rate of annual real output of a society.

There may indeed be a very important growth promoting interaction between technology and educational attainment. This is because imports of machinery and equipment boost productivity only when the economy has an educational attainment that is high enough to allow for an efficient use of the imported technology (Mayer, 2001).

Some other growth-influencing factors have been mentioned in the literature. Population is a factor that has been mentioned in Hassan (2003). Levine and Renelt (1992) have discussed inflation. Levine and Zervos (1993) and Barro (1991) gave the effect of government consumption extensive consideration while Gallup et al. (1999) gave the role of globalisation some attention.
Empirical Review of Literature
There exist a plethora of literature on the technology and economic growth nexus. After identifying the source of technology as exogenously determined, Solow (1957) made a basic and tremendously important calculation when he examined United States economic data from 1909 to 1949 and wanted to know the source of economic growth over that period of time. By extracting the part of economic growth that was due to more capital accumulated per person from the part that was due to the advance in technology, he found that technological change accounted for seven-eighths of the growth of the United States economy and that increases in capital stock relative to the population accounted for only one-eighth of the growth of income per person in the United States (Sachs and McArthur, 2008). These findings underscored the fact that understanding long-term economic growth requires understanding technological innovation.
Patent intensity is an indication of technological innovativeness. The ideas for which patents are generally issued are usually R&D derived. As a norm, R&D is productivity enhancing. There is a growing body of literature that provides solid empirical evidence for R&D and productivity nexus in manufacturing industries in the United States and to a lesser degree for other larger OECD countries. Ducharme (1991) found statistically significant associations between the rate of growth of industry’s own TFP and R&D and a series of proxies for R&D spillovers. Longo (1984) and Bernstein (1988) found a statistically significant association between R&D and TFP for samples of Canadian manufacturing firms. In a study of Canadian small and medium-sized enterprises (under 500 employees) which had expanded their sales between 1984 and 1985, growth factors were analysed. R&D innovation capabilities showed the highest correlation with growth (Baldwin, 1996).

Ranis (2011) examined the contributions of some variables to the enhancement of 22 developing countries’ TFP. The dependent variable was countries’ TFP value relative to the United States based on the estimates of UNIDO. Initially, the independent variables included export over GDP as an indicator of openness to trade, net inflows of FDI over GDP and both international and domestic patent applications. Later, another measure of openness (average applied tariff rate on all products) and another indicator of internal technology activity (official R&D expenditure as a percentage of GDP) were added as independent variables. The coefficients of both variables turned out positive. As for the earlier regression, the results showed that the coefficient on exports was significantly positive, confirming that openness to trade is conducive to technology development. Domestic patent applications clearly mattered positively while international patent application impacted TFP negatively. This may be due to the frequently referred to possibility that foreign patents are used less to transfer technology and more to prevent entry, enforce market shares and restrict exports to third countries (which are different from those granting the patent and those receiving it) and the like.
In order to assess whether education and its interaction with machinery imports by developing countries from both developing and developed countries with significant R&D expenditures aided economic growth, Mayer (2001) collected data on per capita income, capital stock per worker based on aggregate investment, education and machinery imports of 53 developing countries over the period 1970 to 1990 to run Ordinary Least Squares (OLS) growth regression with White’s heteroscedasticity consistent covariance estimation method. He specified per capita income as the dependent variable while capital stock, education and machinery imports were specified as the independent variables. The
growth accounting results suggested that machinery imports combined with human capital stocks have a positive and statistically
significant impact on cross-country growth differences in the transition to steady state.

RESEARCH METHODOLOGY

Secondary data on the identified Total Factor Productivity (TFP) macroeconomic variables in the Nigerian economy from 1986 to 2010 were collected. Data on these variables were expressed in bi-annual terms. The variables were chosen because they are known to be the conduits through which improvements in technology (the unexplained residuals) are largely manifested. The variables are: the degree of openness which was captured by the addition of nominal exports and imports and expressed as a ratio of nominal Gross Domestic Product (GDP), nominal Research and Development (R&D) expenditures, Nominal Foreign Direct Investment, Patents issued to Nigerians by the United States government, Human Capital as captured by secondary school enrolment and Nominal Expenditures on Machinery Imports. Three traditional growth factors data were also included. They are: Nominal Gross Domestic Capital Formation, population and population growth and Nigeria’s inflation rates. A consumer price index (CPI) was constructed with the data on inflation rates. The CPI was used to deflate all the nominal figures. Thus, Nominal Exports became Real Exports (REX), Nominal Imports became Real Imports (RIM), Nominal Gross Domestic Product became Real Gross Domestic Product (RGDP), Nominal R & D Expenditures became Real R&D Expenditures (RRDE), Nominal Foreign Direct Investment became Real Foreign Direct Investment (RFDI), and Nominal Gross Fixed Capital Formation became Real Gross Fixed Capital Formation (RGFCF), and Nominal Expenditures on Machinery Imports became Real Expenditures on Machinery Imports (REMI). The number of patents issued to Nigerians by the United States Patent and Trademark Office (USPTO) per year was divided by the number of millions of Nigerians per year to become Patent Intensity (PI) figures. Openness (OPN) is derived by adding Real Exports and Real Imports figures together and dividing by the Real Gross Domestic Product figures.

Some clarifications must be made though, on Nominal Expenditures on Machinery Imports and its derivative REMI. First, it is an aggregated data in the sense that the reporting agency (Central Bank of Nigeria) did not differentiate between general purpose and specialised equipment. Second, sectoral use of this equipment was not indicated. Third, it is unclear if the exporting countries had substantial R&D expenditures. However, it is known that about 52% of these imports into Nigeria are from the United States, a country with substantial R&D expenditures.

Since the reporting agency derived its data from Section 7 of United Nations Statistics Division’s Standard International Trade Classification (SITC) and the equipment reported in this section included machinery specialised for particular industries, metal working machinery, general industrial machinery and equipment, office machines and automatic data processing machines, telecommunication and sound-recording and reproducing apparatus and equipment, electrical machinery, apparatus and appliances and electrical parts, road vehicles and other transport equipment, it can therefore be seen that the ICT infrastructure are also reported under section 7 of the SITC. The sources of the data used for the study are the CBN Annual Report and Statement of Accounts, CBN Statistical Bulletin, USPTO and the appendix of Akinwale, et al. (2012).
The data were fitted into two econometric models of the forms:

\[
\text{RGDP} = \beta_0 + \beta_1 \text{PI} + \beta_2 \text{RFDI} + \beta_3 \text{HC} + \beta_4 \text{REMI} + \beta_5 \text{OPN} + \beta_6 \text{RRDE} + \beta_7 \text{RGFCF} + \beta_8 \text{POP} + U_1 \ldots \ldots (1)
\]

\[
\text{RGDP} = \gamma_0 + \gamma_1 \text{PI} + \gamma_2 \text{RFDI} + \gamma_3 \text{HC}[\text{REMI}] + \gamma_4 \text{OPN} + \gamma_5 \text{RRDE} + \gamma_6 \text{RGFCF} + \gamma_7 \text{POP} + U_1 \ldots \ldots (2)
\]

Where:

\( \beta_0 \) = Estimator of the Intercept Term Variable

\( \beta_1 \) = Estimator of the Patent Intensity Variable

\( \beta_2 \) = Estimator of the Real Foreign Direct Investment Variable

\( \beta_3 \) = Estimator of the Human Capital Variable

\( \beta_4 \) = Estimator of Real Expenditures on Machinery Imports Variable

\( \beta_5 \) = Estimator of Real Expenditures on Machinery Imports Variable

\( \beta_6 \) = Estimator of the Degree of Openness Variable

\( \beta_7 \) = Estimator of the Research and Development Expenditures Variable

\( \beta_8 \) = Estimator of the Real Gross Fixed Capital Formation Variable

\( \gamma_0 \) = Stochastic Disturbance Term

\( \gamma_1 \) = Estimator of the interaction of the Human Capital Variable with the Real Expenditures on Machinery Imports Variable

\( \gamma_2 \) = The interaction of the Human Capital Variable with the Real Expenditures on Machinery Import Variable

\( \gamma_3 \) = Estimator of the interaction of the Human Capital Variable with the Real Expenditures on Machinery Imports Variable

It should be noted that the introduction of HC [REMI] variable in model (2) is in the spirit of Romer (1990b), Benhabib and Spiegel (1994) and Mayer (2001) to highlight the effects of the interaction between human capital and machinery imports on growth. All the other variables in model (2) remain as defined in model (1).

The other growth variables identified in the growth literature such as government consumption, inflation, industrial growth, unemployment and the level of development of the financial institutions (financial deepening) are excluded from these models because they are not really relevant to the study at hand.

**Method of Data Analysis**

The data utilised in this study are of time series origin. For this reason, they may trend in which case their means and variances become variant under time translations. Using them in that state for a regression analysis may lead to what is referred to as spurious regression. In order to side-step this problem, all the variables were subjected to the Augmented Dickey-Fuller (ADF) and Phillip-Perron (PP) unit root tests in order to determine their orders of integration or stationarity and if necessary, to detrend them. The variables must thereafter be subjected to the Johansen Juselius cointegration test to
ascertain whether the variables demonstrate long-term co-movement with one another. Also, some macroeconomic variables sometimes exhibit a bi-directional or feedback relationship with one another. In this study for instance, because of the RGDP component of OPN [an independent variable in models (1) and (2)], it is quite conceivable that RGDP [the dependent variable in models (1) and (2)] may indeed influence OPN just as it is possible for OPN to influence RGDP. This therefore calls for performing the Granger causality tests on the variables to determine which of them have feedback relationships with one another.

### FINDINGS

**Table 1: Results of the Augmented Dickey-Fuller (ADF) and the Phillip- Perron (PP) Unit root tests performed on the variables in the Regression models**

<table>
<thead>
<tr>
<th>S/N</th>
<th>Variable</th>
<th>ADF Statistics</th>
<th>Order of Integration</th>
<th>PP Statistics</th>
<th>Order of Integration</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>RGDP</td>
<td>-5.08</td>
<td>I(1)</td>
<td>-6.86</td>
<td>I(1)</td>
</tr>
<tr>
<td>2</td>
<td>PI</td>
<td>-6.21</td>
<td>I(1)</td>
<td>-2.96</td>
<td>I(0)</td>
</tr>
<tr>
<td>3</td>
<td>RFDI</td>
<td>-5.87</td>
<td>I(1)</td>
<td>-6.91</td>
<td>I(1)</td>
</tr>
<tr>
<td>4</td>
<td>HC</td>
<td>-4.00</td>
<td>I(1)</td>
<td>-6.21</td>
<td>I(1)</td>
</tr>
<tr>
<td>5</td>
<td>REMI</td>
<td>-5.33</td>
<td>I(1)</td>
<td>-6.94</td>
<td>I(1)</td>
</tr>
<tr>
<td>6</td>
<td>HC[REMI]</td>
<td>-6.03</td>
<td>I(1)</td>
<td>-6.24</td>
<td>I(1)</td>
</tr>
<tr>
<td>7</td>
<td>OPN</td>
<td>-4.99</td>
<td>I(0)</td>
<td>-3.95</td>
<td>I(0)</td>
</tr>
<tr>
<td>8</td>
<td>RRDE</td>
<td>-5.72</td>
<td>I(2)</td>
<td>-6.93</td>
<td>I(1)</td>
</tr>
<tr>
<td>9</td>
<td>RGFCF</td>
<td>-5.49</td>
<td>I(1)</td>
<td>-6.87</td>
<td>I(1)</td>
</tr>
<tr>
<td>10</td>
<td>POP</td>
<td>-6.30</td>
<td>I(1)</td>
<td>-7.03</td>
<td>I(1)</td>
</tr>
</tbody>
</table>

ADF critical value = -2.92
PP critical value = -2.92
Source: Computed by Author

**Table 2: Johansen Cointegration Procedure Results for Variables in the Regression Models**

**Sample:** 1986:1-2010: 2
**Included observations:** 38

**Test Assumption:** Linear Deterministic Trend in the Data

**Series:** RGDP PI RFDI HC REMI HC[REMI] OPN RRDE RGFCF POP

<table>
<thead>
<tr>
<th>S/N</th>
<th>Eigenvalue</th>
<th>5% Critical value</th>
<th>1% critical value</th>
<th>Hypothesised No of CE(S)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.999905</td>
<td>233.13</td>
<td>247.18</td>
<td>None**</td>
</tr>
<tr>
<td>2</td>
<td>0.99584</td>
<td>192.89</td>
<td>204.95</td>
<td>At most1**</td>
</tr>
<tr>
<td>3</td>
<td>0.992357</td>
<td>156.00</td>
<td>168.36</td>
<td>At most 2**</td>
</tr>
<tr>
<td>4</td>
<td>0.915641</td>
<td>124.24</td>
<td>133.57</td>
<td>At most 3**</td>
</tr>
<tr>
<td>5</td>
<td>0.873896</td>
<td>94.15</td>
<td>103.18</td>
<td>At most 4**</td>
</tr>
<tr>
<td>6</td>
<td>0.675609</td>
<td>68.52</td>
<td>76.07</td>
<td>At most 5**</td>
</tr>
<tr>
<td>7</td>
<td>0.592774</td>
<td>47.21</td>
<td>54.46</td>
<td>At most 6**</td>
</tr>
<tr>
<td>8</td>
<td>0.299772</td>
<td>29.68</td>
<td>35.65</td>
<td>At most 7</td>
</tr>
<tr>
<td>9</td>
<td>0.243133</td>
<td>15.41</td>
<td>20.04</td>
<td>At most 8</td>
</tr>
<tr>
<td>10</td>
<td>0.026213</td>
<td>3.76</td>
<td>6.65</td>
<td>At most 9</td>
</tr>
</tbody>
</table>

*(**) denotes rejection of the null hypothesis at the 5% (1%) level.
Source: Computed by Author
Table 1 shows the ADF and PP unit root tests results. The ADF tests showed that except for OPN, all the other variables had to be differenced once or twice before becoming stationary. The PP tests showed that except for PI and OPN, all the other variables possessed unit roots and also had to be differenced once before becoming integrated.

The summary of the results of cointegration analysis using the Johansen maximum likelihood ratio test based on the trace of the stochastic matrix and maximal eigenvalues are presented in Table 2.

Table 2 shows the cointegrating test for RGDP, PI, RFDI, HC, REMI, HC [REMI], OPN, RRDE, RGCFC and POP. The likelihood ratios and the eigenvalues were utilised. The first row of Table 2 tested the hypothesis that there were no cointegrating equations. This was rejected at both the 5% and 1% levels. In the second, third, fourth, fifth, sixth and seventh rows of the Table, the same hypothesis was tested and was also rejected at both 5% and 1% significance levels. It can therefore be said that there existed at least seven cointegrating vectors. Thus, it can be concluded that there is a long-run co-movement among these nine variables.

The results of the OLS regression performed on model 1 are presented in Table 3.

Model (1) is a Solow-type growth model with the TFP and traditional growth factors separately introduced into the model. With an R² of 0.99, the model can be adjudged to be appropriate. The model initially showed signs of serial correlation but 1 round [AR (1)] of Cochrane-Orcutt iteration procedure improved the D.W. statistic substantially to 1.97, thus purging it of the autocorrelation problem. The estimator of the PI variable was statistically significant but wrongly signed. The estimator of the RFDI variable was rightly signed, thus conforming to a priori expectations. It was also statistically significant. The estimator of the HC variable was rightly signed and conform to a priori expectations. It was also statistically significant. The estimator of the REMI variable did not conform to a priori expectations in that it was wrongly signed. However, it was statistically significant. The estimator of the OPN variable was rightly signed so it conformed to a priori expectations but was not statistically significant. The estimator of the RRDE variable conformed to a priori expectations by being rightly signed. However, it was not statistically significant.

Table 3: Results of the OLS regression Performed on Model (1)

<table>
<thead>
<tr>
<th>Dependent Variable: RGDP</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Independent Variables</strong></td>
</tr>
<tr>
<td>C</td>
</tr>
<tr>
<td>PI</td>
</tr>
<tr>
<td>RFDI</td>
</tr>
<tr>
<td>HC</td>
</tr>
<tr>
<td>REMI</td>
</tr>
<tr>
<td>OPN</td>
</tr>
<tr>
<td>RRDE</td>
</tr>
<tr>
<td>RGCFC</td>
</tr>
<tr>
<td>POP</td>
</tr>
<tr>
<td>AR(1)</td>
</tr>
<tr>
<td>F-statistic</td>
</tr>
</tbody>
</table>

R² = 0.99
Adj.R² = 0.99
DW = 1.97
* Significant at 5% level
Source: Computed by Author
significant. The estimator of the RGFCF variable was rightly signed, making it to conform to a priori expectations. The estimator was also highly statistically significant. The estimator of the POP variable was rightly signed. This made it to conform to a priori expectations but was not statistically significant. The results of the OLS regression performed on model 2 are presented in Table 4.

Model (2) is a Paul Romer-type growth model in which HC and REMI were allowed to interact with each other and other factors were introduced separately as was done in model (1). With an R² of 0.99 and an adjusted R² of 0.99, the model is quite appropriate in the sense that it captured almost all the TFP and traditional variables that can possibly influence RGDP. The model initially showed signs of serial correlation but exactly 3 rounds [AR(3)] of Cochrane-Orcutt iteration procedure took care of this problem thereby improving the D. W. statistic to 1.83. All the independent variables except the interactive variable HC [REMI] and RRDE behaved as they did in model (1). HC [REMI] was rightly signed, conforming to a priori expectations and statistically significant. The

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**Table 4: Results of the OLS Regression Performed on Model (2)**

<table>
<thead>
<tr>
<th>Dependent Variable: RGDP</th>
<th>Independent Variables</th>
<th>Coefficients</th>
<th>t-values</th>
<th>Probabilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>0.39</td>
<td>0.14</td>
<td>0.89</td>
<td></td>
</tr>
<tr>
<td>PI</td>
<td>-233.23*</td>
<td>-5.01</td>
<td>0.00</td>
<td></td>
</tr>
<tr>
<td>RFDI</td>
<td>6.01*</td>
<td>2.47</td>
<td>0.02</td>
<td></td>
</tr>
<tr>
<td>HC[REMI]</td>
<td>0.72*</td>
<td>2.42</td>
<td>0.02</td>
<td></td>
</tr>
<tr>
<td>OPN</td>
<td>5.09</td>
<td>1.75</td>
<td>0.09</td>
<td></td>
</tr>
<tr>
<td>RRDE</td>
<td>104.18*</td>
<td>3.08</td>
<td>0.01</td>
<td></td>
</tr>
<tr>
<td>RGFCF</td>
<td>5.73*</td>
<td>5.83</td>
<td>0.00</td>
<td></td>
</tr>
<tr>
<td>POP</td>
<td>-0.46</td>
<td>-0.47</td>
<td>0.65</td>
<td></td>
</tr>
<tr>
<td>AR(1)</td>
<td>0.71*</td>
<td>3.77</td>
<td>0.00</td>
<td></td>
</tr>
<tr>
<td>AR(2)</td>
<td>-0.92*</td>
<td>-7.13</td>
<td>0.00</td>
<td></td>
</tr>
<tr>
<td>AR(3)</td>
<td>0.59*</td>
<td>2.92</td>
<td>0.01</td>
<td></td>
</tr>
<tr>
<td>F-Statistic</td>
<td></td>
<td></td>
<td>0.00</td>
<td></td>
</tr>
</tbody>
</table>

R² = 0.99  
Adjusted R² = 0.99  
D. W. = 1.83  
* Significant at 5% level  
Source: Computed by Author

---

**Table 5: Granger Causality Test Results**

<table>
<thead>
<tr>
<th>S/N</th>
<th>Variable</th>
<th>Observation</th>
<th>Causality Direction</th>
<th>F-value</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>REMI, RGDP</td>
<td>48</td>
<td>REMI → RGDP</td>
<td>5.54</td>
<td>0.01</td>
</tr>
<tr>
<td>2</td>
<td>RGDP, REMI</td>
<td>48</td>
<td>RGDP → REMI</td>
<td>7.58</td>
<td>0.00</td>
</tr>
<tr>
<td>3</td>
<td>RRDE, RGDP</td>
<td>42</td>
<td>RRDE → RGDP</td>
<td>6.10</td>
<td>0.01</td>
</tr>
<tr>
<td>4</td>
<td>RGFCF, RGDP</td>
<td>48</td>
<td>RGFCF → RGDP</td>
<td>6.62</td>
<td>0.00</td>
</tr>
<tr>
<td>5</td>
<td>RGDP, RGFCF</td>
<td>48</td>
<td>RGDP → RGFCF</td>
<td>5.73</td>
<td>0.01</td>
</tr>
</tbody>
</table>

Source: Computed by Author
estimator of the RRDE variable remained rightly signed but became statistically significant. The results of the Granger causality test are presented in Table 5. Based on the F-values, it can be said that there existed bi-directional relationships between RGDP and REMI and RGDP and RGFCF. Only a uni-directional relationship existed between RGDP and RRDE. The remaining variables [PI, HC, HC(REMI), OPN, POP] neither showed a bi-directional nor a uni-directional relationship with RGDP. Therefore, their Granger causality results are not reported.

**DISCUSSION**

In the preceding section, the following were revealed: First in model (1), the PI variable was wrongly signed but statistically significant. This showed that Nigerians were not technologically innovative and inventive during the study period, so PI cannot be seen as having contributed positively to TFP and real growth during the study period. Second, the RFDI variable was rightly signed and statistically significant. This suggests that some measure of real direct foreign investment flowed into Nigeria from foreign sources. The technology embedded in the equipment brought in by the multinational corporations may have been given proper direction in terms of efficient and correct utilisation by the foreign technicians and the well-supervised local technicians who operated them. This probably made the equipment to contribute positively to TFP and real growth during the study period. Third, the HC variable was rightly signed and statistically significant. This hints at the fact that Nigerians, at least those who enrolled in schools became better educated and when able to secure employment, were more disciplined and productive, thereby contributing positively to TFP and hence real growth during the study period.

Fourth, REMI variable was wrongly signed but statistically significant. This outcome shows that the imported equipment may have had technology embedded in them thus having the potential to contribute positively to TFP and real growth but were probably not well utilised so this desired outcome was not realised during the study period. Fifth, the OPN variable was rightly signed but was not statistically significant. This was probably due to the fact that openness may encourage commercial exchanges between nations. These exchanges may conceivably have enormous technology content i.e these exchanges may involve some state of the art equipment that may positively influence TFP and growth. Nigeria though, may not have been selective enough in her choice of exchanges such that such equipment were not imported. The outcome of this was that OPN did not contribute positively to TFP and growth during the study period.

Sixth, the RRDE variable was rightly signed but not statistically significant. This outcome may be due to the fact that somehow in this model, Nigeria’s expenditures on research efforts did not translate into innovations during the study period. So, TFP and real growth were not positively affected. Seventh, the RGFCF variable was rightly signed and highly statistically significant. This implies that Nigerians accumulated this traditional factor during the study period. This probably resulted in a measure of increased capital deepening and real growth during this period. Eighth, the POP variable was rightly signed but not statistically significant. This implies that the growth rate of this traditional factor did not positively influence real growth. This may not be unconnected with the fact that youth and adult (educated or otherwise) unemployment rate was very high in Nigeria during the study period. The gains in population were not engaged productively because the country seemed to be industrially stagnant.
In model (2) the behaviours of the variables except HC [REMI] and RRDE remained unchanged. HC [REMI] was rightly signed and significant. This outcome is very important in the sense that it is only when human capital is allowed to interact with imported machinery that the technology that is probably embedded in it can be better understood and improved upon. This suggests that Nigeria has a very great potential to be a successful technology adopter or imitator economy that may eventually transit into the cadre of technology inventor economies if requisite policies are put in place. Based on this, it can be said that Nigeria’s growth model exhibits characteristics similar to the Paul Romer growth model. The RRDE variable remained rightly signed but became statistically significant. This hints at the fact that it is only when human capital is allowed to interact with imported machinery that the research efforts/expenditures of Nigeria can yield positive outcomes in terms of RGDP growth.

The bi-directional relationships between RGDP and REMI and RGDP and RGFCF and the uni-directional relationship between RGDP and RRDE should be discussed. As for the relationship between RGDP and REMI, it is quite possible that an increase in RGDP (national income) may encourage businessman to embark on the importation of machinery from abroad. By the same token, if the productivities of the imported machinery increase, output may also increase. Regarding the relationship between RGDP and RGFCF, it is quite plausible that an increase in RGDP (national income) can induce increased capital formation as a result of businessmen’s acquisition of capital for production. Increased capital formation may spur an increase in the number of capital per worker (capital deepening). The uni-directional relationship that existed between RRDE and RGDP is also plausible in the sense that research may lead to innovations which can positively affect TFP and real growth. This has been affirmed by one of the findings in model (2).

CONCLUSIONS AND RECOMMENDATIONS

Conclusions
From the foregoing discussion, the following conclusions can be made. When PI, RFDI, HC REMI, OPN and RRDE (TFP or residual) variables were introduced separately into a Solow-type growth model, only RFDI and HC were significant. This implies that Nigeria can neither be a successful technology adopter nor a technology inventor under the Solowian regime. But when HC and REMI interacted in a Paul Romer-type growth model, RFDI, RRDE and HC [REMI] were the residual variables that were statistically significant. This implies that Nigeria has a great potential to becoming a successful adopter and possibly a successful technology inventor under the Paul Romer regime. Furthermore, it can be concluded that RGFCF, a traditional factor was statistically significant implying that capital accumulation can engender real output growth in Nigeria.

Recommendations
Based on these conclusions, the following are recommended:

1. Governments in Nigeria Should Emphasise Technical and Technology-Based Education: Nigerian governments at the federal, state and local levels should emphasise technical and technology-based education by increasing the technical and technology content of the curricula at the tertiary, secondary and primary levels of education in the country. With enough technical and technology backgrounds, Nigerian scientists would readily have a grasp of the way the imported equipment work. This should be complemented with a regime of increased funding of all areas of education. With the establishment of the Education Trust Fund (ETF), money for development of infrastructure has now been flowing to the tertiary level of education and with the introduction of Tertiary
Education Fund (Tet-fund) also at the tertiary level, human capital development is being encouraged. These are all welcome developments. But more needs to be done and can be done in this regard so that technology diffusion can be aided.

2. Governments should increase spending on research and development (R&D): The Nigerian governments at all levels must encourage research and development in both the public and private sectors of the economy. As for the public sector, the research institutes spread across the country must be better funded. Increased funding of these institutes must be complemented with a regime of adequate monitoring of the disbursements of these funds so that proper utilisations are ensured. As for the private sector, it is quite conceivable that this sector may be unwilling to commit funds into research and development because of the diffusion or spillover or social nature of R&D which makes it virtually impossible for the private sector to fully appropriate returns on R&D investment. Governments therefore may help defray private sector research and development costs by instituting a policy of indirect subsidy by way of granting accelerated depreciation of capital and tax breaks to businesses that indeed make R&D investments.

3. Establishment of technology villages: Governments at all levels in Nigeria should strive to establish technology villages in their areas of authority. The best brains in academia (Lecturers and graduates) in the chosen areas of comparative advantage or specialisation of the country should be assembled in these villages to look for ways of studying imported equipment and finding ways to invent around these equipment. In order to make the assembled scientists to perform optimally, the following should be provided for them: good salary, family medical care, good education for their wards, adequate supply of electricity and water. An availability of these items would enable the scientists to focus on the business for which they have been assembled without wanton distractions. A continuous enjoyment of these perquisites by the scientists must however be tied to performance. Efforts must also be made to establish linkages between the activities in these villages and the industries.

4. Relaxation of intellectual property rights (IPR) laws: The Federal Government of Nigeria must relax Nigeria’s IPR laws which are heavily influenced by the British laws and are just too stringent for a developing country like Nigeria. A relaxation of these laws would make it easy for Nigerians to invent around products and processes that flow into the country. This strategy was adopted by Japan, South Korea and Taiwan before these economies became the technology innovators they now are. This strategy is now pursued by Singapore, Thailand and Indonesia. India is a perfect example of a country that is profiting enormously from the relaxation of IPR laws in the area of pharmaceuticals. The country now produces and sells pharmaceutical products very competitively worldwide with her industry garnering a respectably robust market share that now probably surpasses that of many countries in the industrially developed west. Although this may be against to the spirit of the Trade Related Aspects of Intellectual Property Rights (TRIPS) signed by WTO members on 15th April, 1994 in Marrakesh, Morocco and may therefore meet with disapprovals from members countries, this should not deter the country from embarking on such a policy because the issue of national economic survival is at stake here.

5. Encouragement of foreign direct investment inflows: The Nigerian governments must encourage real direct investment from abroad by further strengthening Nigeria’s openness and deregulation policies. Investors from abroad should be lured with supply-side inducements such as tax breaks and accelerated capital depreciations to mention a few. Also, education
must be well funded as earlier discussed because foreign capital will only flow into areas of the world with well-educated and disciplined workforce. Infrastructure must not be neglected and Nigeria’s institutions such as the judiciary must be functioning properly.

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