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Capital Formation, Technological Diffusion and Economic Growth in Nigeria: An ARDL Bound Testing Analysis

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Abstract
This study examines the impact of human capital on economic growth in Nigeria from 19 ... to 20 through the application of Auto-Regressive Distributed Lag (ARDL) Bound Testing methodology. The study is based on the Benhabib and Spiegel (1994) model of technology diffusion which assumed a Cobb-Douglas production functions. While positive relation were found between all forms of capital formation and economic growth except secondary enrolment, the result from the interacting role of FDI and domestic investment appears positive indicating substituting relationship. This indicates that foreign investment is gradually substituting domestic investment which can be detrimental to the Nigeria Economic growth in the long run. Redirection and optimal combination between FDI and domestic investment is therefore suggested for long run economic growth in Nigeria. The results have been found robust concerning data issues and series stability.
JEL Code: I20, C22, C51, O56
Keywords: Capital Formation, Technological Diffusion, ARDL Bound Testing, Economic Growth, Nigeria.

1. Introduction

Nigeria has enjoyed relative macro-economic stability in the recent decades with average real per capita income of 4.0 percent in 2010 (National Bureau of Statistics, 2011). Detailed analysis revealed that the growths were 2.51%, 2.78% 3.76% and 4.7% in 2007, 2008, 2009 and 2010 respectively. However, there was an unequal distribution of the fruits of growth over the years where the gini coefficient showed that income inequality rose to 0.45 in 2010 as against 0.43 and 0.41 in 2006. Meanwhile, estimates shows that about 56 percent of Nigerian population live in poverty (National Buarea of Statistics, 2010). Sustained economic growth is regarded as an essential ingredient for expanding economic opportunities for poor people depending on innumerable factors, including the accumulation of capital. The role of capital formation in the development of a society is very important, as such, there is need to pay close attention to the sector. This is because the socio-political and economic developments of a nation are determined by the quality and level of capital attainment. In view of the government transformation agenda and the realization of Vision 20:2020, the capital formation must be strengthened to produce sustained output and quality workforce.

Nelson (2005) consider human capital as a key determinant of absorptive capacity since it enables workers to understand and assimilate new technology; a particular formulation of the convergence process. The idea originates in Nelson and Phelps (1966) who assessed education to be a catalyst in the diffusion of new technologies and Benhabib and Spiegel (1994) integrate the ideas in a generalised model of human capital that aims to explain both innovation and technology diffusion. They build on the intuition that the two views of human capital are complementary rather than competing. They explain different stages of economic development; i.e., nations closer to the technology frontier have accumulated high levels of human capital that could support innovation while countries far from the frontier focus on technology diffusion. Although intuitively appealing, the original Nelson-Phelps hypothesis, suggests that the imitation of foreign technology is always beneficial provided that educated workers follow and understand new technological developments (Nelson and Phelps 1966, p.69). Moreover, the hypothesis implies that a backward economy could overtake the technology leader by simply relying on investment in human capital.

In order to account for inconsistencies between theory and facts, Benhabib and Spiegel (2005) have revisited Benhabib and Spiegel (1994) to further extend the Nelson-Phelps hypothesis. They considered a logistic diffusion process that acknowledges impediments to imitation and allows for divergence in world income. The results from their empirical application revealed that logistic diffusion better explains world income growth patterns. Further, they are able to identify a number of countries that have been at risk of falling into poverty traps but reported that this number appears to have diminished over time. While there is a rather strong theoretical support for a key role of human capital on growth, the empirical evidence is not clear-cut. In contrast to microeconomic studies which generally suggest significant returns to education on individual earnings, growth regressions on the macro level have often failed to find a significant and positive contribution of human capital to economic growth. Moreover, the relationship between most measures of human capital and output growth has frequently been found surprisingly weak. The evidence comes almost entirely from cross-country regressions, and there is very little empirical analysis for individual countries (see Loening, 2004). For the case of Guatemala there is no single study that assesses the direct impact of education on economic growth.

This study is motivated by the proliferation of the literature on capital-skill complementarity (CSC) and skill-biased-technical-change (SBTC). The second is a more flexible approach and facilitates the differentiation between CSC and skillbiased- technology-change (SBTC). Note, however, that the principal objective here is to examine the robustness of Benhabib and Spiegel's (2005) logistic model within the framework of Cobb-Douglass production technology. Following this introduction is section 2 which presents the literature review. 3 is the methodology. Section 4 presents the empirical results while conclusion and suggestion for further study are contained in section 5.

2 Literature Review

The debate on role of technology and human capital can be attributed to Nelson and Phelps (1966) while studying the relationship between structures of capital and technological progress. According to their findings the returns to education are higher, although their findings are based on countries which are technologically advanced. Hence, technology diffusion can be accelerated by investing more in education. Lucas (1988) provides the basis for empirical research on human capital based endogenous growth models. According to him, investment in human capital and constant returns can be avoided. Uzawa (1965) consideres human capital is skill embodied-labour, and if labour uses its skills in one profession, it precludes the use in some other profession. Romer (1990) modelled long run economic growth on research and development (R&D). To Romer, when firms are involved in R&D, it results in technological change and enhances total factor productivity (TFP) which becomes the immediate cause of economic growth.

Benhabib and Spiegel (1994) have deduced that international technology spillover rates depends upon the availability of human capital in follower country and that human capital is guaranteed through education. Abbas and Foreman-Peck (2008) identified the crucial role of human capital to absorb the world technological progress. They concluded that the nature of economic growth in Pakistan is of endogenous nature. Returns to secondary education are below the expected level which means there is a deficiency in investment in human capital formation. There is inconsistency in policies for human capital formation in Pakistan because population have increased so rapidly in the last decade but educated labour force has not increased at the same rate which reflects negative contribution towards economic growth. In contrast however, Amir *et al* (2012) established a long run relationship between human capital and economic growth for the same Pakistan using Johansen co-integration test followed by error correction model (ECM) for short run analysis.

As a source of productivity, Haouas and Yagoubi (2005) examined openness and human capital for MENA countries. Controlling for fixed effects as well as endogeneity in the model, they found that while human capital significantly influence growth, it has no underlying effect on productivity growth. Jorgenson and Fraumeni (1992) use growth accounting methodology in a third generation framework to demonstrate that investment in human and physical capital accounts for a very high proportion of growth in both the education and production sectors of the US economy over the post – war period. Specifically, growth in labour input is found to account for just over 60% of overall economic growth and increases in labour quality (education and training) explain some 42% of this labour contribution.

At a national level, however, recent studies have found that increases in educational attainment are unrelated to economic growth. These finding are shown to be a spurious with extremely high rate of measurement error in first-differenced cross-country education data. Reconciling evidence on the effect of schooling on income and GDP growth from the microeconometric and empirical macro growth literatures Krueger and Lindahl (1999) suggested that education is an important causal determinant of income for individuals within countries as diverse as Sweden and the United States. After accounting for measurement error, Krueger and Lindahl found that the effect of changes in educational attainment on income growth in cross-country data is at least as great as microeconometric estimates of the rate of return to years of schooling. On their investigation on the macro growth literature they however found that the initial level of education does not appear to have a significant effect on economic growth among OECD countries.

Acemoglu (1998) has offered a formal demonstration of how positive spill-over effects (pecuniary externalities) created by workers' educational and training investment decisions can give rise to macro-level increasing returns in human capital. His model supposes that workers and firms make their investments in human and physical capital, respectively, before being randomly matched with one another. The direct consequence of random matching is that the expected rate of return on human capital is increasing in the expected amount of (complementary) physical capital with which a worker will be provided; similarly, the return on physical capital is increasing in the average human capital that the firms expect the workers to bring to the job. Hence, an increase in education for a group of workers induces the firms to invest more in tangible assets, thereby increasing the return to all workers in the economy. Through a similar argument, the model is seen also to imply that there are "social increasing returns" in physical capital.

Driffield and Henry (2007) examines the impact of inflows of foreign knowledge on economic development, in the context of different institutional development and differing levels of human capital. Employing threshold regression analysis based on Hansen (2000) to determine whether there is cross-country heterogeneity in the flows of foreign knowledge from advanced industrialised countries to a group of 57 developing countries based on the latter group's absorptive capacity and institutional quality over the period 1970-1998, Initial results for the trade channel show that the differing productivity effects accruing to groups of countries as a result of differing levels of absorptive capacity and institutional quality are small at best and non-existent at worst. Musibau and Rasak (2005) have studied long run relationship between education and economic growth in Nigeria. They have used two channels to test the significance of human capital for economic growth. In the first channel, human capital is used as an independent factor of production and in the second channel; human capital affects economic growth through technology parameter. According to their findings, a well educated labour force significantly affects economic growth through both channels. Employing annual time series data from 1977 to 2007 employs through Johansen co integration technique and error correction methodology, Dauda (2010) similarly found that there is a long-run relationship between investment in education and economic growth in Nigeria. Bakare (2006) investigated the growth implications of human capital investment in Nigeria using vector autoregressive error corrections mechanism. The study revealed that there is a significant functional and institutional relationship between the investments in human capital and economic growth in Nigeria. It was revealed that 1% fall in human capital investment led to a 48.1% fall in the rate of growth in gross domestic output between 1970 and 2000. Babatunde and Adefabi (2005) investigated the long run relationship between education and economic growth in Nigeria between 1970 and 2003 through the application of Johansen cointegration technique and vector error correction methodology. Their findings reveal that the Johansen cointegration result establishes a long run relationship between education and economic growth. A well educated labour force appears to significantly influence economic growth both as a factor in the production function and through total factor productivity. On the contrary, Ayara (2003) provided evidence on the relationship between the paradox of education and economic growth in Nigeria using the standard growth-accounting model. The findings suggest that education has not had the expected positive growth impact on economic growth.

The broad interpretation of these findings in the context of recent growth models is that raising the general level of educational attainment interacts positively with other forces -- among them the accumulation of complementary physical capital and the application of new technologies. Higher human capital intensity thus permits countries to accelerate their productivity growth rate and narrow the relative size of the per capita real income gaps separating them from the leading economies. Maintaining a high average level of educational attainments, and correspondingly high rates of investment in other forms of human capital (e.g. health, internal spatial and occupational mobility), would appear to serve as a *stabilising* force – although not a guarantee – against continuing secular decline in a country's relative per capita income position. Most of the theoretical literature on economic growth focuses on the role that investment in formal education plays in modern economies.

3 Methodology: Modelling Framework

Generally theories of capital formation and growth define output, Y, as

$$Y_{j,t} = F(A_{j,t}(K_{j,t}), X_{1j,t,\ldots\ldots,} X_{n.j,t}) \qquad 1$$

Where $Y_{j,\,t}$ is per capita output in country j period t. A represents technology being a function of total capital, K, and $X_1,\ldots,X_n$ are n factors of production. Following Benhabib and Spiegel (1994) model of technology diffusion which assumed a Cobb-Douglas production functions and dropping the country indicator we have:

$$Y_t = A_0 K_t^{\alpha} L_t^{\beta} \varepsilon_t \qquad 2$$

Where A_0 is initial technology

K is physical capital

L and ε represent labour and an error term respectively.

Technology interacts with both human and physical capital implying that technical change cannot be seen independently of capital (i.e., the idea of capital being the 'engine of growth' in Solow (1956) and endogenous growth theory). Benhabib and Spiegel separating the role of human capital and technological development – where a country's level of human capital enhances absorption of its own and foreign technology - is an endogenous growth framework, specify technological progress, Δa, as:

$$\Delta a_t = g h_t + m h_t \left[\frac{A_t^{max} - A_t}{A_t} \right] = (g - m) h_t + m h_t \left[\frac{A_t^{max}}{A_t} \right] + \varepsilon_t \qquad 3$$

Here, h_t is the natural logarithm of H_t, and g, m >0. In this equation, the first term represents domestic capital formation (innovation) and the last tem is technological diffusion interpreted as the product of a country's level of human capital (i.e., absorptive capacity) and the gap between the technological level of a leading country, max A_t, and that of the home country, A_t, terms "backwardness" and "distance to the frontier" (Krueger and Lindahl, 2001).

Taking the log difference of (2) and substitute for (3) we arrive at the growth equation:

$$\Delta y_t = c + \alpha \Delta k + \beta \Delta l_t + (g - m) h_t + m h_t (A_t^{max} / A_t) + u_t \quad 4$$

where y_t, k_t and lt are Yt, Kt and Lt in logs respectively. Equation (3) predicts that, in addition to growth in physical capital and labour, Δk and Δl, economic growth will also depend on the stock of human capital and the distance to the frontier; u_t is a serially correlated error term. Note, technology diffusion is an exponential process; i.e., countries further away from the frontier catch-up faster than those closer, and any country in some distance from the frontier could specialise in imitation without any further. The model also implies that imitation could be more beneficial than innovation for countries closer to the frontier, as long as the distance to the frontier is greater than (g-m)/m R&D effort (Jones 2008).

Benhabib and Spiegel (1994) follow Romer (1990) and Nelson and Phelps (1966) postulate that higher levels of human capital directly influence productivity via its impact on domestic innovation cause improvements in total factor productivity by facilitating the adoption and implementation of foreign technology and therefore reducing the knowledge gap between the technologically leading nations and the developing world. In addition, Lee (1995) emphasizes

that relatively cheaper foreign inputs are important determinants of growth since they provide a wider range of intermediate inputs (which in turn might enhance technological progress) and affect the efficiency of capital accumulation. Using cross-country data, Lee shows that the ratio of imports in investment has a significant positive effect on economic growth.

Following Loaning (2004) by standardizing output through labour to avoiding multicollinearity between capital and labour units and converted into logarithmic expression we have:

$$\ln y_t = \ln A_t + \alpha \ln k_t + u_t \quad 5$$

Combining the long-run information of the variables with a short-run adjustment mechanism, the equation can be represented in its error-correction form:

$$\Delta \ln y_t = \psi_1 \Delta \ln k_1 - \psi_2 (\ln y_{t-1} - \alpha \ln k_{t-1} - \ln A_t) \quad 6$$

Treating the technology as a non-constant parameter and allowed other determinants of growth it to change over time:

$$\ln A_t = c + \psi_4 + \psi_5 . \frac{imp}{gdi} + \psi_6 \ln se + \psi_7 \ln lte + \psi_8 \ln gcffdi \quad 7$$

where *c* is a constant or exogenous technological progress, *h* represents the level of human capital proxied by secondary and tertiary education enrolments , and *imp/gdi* is the ratio of total imports to gross domestic investment. Moreover, the effect of fdi dominance is assumed to have a negative impact on productivity and output growth. Combining equations (6) and (7) yields the "one step" error-correction model in its re-parameterized form:

$$\Delta y_t = c + tr + \psi_1 y_{t-1} + \psi_2 gcffdi - \psi_4 imp / gdi + \psi_5 fdi + \psi_6 lse + \psi_7 lte$$
$$+ \psi_8 \Delta gcffdi_{t-1} - \psi_9 \Delta imp / gdi_{t-1} + \psi_{10} \Delta fdi_{t-1} + \psi_{11} \Delta lse + \psi_{12} \Delta lte_{t-1}$$

Growth of output per worker now depends positively upon the average level of human capital through its impact on productivity. As Loening (2004) points out, despite some efforts in increasing average years of schooling, Nigeria's human capital base still remains far behind the developed economies average. If these equations are significant, they could yield information about the low performance of Nigeria's economy in terms of annual per capita growth.

4 Results and Discussion

Before proceeding for the ARDL bound test therefore, we test for the stationary status of variables to determine their order of integration. This is to ensure that the variable are not I(2) stationary so as to avoid spurious results. According to Quatarra (2004), in the of I(2) variables the computed F-statistics provided by Pesaran et al (2001) are not valid because the bounds testing is based on the assumption that the variables are I(0) or I(1). Therefore, the implementation of unit root tests in the ARDL procedure might still be necessary in order to ensure that none of the variables is integrated of order 2 or beyond.

Table 1: Unit Root Test using ADF Statistic

Stationarity test for variables					
Variables		**ADF test stat**	**Critical values** 1%	5%	**Order of integration**
LRGDP	Level	-2.212971	-4.205004	-3.526609	I(1)
	1st diff	-5.852927	-4.211868	-3.529758	
GCFFDI	Level	-1.845194	-4.226815	-3.536601	I(1)
	1st diff	-7.069919	-4.211868	-3.529758	
IMPGDI	Level	-1.867351	-4.211868	-3.529758	
	1st diff	-7.526624	-4.219126	-3.533083	I(1)
LSE	Level	-3.609467	-4.226815	-3.536601	
	1st diff	-6.588705	-4.211868	-3.529758	I(0)
LFDI	Level	-1.906399	-4.205004	-3.526609	
	1st diff	-5.762439	-4.211868	-3.529758	I(1)

Source: Computed by the author. Note: Tests include both intercept and trend

Using the ADF unit root tests, Table 1 confirm that all the variables are stationary at first difference except LSE which is stationary at level. This confirms that the variables in our study are integrated of both I(1) and I(0) which necessitates the adoption of ARDL-Bound testing modelling of long run relationship.

In the first step of the ARDL, we tested for the presence of long-run relationship in Equation (5), using (6). Following the procedure in Pesaran et al. (2001), we first estimated an OLS regression for the first differences part of Equation (6) and then tested for the joint significance of the parameters of the lagged level variables when added to the first regression. Table 3 reports the results with F-statistics when each variable is considered as a dependent variable (normalized) in ARDLOLS regressions.

Table 2: Co integration: Results of bounds test

Model For Estimation	**F-Statistics**	**Lag**	**Outcome**
F_{RGDP}**(GDP)**	3.986**	**2**	**Co integration**
Critical Bounds	**Lower**		**Upper**
1%	**3.66**		**5.464**
5%	**2.73**		**3.829**
10%	**2.31**		**2.35**

Note: The lag selection is based on AIC. Note: Sig at 5 percent

Thus the null hypothesis of no cointegration is rejected, implying long-run cointegration relationships between them.

4.2 Long Run Estimates from OLS and Dynamic OLS

The result of general model is in table 5, appendix 2 and the specific model is reported in table 5. Apart from the primary and tertiary enrolment that lost their significance in the general model other variable of interests are reported in the specific model. Overall, the adjusted R^2 in all specifications of the error-correction model is rather high indicating a good fitting of the respective model to the data. The coefficient of the error-correction terms carries the correct sign (negative) and is statistically significant at 1% and 5% with t statistics of -4.408173 and its corresponding probability value of 0.0001. The speed of adjustment of economic parameters to equilibrium is approximately 58.53 percent to real gross domestic product growth rate in the short run. Hence, the ECM is able to correct any deviations in the relationship between real GDP growth rate and the explanatory variables.

As the result shows, the convergence coefficient, which is the coeffifient of the lag value of the explained variable is negatively and significant, for its p-value is 0.0001. The result reveal that past economic growth adjust to realisation of economic growth produced some contemporaneous adjustment impact on economic growth. Precisely, a 10 percent increase in the past realisation of growth is explains positively about 59 percent of current growth levels.

As expected there is a positive relationship between economic growth and foreign direct investment. If foreign direct investment goes up by 1 percent, on average economic growth would increase by about 305 percent. Interestingly, the regression result shows that increase in gross capital formation have positive impact on economic growth. The interpretation here is that if rate of domestic capital formation increases by 1 percent, on average economic growth would increase by about 11 percent. Oddly, secondary school enrolment rate has negative effect on economic growth although at the probability value of 0.0780, this indication that the variable gains its significance at 10 percent level of significance. This unexpected result suggests that secondary school education is not a direct link to growth.

To this end, we estimate equation (2), which allows the impact of fixed gross capital formation on growth to vary across levels of foreign direct investment and import. The positive relation from the interactive coefficient between gross fixed capital formation and foreign direct investment and economic growth shows that foreign investment in Nigeria is dominating domestic investment. This indicates that foreign investment is substituting domestic investment which can be attributable to the overwhelming spread of multinational not only in terms of production and trade but also in term of finance.

More specifically, a positive interaction term reveals that GCF and GDI are substitute and that more foreign direct investment although brings about more economic growth but to the detriment of long run domestic capital formation. Again, the empirical results imply that foreign technology inputs are important determinants for productivity growth (the ratio of total imports to domestic investment may hold as an indicator for the quality of investment).

The coefficient of the ratio of import on growth of gross fixed capital formation has positive and statistically significant effect. It implies that relatively cheaper foreign inputs are important determinants of growth since they provide a wider range of intermediate inputs (which in turn might enhance technological progress) and affect the efficiency of capital accumulation. While, the short run regression results for FDI and import signifies negative and significant relationship that of secondary school enrolment is positive.

5 Conclusion

This study is motivated by the proliferation of the literature on capital-skill complementarity (CSC) and skill-biased-technical-change (SBTC). The second is a more flexible approach and facilitates the differentiation between CSC and skill-biased- technology-change (SBTC). We therefore examine the robustness of Benhabib and Spiegel's (2005) logistic model within the framework of Cobb-Douglass production technology. Using the ADF unit root tests, the study confirm that all the variables were stationary at first difference except secondary school enrolment which necessitates the adoption of ARDL-Bound testing modelling of long run relationship. Thus ARDL test shows long-run relationship between the variables. All the long run model estimates except secondary school enrolment using an auto regressive distributed lag (ARDL) bound testing confirm our hypotheses. The positive coefficient estimates of the interaction between fixed capital formation and foreign direct investment represented diffusion in capital in term of innovations. These results emphasizes that relatively cheaper foreign inputs are important determinants of growth since they provide a wider range of intermediate inputs (which in turn might enhance technological progress) and affect the efficiency of capital accumulation. Meanwhile the positive empirical evidence in favour of import-GDP interactive coefficient seems to be at most fragile. As a policy measure we can conclude that, optimal combinations in physical capital stock and FDI would yield better results. We strongly believe that study towards in depth human capital data and other components of human capital formation and foreign capital variables will create stronger evidence towards capital formation, technological diffusion and economic growth hypothesis in Nigeria.

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Appendix Table 1
Dependent Variable: DLRGDP
Method: Least Squares
Date: 07/04/07 Time: 23:04
Sample(adjusted): 1972 2010
Included observations: 39 after adjusting endpoints

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LRGDP(-1)	-0.585294	0.132775	-4.408173	0.0001
GCFFDI(-1)	3.960468	2.288244	1.730789	0.0945
IMPGDP(-1)	0.033798	0.061998	-0.545147	0.0400
LFDI(-1)	305.7647	61.33042	4.985530	0.0000
LGCF(-1)	11.16752	6.508862	1.715740	0.0973
LSE(-1)	-0.731155	0.399709	-1.829216	0.0780
DLFDI(-1)	-237.8330	50.87634	-4.674728	0.0001
DLIMP(-1)	-0.274034	0.194953	1.405643	0.0708
DLSE(-1)	0.865678	0.380841	2.273070	0.0309
C	-843.8198	168.5616	-5.006001	0.0000
@TREND	-0.304737	0.070789	-4.304886	0.0002

R-squared	0.680856	Mean dependent var	0.135897
Adjusted R-squared	0.566876	S.D. dependent var	0.335988
S.E. of regression	0.221121	Akaike info criterion	0.052531
Sum squared resid	1.369045	Schwarz criterion	0.521741
Log likelihood	9.975641	F-statistic	5.973477
Durbin-Watson stat	2.404372	Prob(F-statistic)	0.000085

Appendix Table 2
Wald Test:
Equation: Untitled

Test Statistic	Value	df	Probability
F-statistic	3.986175	(8, 12)	0.0158
Chi-square	31.88940	8	0.0001

Null Hypothesis Summary:

Normalized Restriction (= 0)	Value	Std. Err.
C(1)	-0.094644	0.046835
C(2)	0.145266	0.093209
C(3)	0.120774	0.077965
C(4)	-0.307368	0.166011
C(5)	-0.001901	0.001503
C(6)	-0.037143	0.008737
C(7)	0.012362	0.005135
C(8)	-0.015422	0.008075

Restrictions are linear in coefficients.

Authors' Note

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