Human Capital and Economic Growth: The Sudan Case
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Abstract

There can be no significant economic growth in any country without adequate human capital development. In the past decades, much of the planning in Sudan was centered on the accumulation of the physical capital for rapid growth and development, without due recognition of the important role of the human capital in the development process. The overall objective of the paper is to investigate the long, as well as the short–term impact, of human capital on the economic growth in Sudan during the period of 1970 to 2009. The auto regressive distributed lag (ARDL) approach was used to ascertain this relationship. The basic macroeconomic variables of concern derived from the literature review are: the real gross domestic product, the labor force, the real capital stock as well as the average years of schooling. The results detect the existence of a long–run relationship among the variables when economic growth and human capital are considered as dependent variables. Furthermore, the none–causality test suggests existence of two long–run causality relationships: (a) labor, capital and education to economic growth, and (b) labor, capital and growth to human capital. The short–run causality test indicates the existence of two way relationship between economic growth and capital stock.

رأس المال البشري والنمو الاقتصادي: درس من السودان
عاطف عوض*
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ملخص

تهدف هذه الدراسة الى فحص اثر تراكم راس المال البشري علي النمو الاقتصادي على المدي الطويل والقصير فى السودان فى الفترة مابين 1970-2010. استخدمت الدراسة مدخلAuto Regressive Distributed Lag (ARDL) فى تحليل العلاقة بين المتغيرات محل الدراسه . تشير نتائج الدراسه الى انه و في الاجل الطويل يلعب كلا من متغيري العمالة وراس المال المادي دور موجب ومعنوي على النمو الاقتصادي ، اما فى الاجل القصير فان راس المال المادي فقط له تاثير معنوي . اختبار Wald للعلاقة السببية يشير الى ان كلا من راس المال البشري والمادي اضافة الى العمالة لها تاثير قوي على النمو لاقتصادي فى الاجل الطويل الشئ الذي يدعو الى مزيد من الاهتمام بتنمية راس المال البشري فى السودان.

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1. Introduction

Models of economic growth aim to discover the productive factors that might contribute to increased economic productivity and generate a sustainable growth. There is no consensus in recog–

nizing these factors. There are divided opinions between the relative importance of each productive factor, as well as the particular way in which each factor participates in the economic growth.

In this respect, human capital is no exception. Undoubtedly, there is a relationship between economic development and human capital. The most progressive ones are also those that have higher levels of education in their populations. However, empirical studies do not always support the notion of positive and significant relationship between human capital accumulation and economic growth.

Models of economic growth treat human capital in two main forms. On one hand, a productive factor is considered similar to physical capital, technology and labor. On the other hand, it is accepted as a factor that facilitates the acquisition of technology. Human capital is a crucial productive factor in neoclassical models of exogenous growth such as shown by Mankiw et al. (1992) model and also in endogenous growth models as in Lucas (1988). Other endogenous growth models – such as the ones from Nelson and Pheleps (1966), Romer (1986, 1990), and Benhabib and Spiegel (1994) – state that human capital accumulation facilitates technology adoption, creation and diffusion.

Despite the consensus found in the theoretical interpretations of the relationship between human capital accumulation and economic growth, there is a large controversy surrounding the empirical findings. In international literature, three types of conclusions for the empirical studies may be considered: (a) studies that consider human capital accumulation as essential

for economic growth; (b) studies that support the assumption that human capital accumulation is not capable of explaining the differences in the income per capita distribution at a world scale; and (c) studies that consider human capital accumulation as a result of economic growth. These mixed findings are justified by economists based on different reasons – the most important ones being: (a) mis–specification of the models; (b) measurement errors in education data; and (c) the selected proxies for human capital.

This study tries to examine the contribution of human capital to the economic growth in Sudan over the past 40 years. The interest is twofold: Firstly, there are very few studies that have thoroughly analyzed the past growth patterns for the country; and there are also few studies that have empirically appraised the direct impact of human capital on growth. In general, the evidence on human capital and growth comes almost entirely from a cross country analysis. Single–country studies, however, may be more illuminating since they overcome the heterogeneity problem and take into account the unique historical information for each country. Indeed, the original studying of economic growth focuses on the time–series dynamics of macroeconomic variables. Moreover, the cross–section focus may be inadequate if returns to human capital or the quality of education differ substantially across countries. Secondly, the empirical analysis is based on an error–correction methodology which deals with endogeneity, and explores several data construction and robustness issues.

2. Human Capital in Sudan

Sudan, like many less developed countries, is characterized by its low level of human capital. According to Baroo and Lee (2010), the data on average years of schooling for Sudan shows that since independence, the country has witnessed a relatively modest educational achievement. In terms of human capital, the data reveal that the average years of schooling for the appropriate population category in Sudan were only 0.41 year in 1960 but rose to an estimated 3.28 years by 2010. For the year 2010, the

educational achievement of Sudan was much lower than that of the world (average of 7.76 years), of the developing world (average of 7.09 years), of South Asia (average of 5.24 years) and of sub-Saharan Africa (average of 5.23 years).

The World Bank (1998) argues that with this level of achievement, Sudan is still far below the threshold of four years beyond which increasing returns to scale for human capital will begin to accrue. When this threshold level of education is achieved, the quality of labor reaches a critical mass, allowing greater overall productivity. In economic growth theories, namely the endogenous growth theory, human capital plays a significant influence and one of the most important determinants for a country's growth.

In Sudan, a recent study of Ali (2000) aimed to investigate whether there is a relationship between human capital and economic growth in Sudan during the period 1960-2000. The study reveals that the stock of human capital per worker in Sudan has recorded a rather impressive growth over the period. The high annual growth rate for the stock of human capital was registered in 1975-1980 with 6.55% while the low rate was recorded in the end of the period with 2.09%. The growth rate of the human capital per worker recorded an increasing pattern until 1980 and after that it started to fluctuate on a declining trend. For the whole period of 1960-2000, the annual rate of human capital growth was at 4.28%.

Looking at per capita growth during the same period, a fluctuation in its value since 1960 may be observed. Clearly, despite the impressive expansion in the stock of human capital as measured by the average years of schooling in the population, GDP per capita did not show a similar trend. This result means that the growth of educational capital per worker does not seem to have any association with the growth of output per worker. For example, for the period 1960-1975 and the period 1980-1990, there was a negative relationship between the growth in the stock of human capital per worker and per capita GDP.

A positive relationship between the two is recorded during the period of 1975–1980 and 1990s. Ali ⟨2002⟩ concludes that "on the whole, no systematic relationship between the growth rate of human capital stock per worker and per capita GDP growth can be detected from Sudan's growth experience".

Figure 1 below which describes the relationship between human capital measured in term of average years of schooling and per capita annual growth rate during the period 1970–2009 confirms Ali's ⟨2000⟩ observations.

Figure ⟨1⟩: Average years of schooling for people aged 15 years and above ⟨H⟩, per capita annual growth rate in % ⟨Y⟩, Sudan, 1970–2009.
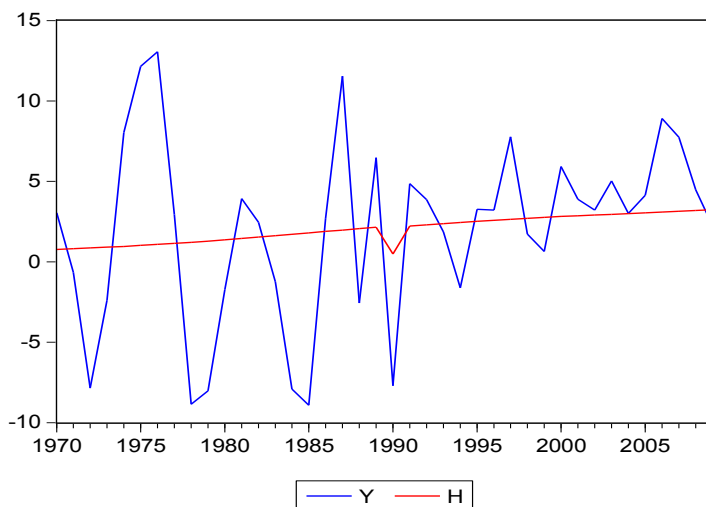
3. Literature Review

The quantity of empirical studies that include different proxies for human capital in their growth regressions is large and growing. Most of these studies have adopted a somewhat narrow focus on education, or, more precisely, schooling. Among the most popular proxies for human capital are school enrolment rates ⟨i.e., the percentage of the relevant part of the population enrolled in school⟩ and educational attainment measured in years of schooling

(i.e., the average years of formal education of the working-age population). Indeed, De la Fuente and Ciccone (2002) classified the previous studies made in this area through the econometric specification criteria. Thus, through these criteria, the studies are classified into: (a) studies that are based on a convergence equation, which comprises ad-hoc specification and structural convergence equations; and (b) studies that estimate an aggregate production function.

A small number of studies have estimated a macroeconomic production function by employing some sort of physical capital stocks measurement. These studies begin with a production function in the form:

$$Y = A_t K^{\alpha}_t H^{\beta}_t L^{\lambda}_t \qquad \text{(Equation 1)}$$

The coefficients on K, H, and L are assumed to be to the sum of 1. Rewriting the function in per capita terms, taking logs, and differentiating with respect to time yields, an equation in growth rates (denoted by ΔIn y) for country i at time t is as shown:

$$\Delta \ln y_{it} = \Delta \ln a_{it} + a \Delta \ln k_i = + \beta \Delta \ln h_{it} \qquad \text{(Equation 2)}$$

Equation 2 may seem reminiscent of conventional growth accounting exercises which analyze the growth experience of a particular country by decomposing the growth rate of outputs into growth rates in inputs and (residual) total factor productivity (TFP). The difference is that in this case, the analysis relates to a cross-section of countries. Correspondingly, it has sometimes been labelled as a cross-country growth accounting.

Note that this approach circumvents the problem that A_0 is unobservable by working with the growth rates and thereby eliminating the A_0 term, which is a major advantage. However, Equation 2 still contains the (unobservable) growth of the technical efficiency, Δln a_{it}, which needs to be dealt with in some ways. For example, if it is assumed to be constant across countries, it can be estimated as the regression constant (de la Fuente and Ciccone, 2002).

Benhabib and Spiegel ⟨1994⟩ were among the first to implement this cross-country growth accounting approach to study the role of human capital. In their influential paper, they used various measurements of physical capital stock constructed from observed investment flows and estimates of the initial capital-output ratios. Their preferred human capital proxy is derived through a procedure in which the enrolment rate is regressed to obtain the educational attainment of the labor force for a sample of countries for which both are available. The relationship found is then extrapolated to a larger sample for which only school-enrolment ratios are available.

Benhabib and Spiegel ⟨op. cit.⟩ found that the growth of human capital between 1965 and 1985 has an insignificant effect on the per capita output growth, and enter with mostly negative coefficients. This result has strongly proven the inclusion of several "ancillary variables" ⟨such as the initial level of income⟩ among the regressors, and to the use of alternative measurement of human capital, especially the years of schooling measurement from Barro and Lee ⟨1993⟩. Moreover, Benhabib and Spiegel were unable to confirm their suspicion that the results might have been driven by a few African countries which, despite having expanded their education levels considerably relative to their low starting levels, experienced extremely slow growth of output over the considered period. The insignificant and negative coefficient on the education variable is not sensitive to the inclusion of a regional dummy variable for Africa,[1] neither is it sensitive to the exclusion of the African countries from the sample.

Benhabib and Spiegel ⟨op. cit.⟩ interpreted their findings as an indication that the conventional way of incorporating human capital, that is, as an additional input in production, may be mis-specifying its role in the growth process. Indeed, they did find some evidences of a relationship ranging from the initial levels of human capital to the rate of economic growth when the initial level of income is held constant. They also estimated a more structural specification inspired by Nelson and Phelps ⟨1966⟩ and Romer ⟨1990⟩ with the TFP growth as the dependent variable in which they included elements intended to capture the effect of a human

capital on the technological catch–up and innovation. The catch–up term turns out to be significant for the broad samples as well as for the samples of the poorest countries. On the other hand, for the richest third of the samples, the innovation term is found to be more important than the catch–up term.[2] Finally, their results indicated that human capital attracts physical capital, thus suggesting there are some degrees of complementarily between the two factors. Benhabib and Spiegel regarded all of these as supportive to their view that human capital affects growth through channels other than the ones usually allowed for, within a growth–accounting framework.

In another well–known contribution, Pritchett (2001) extended this literature by constructing the 'Mincerian' stocks of human capital. His starting point is the well–documented microeconomic evidence on the wage increments resulting from the additional years of education. Mincer (1974) found empirically that a log–linear relationship where the log wage is a linear function of the years of formal education a person has received (along with his or her years of work experience) fits the data exceptionally well. This formulation implies that, on the average, each additional year of schooling yields a constant percentage increase in the wage. At the same time, obviously, the nth year of schooling increases the wage by a greater absolute amount than the n–1th year.

Pritchett (op. cit.) defines human or educational capital as the discounted value of the wage premiums due to education (a premium being defined with respect to the unskilled wage). With some further assumptions, these allowed him to write the proportional growth rate of the human capital stock as the growth rate H. The H is expressed as below:

$$H(t) = e^{\theta s(t)} - 1 \qquad\qquad (\text{Equation } 3)$$

Where θ is the percentage increment to wages resulting from an additional year of schooling while $S(t)$ is years of schooling at time t. He assumed $\theta = 10\%$ (a value based on consensus estimates from labor economics). For S, he used the data on average years of schooling

from Barro and Lee 〈1993〉 and a second group of authors. With this information, Engelbrecht obtained an aggregate measurement of growth of the educational capital per worker for a large sample of countries, which he used to estimate Equation 3 above.

Like Benhabib and Spiegel 〈1994〉, Pritchett 〈2001〉 reported a negative and insignificant coefficient on the growth of human capital. This contrasted sharply with the expected value for the coefficient β in Equaiton 2. β should reflect on the human capital's share in the income and therefore, according to Pritchett, ought to be between 0.2 and 0.4. The result is robust against outliers 〈i.e., influential and atypical observations〉 and, once again, to the exclusion of the African countries and to other variations of the sample composition, as well as to the inclusion of regional dummies. Pritchett contended that these findings constitute a "micro–macro paradox": although the microeconomic literature finds consistent evidence of substantial private returns to education in the form of higher wages. Macroeconomic studies are unable to come up with a proof that growth in education spurs income growth. He went on to present some interesting explanations with the potential to reconcile these apparently conflicting observations:

"Where has all the education gone? I do not propose a single answer, but put forward three possibilities that could account for the results:

- The newly created educational capital has gone into piracy; that is, privately remunerative but socially unproductive activities.
- There has been a slow growth in the demand for educated labor, hence the supply of educational capital has outstripped demand and returns to schooling have declined rapidly.
- The education system has failed, so a year of schooling provides few 〈or no〉 skills" 〈Pritchett 2001〉.

The first possibility refers to rent–seeking and other distortions in the economy.[3] The third possibility is compatible with a signalling model of wages in the spirit of Spence 〈1973〉,

where schooling creates no skills but still leads to higher wages by signalling qualities, like ambition or innate ability to the employer (because individuals with those qualities may find it easier to obtain a degree).

As mentioned previously, most of the empirical studies estimate an aggregate production function that utilizes cross section data. Irrespective of the reason on why this type of data is employed, few current studies have used time series data for studies on certain countries. For example, Wang and Yao (2003) investigated the change in the sources of economic growth in China during the reform period 1978–1999 relative to that of the pre–reform period 1953–1977. The investigation was made by undertaking a simple growth accounting exercise incorporating human capital. The results showed that, firstly, the accumulation of human capital in China as measured by the average years of schooling in the population age of 15–64 is quite rapid and it contributes significantly to growth and welfare. However, the rate of growth of human capital declined significantly in the reform period in 1978–99, and its contribution to the GDP growth is smaller as compared to the pre–reform period. Secondly, after incorporating the human capital, the growth of the TFP still plays a positive and significant role during the reform period 1978–1999, in contrast to the negative productivity growth during the pre–reform period 1952–1977.

Adawo (2011) analyzed the contribution of human capital to the economic growth in Nigeria in the long run during the period 1970–2006. Based on the production function framework, the selected human capital indicators are enrolment rates in primary, secondary and tertiary education. Other variables included physical capital formation. The result of this study showed that the human capital of primary school contributes to the growth while in most cases, the secondary school and that of tertiary institutions, dampen the growth. Above all, it is noted that in the short–run, physical capital plays a very important role in encouraging growth.

Babatunde and Adefabi (2005) investigated the long–run relationship between the education and the economic growth in

Nigeria during the period 1970–2003. The investigation was made through the application of the Johansen cointegration technique and the vector error correction methodology. The results of the cointegrating technique suggest that there is a long-run relationship between the enrolments in the primary and the tertiary levels as well as the average years of schooling with the output per worker. The two channels through which human capital can affect growth, were analyzed. While it may be difficult to separate the two different channels from each other, results revealed that a well educated labor force possesses a positive and significant impact on the economic growth through factor accumulation and on the evolution of the TFP. A good performance economy in terms of per capita growth may therefore be attributed to a well-developed human capital base.

Afzal et al. (2010) investigated the short-run and the long-run relationship between the school education and the economic growth in Pakistan during the period from 1970–71 to 2008–09. For this purpose, the authors used the annual time series data on the real GDP, the real physical capital, the inflation and the general school enrolment. Cointegration between school education and economic growth is discovered in this study. Furthermore, the results confirmed the existence of two-way direct long-run relationships between school education and economic growth. In the short run, there is a two- way inverse relationship between school education and economic growth. Meanwhile, in the long run, the macroeconomic instability due to inflation retards economic growth and school education. A statistically significant and inverse relationship between school education and poverty is observed only in the short-run.

For Sudan, as previously mentioned, one of the main contributions of this study is to close the existing gap in the literature related to the relationship between economic growth and human capital in the country. The only and recent study attempt to investigate the impact of investment in education in Sudan is made by Ali (2006). The author estimated the rate of returns to the human capital in Sudan in terms of the general population and

by gender. The set of data for estimating the rate of returns to the human capital in Sudan was obtained from the 1996 Migration and Labor Survey conducted by the Ministry of Labor. By using the Mincer's equation (1974), the results demonstrated that, all the estimated coefficients are highly significantly at the 1% level for the whole sample and that of the males. For the female sub-sample, the coefficients for experience and its square are significantly different from zero at the 5% level of significance. Looking at the coefficient of the years of schooling, it is clear that, the rate of returns to the investment in human capital is about 6.1% for the Sudan as a whole, and about 6% for males and 6.3% for females. These rates of returns, , are rather low and do not support the world pattern. The difference in the rates of returns between the males and the females is not very striking and amount to about 0.3 percentage points, much lower than that expected from the world patterns. Such results of low rates of returns to the investment in human capital have been reported for a number of low income countries in Sub-Saharan Africa as well as in Arab countries.

Ali (2006) also estimated the extended Mincer equation for Sudan where he used dummies for four levels of education: (a) literate; (b) primary; (c) secondary; and (d) tertiary with the alliterated category used as a reference category. The results demonstrated that all the coefficients for the entire sample and that for the males, are highly significantly at the 1% level. For the female sample, the coefficient on the illiterate dummy is not significant while that on the primary dummy, is significantly different from zero at the 10% level. For those with experience, the squares are significantly different from zero at the 5% level, while the rest are highly significant at the 1% level. Based on the above results and by using six years as the length for both the primary and the secondary levels of education and four years for tertiary level, Ali (op. cit.) calculated the rates of returns to the education level. His result revealed that contrary to the world patterns, the rates of returns to the primary and the secondary education are very low, while that for the higher education is rather high. Specifically,

for the primary education, the rate of return is about 4.4% for the country as a whole: 4.2% for the males and 4.7% for the females. For secondary education, the rate of return is about 0.7% for the country as a whole: 1.3% for males and 3.1 for females.

Ali (2006) stated: "We hasten to note that this is a very problematic result in view of the fact that the rate of return for the country is supposed to be a weighted average of the two sub-samples. According to our calculations, such a rate should have been 1.62%. The rate of return to higher education is 15% for the country as a whole: 14.8% for males and 17.3% for females, with a margin of 2.5 percentage points in favor of educating females. Despite its nonconformity with the world patterns, the results exhibited a U-shaped pattern for the rate of return." Ali (op. cit.) concluded that the implication of the above results for resource allocation within the educational sector should be obvious.

Along the same line, a recent study was conducted by Satti (2010) to examine the influence of education and experience on wages (log) between the genders in Sudan. Based on the preliminary results from the survey of Nour (2009) and using the Ordinary Least Squares (OLS) method, Satti estimated the Mincerian earning function and the rate of return to education is defined by gender in Sudan. Their results explain the differences in the correlation between wage and education as well as experience, and its square is defined by gender. This finding implies the very low rate of return to education for all the samples, men and women, and slight gender gap or difference in the rate of return to education in favor of the women at only 0.2, which is not very noticeable. Satti (2010) concluded that, these results at the micro level seem to be consistent with the results at the macro level as discussed by Ali (2006) indicating that the difference in the rate of returns between males and females is not very striking and amount to about 0.3 percentage point which is much lower than that of world patterns.

4. Methodology and Model Specifications

In this section, the methodology and the methods used to obtain the research objectives is discussed. As previously mentioned, the overall objective of this study is to investigate the long- and short-run relationship between the variables as well as the direction of the causality relationship between the same variable in the long and short run. The study estimates the parameters by the log-linearized Cobb-Douglas production function. The choice of this type of production function follows the international literature on neoclassical growth models (Abbas and Peck) (Adawo, 2011; Uwatt, 2002).

From Equation 1, the production function in the log form:

$$logY_t = a + \alpha\ logK_t + \beta logL_t + \gamma logH_t + \epsilon_t \qquad (Equation\ 4)$$

Where Y is the real Gross Domestic Product; K is the physical capital; H is the human capital and $\varepsilon_{??}$ is the error term. This specification implies that the econometric estimations do not impose any restrictions on the value of the parameters (the elasticity's product- factor) in trying to get the answer to our problem from the data. Thus, the existence of constant return to scale is not imposed as a condition for the estimation of the model. This form of estimation, on one hand, allows the elimination of the restrictions imposed in the returns to scale for the set of inputs considered. On the other hand, it allows the determination of the sign of each of the parameters of the function. The economic theory imposes positive values for each of the elasticity product- factor, but the empirical analysis can disclose a distinctive result specific to the economy being analyzed, that will be tested.

This study adopts considerations from selected literature in choosing the relevant proxies for the input variables. The study uses total labor force as an indicator for labor and real capital stock (derived from real gross fixed capital formulation) as an indicator for physical capital (Abbas, 2001; Adawo, 2011. Barro, 1991; Ndiyo, 2002). For human capital the study employs the average years of

schooling for population aged 15 and over. In this respect, Ali (2006) argues that, for developing countries the relevant estimates are the population ages 15 years and over. Data on real gross domestic products, real fixed gross capital formulation and total labor forces are obtained from The World Bank database. Data on average years of schooling is collected from Barro and Lee (2010). In fact, the most widely used estimates of the human capital stock for various countries of the world are those of Barro and Lee (2010, 2001, 1993). Missing data for some variables are estimated using straight-line interpolation or extrapolation method.

Definitions of Variables and Measurement

Real Gross Domestic Products. Real gross domestic products (Y) is actually gross domestic products (GDP) at 2000 constant basic prices (otherwise known as real gross domestic products) equals GDP at 2000 market prices less indirect taxes net of subsidies. Here, real per capita GDP is used as indicator for the country's economic growth.

Total Labor Force. Total labor force (L) is comprised of people aged 15 and older who meet the International Labor Organization definition of the economically active population: all people who supply labor for the production of goods and services during a specified period. It includes both the employed and the unemployed. While national practices vary in the treatment of certain groups such as the armed forces and seasonal or part-time workers, in general, the labor force includes the armed forces, the unemployed and first-time job-seekers. However, homemakers and other unpaid caregivers and workers in the informal sector are excluded.

Real Capital Stock. The total physical capital (K) existing in an economy at any moment of time is referred to as capital stock. For this study, data on real capital stock are derived from real capital formation at the 2000 constant basic price using this

formula $K_t = \sum_{j=0}^{t} (1-d)^{t-j} \left(\frac{I_j}{P_j} \right)$. Where K_t is the capital stock at

period T, d is the rate of depreciation; I_j is the total investment at period J; and P_j is the price level at period J. I_J/P_J is the real value of the investment, in this case it is replaced by the value of real fixed capital formation. Sudan does not provide data on physical capital stock rather data on capital formation (investment) is reported every year. For the purpose of this study, real capital stock (RCS) from real capital formation is computed using the above formula. In the absence of specific micro surveys or information regarding the various tax legislations, the depreciation rate has been set at 10%, in line with other studies, such as Harbenger (1978), Bisat et al. (1997) and Abu-Quarn and Abu-Bader (2007).

Average years of schooling. Average years of schooling for adults are the years of formal schooling received, on average, by adults over the age of 15[4].

Estimation Procedure

Stationary Test. The common procedure in economics is to test the presence of a unit root to detect a non-stationary behaviour in the time series. Two conventional unit root tests are employed namely, the Dickey-Fuller test (ADF) (Dickey and Fuller, 1979) and the Phillips–Perron test (PP) (Phillips and Perron, 1988). Unit root tests are first conducted to establish the stationary properties of the time series data sets.

Stationary Test entails a long-run mean reversion to determine a series stationary property in order to avoid spurious regression relationships. The presence of non-stationary variables might lead to spurious regressions, where regressing a series having a unit root into another, is most likely to produce high R^2 and significant t-distribution results even though in reality, the two variables are independent. This could lead to erroneous inferences and non-objective policy implications. The DF and the Augmented Dickey Duller (ADF) tests are used for this purpose in conjunction with the critical values computed by MacKinnon which allows for calculation of DF and ADF critical values for any number of regressors and sample size.

In order to determine the stationary of each variable for each time series of the sample, the ADF test is employed. The ADF model used is given as follows:

$$\Delta Y_t = \alpha_1 + \gamma Y_{t-1} + \alpha_2 t + \sum^{p} \beta_1 \Delta Y_{t-1} + \varepsilon_t \qquad \langle \text{Equation 5} \rangle$$

$$\text{Where } \gamma = \left(1 - \sum_{i=0}^{n} \alpha_1 \right), \quad \beta_1 = \sum_{i=0}^{n} =_1 \quad . \; Y_- \text{ represents the natural}$$

logarithm of RGDP, α_0 is the intercept term, $\square$ is the coefficient of interest in the unit root test, β_1 is the parameter of the lagged first difference of Y_-, to better represent the ρth–order autoregressive process, and ε_- is the white noise error term.

ARDL Model Specification. To analyze empirically the long–run relationships and dynamic interactions among the variables of interest, the model has been estimated by using the bounds testing $\langle$or autoregressive distributed lag $\langle$ARDL$\rangle\rangle$ cointegration procedure, developed by Pesaran et al. $\langle$1999$\rangle$. The procedure is adopted for the following three reasons:. (a) Firstly, the bounds test procedure is simple. As opposed to other multivariate cointegration techniques such as Johansen and Juselius $\langle$1990$\rangle$, it allows the cointegration relationship to be estimated by OLS once the lag order of the model is identified. (b) Secondly, the bounds test procedure does not require the pre–testing of the variables included in the model for unit roots, unlike other techniques such as the Johansen. It is applicable irrespective of whether the regressors in the model are purely I$\langle$0$\rangle$, purely I$\langle$1$\rangle$ or mutually cointegrated. $\langle$c$\rangle$ Thirdly, the test is relatively more efficient in small or finite sample data sizes as is the case in this study. The procedure will however, crash in the presence of I$\langle$2$\rangle$ series.

Following Pesaran and Shin $\langle$1999$\rangle$ as summarized in Choong et al. $\langle$2005$\rangle$, the bounds test procedure is applied by modeling the long–run Equation 4 as a general vector autoregressive $\langle$VAR$\rangle$ model of order p, in z_t :

$$z_t = c_* + \beta_t + \sum_{i=1}^{p} \Phi_i \, z_{t-i} + \epsilon_t, \quad t = 1, 2, 3 \dots\dots T \qquad \langle \text{Equation } 6 \rangle$$

With corepresenting a $\langle k+1 \rangle$–vector of intercepts $\langle$drift$\rangle$ and β denoting a $\langle k+1 \rangle$–vector of trend coefficients. Pesaran and Shin $\langle 1999 \rangle$ further derived the following vector equilibrium correction model $\langle$VECM$\rangle$ corresponding to Equation 6:

$$\Delta z_t = c_* + \beta_t + \Pi z_{t-1} + \sum_{i=1}^{p} \Gamma_i \Delta z_{t-i} + \square_t, \quad t = 1, 2, 3, \dots., T \qquad \langle \text{Equation } 7 \rangle$$

Where the $\langle k+1 \rangle \times \langle k+1 \rangle$–matrices $\Pi = \quad \mathbf{I}_{k+1} + \sum_{i=1}^{p} \varphi_1$

and $\Gamma_i = - \sum_{j=i+1}^{p} \varphi_j, j = \square, 2, \dots p-1$ contain the long–run multipliers and

short–run dynamic coefficients of the VECM; zt is the vector of variables t y and t x respectively. Y_t is an $I\langle 1 \rangle$ dependent variable defined as $\log Y_t$ and $x = \{L \ K \ H\}$ is a vector matrix of 'forcing' $I\langle 0 \rangle$ and $I\langle 1 \rangle$ regressors as already defined with a multivariate identically and independently distributed $\langle$i.i.d$\rangle$ zero mean error vector $\varepsilon_t = \langle \varepsilon_{1t} \varepsilon_{2t} \rangle$ and a homoskedastic process.

Further assuming that a unique long–run relationship exists among the variables, the conditional VECM $\langle 7 \rangle$ now becomes:

$$\Delta y_t = c_{y0} + \beta_t + \delta_{yy} y_{t-1} + \delta_{xx} x_{t-1} + \sum_{i=1}^{p-1} \gamma_i \Delta y_{t-i} + \sum_{i=0}^{p-1} \theta_i \Delta x_{t-1} + \epsilon_{yt}, \quad t = 1, 2, \dots T \quad \langle \text{Equation } 8 \rangle$$

On the basis of Equation 8, the conditional VECM of interest can be specified as:

$$\Delta lnY_t = c_i + \delta_1 ly_{t-1} + \delta_2 ll_{t-1} + \delta_3 lk_{t-1} + \delta_4 lh_{t-1} + \sum_{i=1}^{p} \varphi_i \Delta ly_{t-i} + \sum_{j=1}^{q} \phi_j \Delta ll_{t-j} + \sum_{\tau=1}^{q} \Psi_\tau \Delta lk_{\tau-1} + \sum_{s=1}^{q} \Omega_s \Delta lh_{s-1} + \varepsilon_t$$

⟨Equation 9⟩

Where δ = the long run multipliers, c_0 are is the drift and ε_t are white noise errors.

Bounds Testing Procedure. The first step in the ARDL bounds testing approach is to estimate Equation 9 by OLS in order to test for the existence of a long-run relationship among the variables by conducting an F-test for the joint significance of the coefficients of the lagged levels of the variables, i.e., ⟨H_0: $\delta_1 = \delta_2 = \delta_3 = \delta_4 = 0$, and H_1: $\delta_1 \neq \delta_2 \neq \delta_3 \neq \delta_4 \neq 0$.⟩. The tests are denoted which normalize on Y by Fy ⟨Y/L, K, H⟩. Two asymptotic critical values bounds provide a test for co integration when the independent variables are I⟨d⟩ ⟨where 0<d<1⟩: a lower value assuming the regressors are I⟨0⟩ and an upper value assuming purely I⟨1⟩ regressors. If the F-statistic is above the upper critical value, the null hypothesis of no long-run relationship can be rejected irrespective of the orders of integration for the time series. Conversely, if the test statistic falls below the lower critical value, the null hypothesis cannot be rejected. Finally, if the statistic falls between the lower and upper critical values, the result is inconclusive. The approximate critical values for the F test are obtained from Pesaran and Shin ⟨1997⟩. In the second step, once cointegration is established, the conditional ARDL ⟨ p_1 ,q_1 , q_2,q_3 ⟩ long-run model for Y_t can be estimated as:

$$ly_t = c_t + \sum_{i=1}^{p} \delta_1 ly_{t-i} + \sum_{i=0}^{q1} \delta_2 ll_{t-i} + \sum_{i=0}^{q2} \delta_3 lk_{t-i} + \sum_{i=0}^{q3} \delta_4 lh_{t-i} + \epsilon_t$$

⟨Equation 10⟩

Where all variables are as previously defined. This involves selecting the orders of the ARDL ⟨ p ,q_1 , q_2,q_3 ⟩ model in the five variables using Akaike Information criterion ⟨AIC⟩ or the Schwarz Bayesian criterion ⟨SBC⟩. In the third and final step, the short-run dynamic parameters are obtained by estimating an error correction model associated with the long-run estimates. This is specified as follows:

$$\Delta ly_t = \mu + \sum_{i=1}^{p} \varphi_i \, \Delta ly_{t-i} + \sum_{j=1}^{q} \Box \emptyset_j \, \Delta ll_{t-j} + \sum_{n=1}^{q} \Psi_n \, \Delta lk_{t-n} + \sum_{s=1}^{\bar{z}} \Omega_s \, \Delta lh_{t-s} + \theta \, ecm_{t-1} + \epsilon_t$$

⟨Equation 11⟩

5. Results and Discussion

Unit Root Test

Before proceeding with the ARDL bounds test, the stationarity status of all variables is tested to determine their order of integration. This is to ensure that the variables are not $I(2)$ stationary so as to avoid spurious results. According to Ouattara ⟨2004⟩, in the presence of $I(2)$ variables, the computed F statistics provided by Pesaran ⟨2001⟩ are not valid because the bounds test 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. The variables are examined in logarithmic forms to achieve linearity. The data series are tested for stationarity by using the ADF and the PP as the starting point to assess the order of integration.

The result of the tests indicates that the null hypothesis ⟨the series has a unit root⟩ at 1% and 5% significance level cannot be rejected at all levels for the variables. At first, the difference of the remaining variables is stationary at $I(1)$. Therefore, the null hypothesis is rejected and the alternative is accepted for each of the variables. It is possible to conclude that the variables are integrated at different order ⟨ $I(0)$, $I(1)$ ⟩. The unit root result is presented in Table 1.

The results of the unit root test at level, as well as first difference order, affirms the need to test for cointegration among these variables. The second step is to test whether a long-run relationship exists among the variables.

Table (1): Unit Root Test

Variables	Variables at level				Variables at first difference			
	With trend		Without trend		With trend		Without trend	
	ADF	PP	ADF	PP	ADF	PP	ADF	PP
LY	0.131772 (0.9964)	-0.630802 (0.9713)	1.002951 (009958)	1.581404 (0.9992)	-3.843582 (0.0258)**	-5.475577 (0.0003)*	-4.142033 (0.0025)*	-3.482302 (0.0055)*
LK	-1.975553 (0.5956)	-1.417555 (0.8403)	0.172602 (0.9672)	0.116470 (0.9630)	-4.726101 (0.0028)*	-3.846842 (0.0246)**	-4.143644 (0.0021)*	-3.922373 (0.0045)*
LL	-2.514357 (0.3198)	-2.615368 (0.2760)	-1.907952 (0.3253)	-2.668935 (0.0885)	-3.883031 (0.0226)**	-3.9421120 (0.0197)**	-3.586034 (0.0105)**	-3.542446 (0.0120)*
LH	-1.324861 (0.562)	-1.144821 (0.577)	2.694811 (0.1109)	1.999872 (0.1820)	-6.554866 (0.0001)*	-6.124839 (0.0001)*	-3.554866 (0.0029)*	-3.093872 (0.0080)*

(*) and (**) indicate significance at 1% and 5% respectively .

Cointegration Test

In the first step of the ARDL analysis, the presence of long–run relationships is tested in equation (4), using equation (7) . A general–to–specific modelling approach guided by the short data span and AIC respectively to select a maximum lag order of 2 for the conditional ARDL–VECM is used. Following the procedure in Pesaran and Shin (1997), an OLS regression is first estimated for the first differences significance of the parameters of the lagged level variables when added to the first regression. Pesaran and Shin (1997 are of the opnion that this OLS regression in first differences is of no direct interest to the bounds cointegration test. The F statistic tests the joint null hypothesis that the coefficients of the lagged level variables are zero (i.e. no long–run relationship exists between them).

Table 2 reports the results of the calculated F–statistics when each variable is considered as a dependent variable (normalized) in the ARDL–OLS regressions.

Table (2): Statistic of Cointegration Relationship

Lag length	Function Form			
	Ly(lh,ll,lk) Eq, No(5)	Lh(lk,ll,ly) Eq, No(7)	Lk(lh,ll,ly) Eq, No(6)	Ll(lh,lk,ly) Eq, No(8)
1	1.5388	3.8552	2.0634	2.8216
2	2.0397	3.3626	1.0813	2.6384
3	2.1455	1.8136	0.68656	3.41613
4	7.2682*	1.1697	1.7267	2.9601
5	3.5932	7.2682*	0.62330	1.3549

The upper limit of the critical value for the F-test (all I(1) variables) is 5.615 (1%) and 4.378 (5%) and critical values obtained from Pesaran **et al.**

Table 2 clearly shows that there is a long–run relationship among the variables when both economic growth, as well as the human capital variables, are considered as dependent variables; and absence of such relationship, if otherwise. From the table above, under lag length 4 when growth is an endogenous variable and 5 when human capital is an endogenous variable, the computed F statistic ⟨7.2682⟩ is greater than the upper bound critical value ⟨5.615⟩.

Since there is evidence of a long–run relationship ⟨cointegration⟩ among the variables, Equation 10 must be estimated ⟨by taking y and H as dependents variables⟩ to obtain the long–run coefficients. Results are presented in Table 3.

Table(3): Long-run Coefficients

Dependent variables	Constant	LK	LL	LH	LY
LY	3.0377 (1.0878)	0.29674 (6.0202)*	-0.20725 (-0.97459)	0.060043 (1.4652)	--------
LH	-18.5095 (-6.69000)*	0.11305 (0.81500)	1.1739 (5.0608)*	----------	-0.31298 (-0.56147)

Table 3 shows that in the long run, only capital stock plays a positive and considerable role on the country's economic growth during the period under study, while human capital plays a positive but insignificant role. On the other hand, labor force plays a negative but unimportant role on the total GDP. The meaningless role of the labor force might be justified via the definition of total labor force data utilized in the study. Thus, including unemployment and non productive agents (army forces) and at the same time exclude other productive agents (homemakers, etc) in the labor force's figure leads to the minimization of their effect on the total output.

Regarding the insignificant contributions of human capital to the final production, it is consistent with The World Bank's (1998) conclusion that Sudan's level of achievement is still far below the threshold of four years; beyond which increasing returns to scale before the human capital begins to accrue. When this threshold level of education is achieved, the quality of labor reaches a critical mass, allowing greater overall productivity. In addition, some economists believe that the average years of schooling contain a measurement error (Loening, 2005). Others believe that using average years of schooling as an education measure implicitly assumes that a year of schooling delivers the same increase in knowledge and skills regardless of the education system. Most people would acknowledge that a year of schooling does not produce the same cognitive skills everywhere. Regardless of the reasons of insignificant contribution of the human capital to the final output or the economic growth, it is still possible to detect the significant contribution of a variable by other specifications or channels. In this regard, Benhabib and Spiegel (1994) and Papageorgiou(2001) argue that the structural specifications that allow human capital to operate as a facilitator to technological progress, is more successful in explaining the growth than the standard growth accounting specification.

When human capital is considered as a dependent variable, it is observed that in the long run, only labor force plays a positive and statistically significant influence on the accumulation of the human capital. Despite the insignificant impact of both capital stock and economic growth on human capital accumulation, their contributions

vary between positive effect (for K) and negative one (for Y). The elasticity of human capital with respect to labor force is equal to 1.17, which means that on average, an increase in the quantity of labor force by one–percent reflects in an increase in the average years of schooling for people aged 15 years and over by one year. In fact, high labor force participation rate means that many people are employed. This could mean that companies are hiring and job opportunities are increasing, which induce people to improve their skills through education.

The negative and insignificant influence of economic growth on human capital might be due, for example, to the imperfection in policies adopted by the country's policy makers to transform the growth into improving the average skills of the people. There are various channels through which growth is expected to affect human capital accumulation such as reallocation of government expenditure, improvements on the distribution of income, etc.[5] Unfortunately, in Sudan, majority of such policies adopted by various government regimes since its independence, failed to exploit growth to improve several human development indicators including education (see for example, Ali and ElBadawi 2004, Maharan (2007).

The relationship in the short run (dynamic relationship) is now examined. For this purpose, Equation 11 is used. The results of the estimation are outlined in Table 4.

From these results, it may be observed that both forms of equations are significant at the 1% level as indicated by the F–ratios. Furthermore, the selected variables suggest that an average of 75% of the variation in the real gross domestic product and 76% are from that of human capital. As per the long run, in the short run, physical capital appear to be the main factor that contributes significantly to the final output. The common feature for the contribution of the remaining variables is that it is insignificant but varies in terms of sign between positive for human capital and negative for the labor force. Furthermore, the same conclusion is reached when looking at the relationship with human capital considered as the dependent variable. As may be observed, all the variables have the same pattern as that of the long run with positive and significant contribution to the labor force, but insignificant contributions by the remaining variables.

Table ⟨4⟩: Short– run Relationship

| Dependent variables	Short run coefficients						Goodness fit			Diagnosis tests			
	Constant	ΔLK	ΔLL	ΔLH	ΔLY	Ecm(-1)	R^2	R^{-2}	F	A	B	C	D
ΔLY	3.0377 (1.0878)	0.29674 (6.0202)*	-0.20725 (-0.97459)	0.060043 (0.4652)	---------	-0.29 (-2.53)	0.75	0.66	10.56	0.128 {0.911}	0.256 {0.665}	0.314 {0.579}	2.8 {0.247}
ΔLH	-18.5095 (-6.69000)*	0.11305 (0.81500)	1.1739 (5.0608)*	---------	-0.31298 (-0.56147)	-0.35 (-3.21)	0.76	0.67	9.77	1.50 {0.233}	0.824 {0.654}	0.422 {0.65}	2.41 {0.130}

N.B. 1. t-statistic is in ( ) and prob value in {}parentheses, and (*) , indicate significance at 1% and 5% level respectively
2. A: is F- statistics of Breusch-Godfrey serial correlation LM test. B: is F- statistics of Reset functional form test. C: is LM – statistics of skewness and kurtosis of residuals for normality test . D: is F- statistics of white Heteroskedasticity test .

The lagged error term $(ECM(-1)$ in both forms of equation in the results, is negative and significant at the 5% level. For example, the coefficient of -0.29 in the equation with economic growth as the dependent variable, indicates a suitable rate of convergence (from actual) towards potential long-run real GDP. In other words, the last period of disequilibrium is an average corrected by about 35% in the following year. Furthermore, the significance of the $ECM(-1)$ coefficient also indicates the evidence of causality in at least one direction.
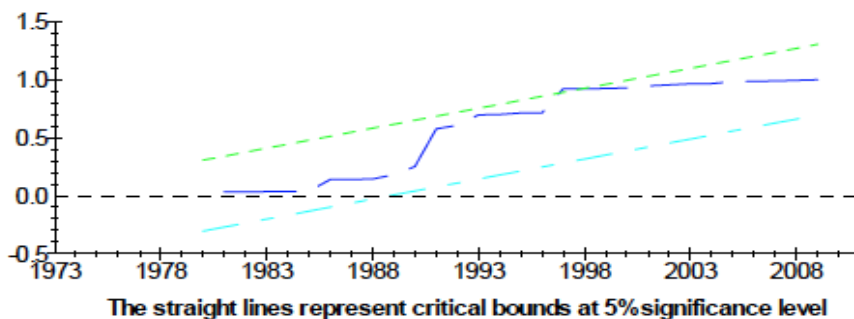
Finally, the stability of the long-run coefficients together with the short-run dynamics is examined based on Pesaran and Pesaran (1997) by applying the CUSUM and the CUSUMSQ proposed by Brown et al. (1979). The CUSUM tests basically use the cumulative sum of the recursive residuals based on the first set of n observations and are updated recursively and then plotted against the break points. If the plot of CUSUM remains within the critical bounds at the 5% significance level (represented by clear and straight lines drawn at 5%) the null hypothesis for all the coefficients, and the error correction model are stable and cannot by rejected. However, if the two lines are crossed, the null hypothesis of coefficient constancy cannot be rejected. The same analysis applies for the CUSUMSQ test, which is based on the squared recursive residuals.

Figures 2 and 3 depict this test when growth is a dependent variable; while Figures 4 and 5 are of the same tests but with human capital as the dependent variable. All these figures indicate that the long-run and the short-run dynamic coefficients are stable.
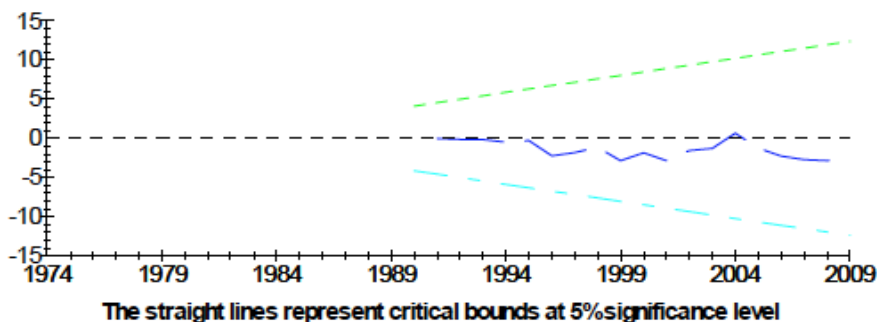
Figure(2) Plot of Cumulative Sum of Recursive Residuals

The straight lines represent critical bounds at 5% significance level
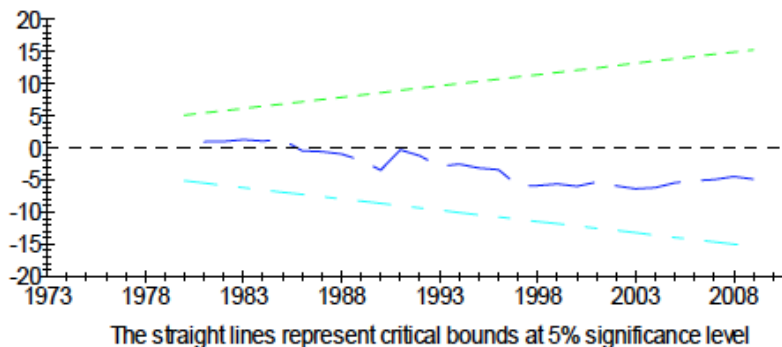
Figure(3) Plot of Cumulative Sum of Squares of Recursive Residuals

The straight lines represent critical bounds at 5% significance level

Figure(4) Plot of Cumulative Sum of Recursive Residuals

The straight lines represent critical bounds at 5% significance level

Figure(5) Plot of Cumulative Sum of Squares of Recursive Residuals

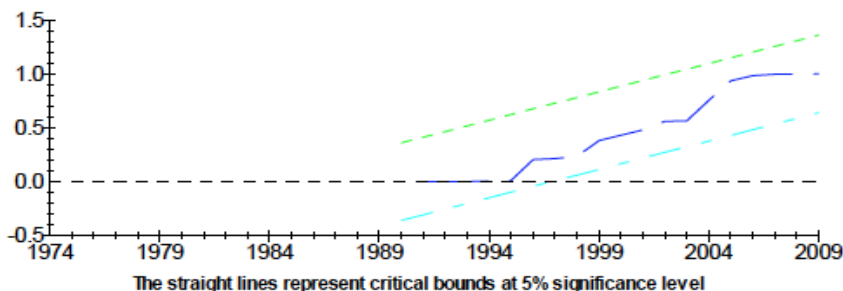The straight lines represent critical bounds at 5% significance level

Figure 5. Plot of cumulative sum of squares of recursive residues.

From the diagrams above, several diagnostic tests for the model are carried out for serial correlation, model specification, normality and heteroskedasticity. The model passed all the above mentioned diagnostic tests.

Causality Test

As mentioned previously, the significance of the ECM(-1) coefficient is that it is an evidence of causality in at least one direction. Moreover, it is important to remember that the existence of a co integration relationship is a necessary condition but not sufficient for the existence of a causality relationship. In this respect, Granger (1980) noted that it is conceivable that two variables may be highly correlated, but not necessarily causality linked. . Hence, the joint significance of the lagged differences of the explanatory variables was constructed using the Wald test . The statistical significance of the F–tests applied to the joint significance of the sum of the lags of each explanatory variable will indicate the Granger causality.

Table 5 below depicts the results of the result of the Wald test for the short–run causality.

Table (5): VEC Granger Causality/Block Endogeneity Wald Tests

Variables	Chi Square	Probability
Δ(LK)does not granger cause Δ(LY)	21.78449*	0.000
Δ(LL)does not granger cause Δ(LY)	0.514205	0.2731
Δ(H)does not granger cause Δ(LY)	1.200914	0.4733
Δ(LY)does not granger cause Δ(LH)	1.1169025	0.2906
Δ(LK)does not granger cause Δ(LH)	0.038354	0.8448
Δ(LL)does not granger cause Δ(LH)	1.851041	0.1737
Δ(LY)does not granger cause D(LK)	2.724403**	0.0988
Δ(LH)does not granger cause Δ(LK)	0.078845	0.7789
Δ(LL)does not granger cause Δ(LK)	0.169716	0.6804
Δ(LK)does not granger cause Δ(LL)	0.0825592	0.7739
Δ(LY)does not granger cause Δ(LL)	0.850917	0.3563
Δ(LH)does not granger cause Δ(LL)	0.916963	0.3383

(*) , (**) indicate significance at the 1% and 5% level, respectively.

The statistical significance of the ECM for the ∆ LY and ∆ LH variables in Table 5 suggests the existence of a long-run causality relationship; from K, L and H to Y, as well as from K, L, and Y to the H. Furthermore, the significance of the ECM term for the ∆ LY and ∆ LH variables indicates the endogeneity of these variables confirming the results obtained from the cointegration test. As to the short-run causality, the Wald test in Table 6 indicates that in the short run, there is a two-way relationship between economic growth and capital stock.

6. Conclusion

The paper investigates empirically the long- and short-run impact of human capital on the real total output of Sudan during the period 1970-2009. The auto regressive distributed lag (ARDL) approach to analyze the relationship among the selected variables was employed. The basic macroeconomic variables of concern are derived from literature review – the real gross domestic product, the total labor force, the real capital stock as well as the average years of schooling which is used to proxy the human capital. Data on the real gross domestic product, the total labor force and real gross fixed capital formulation is collected from the World Bank database, while data for the average of schooling is obtained from Barro and Lee (2010).

Results indicate the existence of a long-run relationship among the variables when economic growth and human capital are treated as dependent variables. Over time, the capital stock plays positive and significant role to Sudan's economic growth, while other factors play insignificant role. Furthermore, over time, labor force influences the human capital process without any effect from capital stock and growth. In the causality side, the non-causality test suggests the existence of two long-run causality relationships: firstly, from labor, capital and education to economic growth; and secondly, from labor, capital and growth to human capital. The short-run causality test indicates the existence of bilateral causality relationship between economic growth and capital stock.

The insignificant influence of the human capital in the economic growth process might be due to several reasons. Firstly, insufficient financial resource devoted to the education system, the government expenditure on education does not exceed 4.5% (from total government expenditure) or 8.5% (from GDP). Therefore, in order to push for more human capital contribution, the Sudan's government should increase the allocation on education to meet up with the UNESCO's recommended budget at 26%. The government should provide a conducive environment by ensuring macroeconomic stability that will encourage increased investment in human capital by the private sector. Secondly, high inequality in the distribution of the human capital in terms of educational attainments . In the middle of the 1990s, the estimated education Gini's coefficient is equal to 0.72, which is fairly high. Thus, the government should adopt and implement specific policies to minimize inequality in the distribution of the human capital – for example, free education at all education levels, labor market reformation, etc. In fact, these policies and others have simultaneous affect on both human capital and economic growth which in turn reflect in a strong complementary relationship between them.

Footnote

(1) Such a dummy variable would usually take a value of one for African countries, and a value of zero for all other countries. If it turns out to be significant or to alter strongly the original results, this would indicate the omission of important variables.

(2) More recently, Engelbrecht (2002) investigated a similar specification and confirmed Benhabib and Spiegel's (1994) result that human capital is important for technological catch-up in developing countries.

(3) Griliches (1997) suggested another possible explanation which does not require that human capital be put to socially dysfunctional use. There is evidence that in many developing countries, much of the growth in educated labor is absorbed by the public sector. Even if the highly skilled state-employed workers are productive in a variety of ways, this may not show up in national accounts data because the output of the public sector is difficult to measure.

⟨4⟩ For more information about methodology used by Barro and Lee ⟨2010⟩ to calculate this indicator visit the authors' website ⟨www.barolee.com⟩.

⟨5⟩With economic growth, following policy failures may occur:⟨a⟩ Jobless growth that does not expend the opportunities for employment; ⟨b⟩ Ruthless growth – the fruits of growth mostly benefit the rich; ⟨c⟩ Voiceless growth –growth has not been accompanied by expansion of democracy and employment; ⟨d⟩ Rootless growth – causes people's culture identity to wither; and ⟨e⟩ Futureless growth – where the present generation squanders resources needed by future generations.

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