Role of Higher Education Growth in Enhancing Economic Growth, Innovation Advancement and Technological Progress in Uganda (1970–2014)

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Abstract[4]

We examine the role of growth in higher education in enhancing economic growth, innovation advancement and technological progress in Uganda during the 1970 to 2014 period. Higher education is measured by the higher (tertiary) education gross enrolment ratio (GER). The major hypothesis of the study is that "Higher education growth enhances economic growth, innovation advancement and technical progress". The study is important because Uganda still has low levels of higher education GER, innovation and technology. Data set employed in the empirical analyses was obtained from the United Nations statistics database and analyzed using the generalised least squares (GLS) technique. First, we find that a 1% increase in higher education GER growth had the potential of causing economic growth, innovation advancement, technological progress and total factor (TF) to increase by 0.82, 0.10, 0.27 and 0.56%, respectively, during the given period. Second, empirical evidence shows that a 1% increase in economic growth, innovation advancement, technological progress and TF the potential of causing higher education GER growth to increase by 1.08, 5.02, 1.36 and 1.42%, respectively, during the given period. Third, over the given period, a 1% growth in innovation, technical progress

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and TF productivity had the potential of causing economic growth to increase by 4.63, 1.33 and 1.14 %, respectively. Fourth, a 1% growth in higher education GER had the potential of causing a rise in labour generation and capital accumulation growth by 0.53 and 1.56%, respectively.

Keywords: *Economic growth; Higher school education growth; Innovation advancement; Input productivity growth; Technological progress.*

Introduction

We examine the role of growth in higher education in enhancing economic growth, innovation advancement and technological progress in Uganda during the 1970 to 2014 period. Higher education is measured by the higher education gross enrolment ratio (GER). The country's higher education (HGER) declined from 6.85% in 2017/2018 to 6.81% in 2018/2019. Thus, during the 2017 to 2019 period, the HGER was far below the world average of 24% and 40% required for economic take-off (National Council for Higher Education [NCHE], 2018, p. 6). The major hypothesis of the study is that "Higher Education enhances economic growth, innovation and technical progress". The study is important because Uganda still has low levels of higher education GER, innovation and technology. Meanwhile, it is the first time in the history of economic research that the theoretical framework and methodology involving causal theory are being applied to investigate the hypothesis that "growth of the dependent variable depends on its acceleration and growth of the first lag of the independent variable". Data set employed in the empirical analyses was obtained from the United Nations and World Bank statistics and analysed using the generalised least squares (GLS) technique. A huge body of research shows that investments in education provide students with long-run benefits. However, little is known about the role of education in enhancing innovation (Biasi et al., 2021). Although higher education growth enhances economic growth, innovation advancement and technical progress, innovation advancement can also directly affect higher education growth (Biasi et al., 2021). Meanwhile, education has been regarded as the principal determinant of endogenous economic growth (Chen et al., 2021). Indeed, tertiary (higher) education plays a major role in enhancing innovation, research, technological progress and sustainable development. Moreover, tertiary education growth directly affects economic growth and employment generation. Tertiary education is at the heart of the knowledge economy (Muresan & Gogu, 2012). The ultimate goal of economic innovation growth is economic growth. Higher education is very important because it provides the advanced skills necessary for a high innovation environment. One of the economic measures of innovation is labour productivity (Hoareau et al., 2013).

Other measures of innovation are capital productivity, technology or a combination of all the three drivers of innovation. On the other hand, innovation and capital supply are some of the ingredients of technological foundation (Diwan & Chakarborty, 1992). Meanwhile, technology is embodied materially in a product and composed of creating tangible objects, codified knowledge and know-how embedded in humans (Carayannis et al., 2015).

Methods

Theoretical framework for causality between dependent and independent variables

The theoretical framework aims at developing models that can provide tight relationships between the dependent and independent variables of concern. In economics, if the quantity of a variable, say the level of technology (A), is measured in terms of logarithm $log\ (A_t)$, then the growth rate $d[log\ (A_t)]$ of variable A at time t can be defined by

$$d[log(A_t)] = log(A_t) - log(A_{t-1}). \tag{2.1}$$

Or
$$log(A_t) = log(A_{t-1}) + d[\log(A_t)]. \tag{2.2}$$

Given that the level of technology depends on the level of higher education , then

$$log(A_{t-1}) = f\,[log\ (H_{t-1}). \tag{2.3}$$

We use timing evidence based on the philosophical principle that if one event occurs after another, the second event must have been caused by the first (Mishkin, p.116).

The principle is valid if we know that the variables behind the events are endogenous. Therefore, the substitution of Equation (2.3) in (2.2) provides

$$log(A_t) = f\,[d\ [log\ (A_t)]] \tag{2.4}$$

$$log(A_t) = f\big[d[log(A_t)]\big]. \tag{2.4}$$

Otherwise
$$log(A_t) = f\big[log(H_{t-1}), d[log(A_t)]\big].$$

Or
$$d(log(A_t)) = \frac{\partial(log(A_t))}{\partial(log(H_{t-1}))} d(log(H_{t-1})) + \frac{\partial(log(A_t))}{\partial(\partial(log(A_t)))} d(d[log(A_t)]). \tag{2.5}$$

Or
$$d(log(A_t)) = \frac{d(log(A_t))}{d(log(H_{t-1}))} d(log(H_{t-1})) + \frac{d(log(A_t))}{d(d(log(A_t)))} d[d(log(A_t))]. \tag{2.6}$$

Since
$$\frac{d(log(A_t))}{d(log(H_{t-1}))} = \left[\frac{d(log(A_t))}{d(log(H_{t-1}))}\ \frac{log(H)_{t-1}}{log(A_t)}\right]\left[\frac{log(A_t)}{log(H_{t-1})}\right] = \beta_{LR}\left[\frac{log(A_t)}{log(H_{t-1})}\right] = \beta_1, \tag{2.7}$$

and
$$\frac{d(log(A_t))}{d(d(log(A_t)))} = \left[\frac{d(log(A_t))}{d(d(log(A_t)))}\ \frac{d(log(A_t))}{log(A_t)}\right]\left[\frac{log(A_t)}{d(log(A_t))}\right] = \beta_{LR}\left[\frac{log(A_t)}{d(log(A_t))}\right] = \beta_2 \tag{2.8}$$

$$d(log(A_t)) = \beta_1 d(log(H_{t-1})) + \beta_2 d[d(log(A_t))]. \tag{2.9}$$

The elasticity β_1 measures the slope of the level of technology curve plotted on the log-log scatter diagram. The plotted curve represents how the log of the level of technology changes as the log of the level of higher education changes. Meanwhile, elasticity β_2 measures the slope of the level of technology curve plotted on the log-log scatter diagram. The plotted curve represents how the log of the level of technology changes as the log of the level of technology accelerates. Hence, Equation (2.9) provides a means of getting estimates of the effects of growth in higher education (H_{t-1}) on growth in innovation (Z_t), total factor (TF_t), aggregate income (Y_t), capital (K_t) and labour (L_t), respectively. Where (X_t) represents the following: A_t, Z_t, TF_t, Y_t, K_t and L_t.

$$\therefore \quad d(log(X_t)) = \beta_1\ d(log(H_{t-1})) + \beta_2\ d[d(log(X_t))]. \tag{2.10}$$

Meanwhile, Equation (2.11) provides the tool for estimation of the feedback effects of growth in technology (A_t), innovation (Z_t), total factor (TF_t), aggregate income (Y_t), capital (K_t) and labour (L_t), respectively, on growth in higher education. Where X_{t-1} represents the following: A_{t-1}, TF_{t-1}, Y_{t-1}, K_{t-1} and L_{t-1}.

$$d(log(H_t)) = \beta_1\ d(log(X_{t-1})) + \beta_2\ d[d(log(H_t))]. \tag{2.11}$$

Similarly, Equation (2.12) gives the tools for estimation of the influence of growth in innovation (Z_t),, technology (A_t) and level of total factor (TF_t), respectively, on economic growth (Y_t). Where X_{t-1} represents the following: Z_t, A_{t-1}, Y_{t-1} and TF_{t-1}.

$$d(log(Y_t)) = \beta_1\ d(log(X_{t-1})) + \beta_2\ d[d(log(Y_t))]. \tag{2.12}$$

Lastly, Equations (2.13) to (2.32) depict the technique for the estimation of effects of growth in innovation (Z_{t-1}) on growth in capital (K_t) and labour (L_t) and technology (A_t) respectively. Where X_{t-1} represents the following: A_t, K_t and L_t.

$$d(log(K_t)) = \beta_1\, d(log(Z_{t-1})) + \beta_2\, d[d(log(K_t))]. \qquad (2.13)$$

Data types and data sources

Annual time series data covering the 1970 to 2014 period was collected on gross capital formation, i.e. investment (I), household consumption (C_n) and Gross Domestic Product (Y), from the database of the United Nations (UN) and the World Bank. Meanwhile, annual time series data for the 1970 to 2014 period on higher education gross enrolment ratio (H) was collected from the World Bank website.

Data generation process

Literature shows that many studies have investigated the contribution of total factor productivity (TFP) to economic growth (Kim & Park, 2017; Woo, 1998; Wu, 2008; Young, 2003). These studies take part of the contribution of TFP to be the residual of economic growth not explained by the changes in factor inputs (Wu, 2010).

This study extends the current method of computing the level of innovation by defining it not as the residual of the level of technology but presenting it as a function of capital and labour productivity. To define TFP, the Cobb-Douglas version of the production function in use is given by output (Y) as a function of technology (A), capital (K), labour (L) and parameters α, β (Lipsey & Carlaw, 2004).

$$Y = AK^{\alpha}L^{\beta}. \qquad (2.14)$$

where $0 < \alpha + \beta < 1$.

The TFP is calculated by dividing through Equation (2.14) by the total factor $K^{\alpha}L^{\beta}$ to provide

$$TFP = \frac{Y}{K^{\alpha}L^{\beta}} = A \qquad (2.15)$$

Similarly, to define innovation (Z), the Cobb-Douglas version of technology function in use is represented by the level of technology (A) as the function of innovation (Z), capital productivity (K_p), labour productivity (L_p) and parameters α, β.

$$A = ZK_p^{\ \alpha}L_p^{\ \beta}. \qquad (2.16)$$

where $Z = Y1\text{-}\alpha\text{-}\beta = AK_p^{\ -\alpha}L_p^{\ -\beta}$. (2.17)

Meanwhile, higher (tertiary) education is the main pillar of the knowledge economy, technological progress and innovation (Muresan & Gogu, 2012).

The level of higher education is measured by tertiary education gross enrolment ratio (). According to the (NCHE, 2018, p. 1), the *higher education GER* is a statistical measure of the *total number of students enrolled in higher education institutions (HEI) regardless of age* () as a percentage of the official age group corresponding to this level of education, i.e. *total population in the age group that is meant to be at HEI* (). Therefore,

$$GER = TN/TP. \qquad (2.18)$$

Measurement of capital, labour, technology and innovation

Depreciation is the decline in value of the capital stock over time and can be represented as provided by Hill (1997). Mathematically, we represent depreciation as follows:

$$\delta_t\, K_{t-1} = D_t = V_{t-1} - V_t, \qquad V_{t-1} > V_t. \qquad (2.19)$$

Where δ_t is the rate of depreciation at time t, while V_{t-1} is the value of capital at time $t-1$; while V_t is the value of capital at time t.
Equation (2.19) can be rewritten as

$$\delta_t = \frac{D_t}{K_{t-1}} = \left[\frac{K_{t-1}}{K_{t-1}} - \frac{K_t}{K_t-1}\right]. \tag{2.20}$$

But
$$\delta_t = \frac{D_t}{K_{t-1}} = -\left[\frac{K_t-K_{t-1}}{K_{t-1}}\right]. \tag{2.21}$$

$\therefore$
$$\delta_t = -\left[\frac{K_t-K_{t-1}}{K_{t-1}}\right] = \frac{dK_{t-1}}{K_{t-1}} = \frac{I_{t-1}}{K_{t-1}}. \tag{2.22}$$

$\therefore$
$$K_{t-1} = \frac{I_t}{\delta_t}. \tag{2.23}$$

Hence, Equation (2.22) can best be represented in logarithm form as follows:

$$\delta_t = -log(I_{t-1}). \tag{2.24}$$

Since
$$\delta_t = \frac{I_{t-1}}{K_{t-1}} = -d[\log(K_{t-1})] = -log(I_{t-1}). \tag{2.25}$$

Where
$$-d[\log(K_{t-1})] = -[log(K_{t-1}) - log(K_{t-2})] = -log(I_{t-1}). \tag{2.26}$$

$$\therefore -[log(K_{t-1}) - log(K_{t-2})] = -[log(I_1.I_2 \ldots I_{t-2}.I_{t-1}) - log(I_1.I_2 \ldots I_{t-2})] = -log(I_{t-1}). \tag{2.27}$$

Most importantly, it can be discerned from Equation (2.26) that decline in the rate of depreciation is a slope of the value of the depreciation curve and can be expressed as follows:

$$log\ (\delta_t) = log\ (1) - log\ [log\ (I_{t-1})]. \tag{2.28}$$

Here it is clear that the Therefore, rewriting Equation (2.10) gives

$$log\ (\delta_t) = log\ [1/log\ (I_{t-1})]. \tag{2.29}$$

Taking the antilog of Equation (2.29) provides

$$\delta_t = \frac{1}{log\ (I_{t-1})} \tag{2.30}$$

Hence, the substitution of Equation (2.30) in (2.23) provides a novel formula that can be used to measure the quantity of capital stock provided the level of investment is known.

$$K_{t-1} = I_{t-1}\ log\ (I_{t-1}) \tag{2.31}$$

Having obtained the time series data on the annual long run capital stock (K_{t-1}) and aggregate disposable income (Y_{dt}), the annual quantities of labour (L_{t-1}) can be generated by using the classical Cobb-Douglas production function $[Y_{dt} = K^{\alpha}_{t-1}\ L^{\beta}_{t-1}]$ and by causality theory (Mishkin, 2004, p. 116), where is average propensity to invest (MPI_t) and β is average propensity to consume (APC_t) From the Cobb-Douglas we make L_{t-1} the subject and obtain

$$L_{t-1} = [Y_{dt}/((K_{t-1})^{(API_t)})]^{[1/APC_t]}. \tag{2.32}$$

since the long run equals long-run Implying, marginal propensity to invest (MPI_t) and average propensity to invest (API_t) are equal in the long run (Hadden, 1965, p. 9).

The generalised least squares method (GLS)

If variance of the error term $\boldsymbol{\Sigma}$ is known, then it is possible to form a Cholesky decomposition as follows:

$$P'\ P = \Sigma^{-1} \tag{2.33}$$

where matrix denotes an upper triangular matrix. Manipulation of Equation (2.33) gives

$$P'\ P\Sigma = I_n. \tag{2.34}$$

Thus
$$P'\ P\Sigma P' = P' \tag{2.35}$$

Therefore,
$$P\Sigma P' = I_n \tag{2.36}$$

In general, we can write a linear regression equation as follows:

$$y = X\beta + \varepsilon. \tag{2.37}$$

where $E(\varepsilon) = 0$ and $Var(\varepsilon) = \Sigma$ and $\boldsymbol{\Sigma}$ is a general symmetric positive definite matrix. But this general case suffers from heteroscedasticity and autocorrelation. In the case of ordinary least squares (OLS) with heteroscedasticity or autocorrelation or both, the OLS is biased, has a variance different from the previous one, provides invalid tests statistic and is inefficient.

In order to minimise or get rid of heteroscedasticity or autocorrelation, we pre-multiply Equation (2.37) by the vector and obtain the following:

$$Py = PX\beta + P\varepsilon. \tag{2.38}$$

Therefore, Equation (2.38) can be rewritten in the OLS format as follows:

$$y^* = X^*\beta + \varepsilon^*. \tag{2.39}$$

Meanwhile, the variance of $\varepsilon^* = P\varepsilon$ is given by

$$(P\varepsilon\varepsilon'P') = P\Sigma P' = I_n. \tag{2.40}$$

Hence, given that $E(\varepsilon) = 0$ & $Var(\varepsilon) = I_n$, Equation (2.37) satisfies the classical assumptions. Thus, the GLS is just the OLS applied to the transformed model such that

$$\hat{\beta}_{GLS} = (X^{*\prime}X^*)^{-1}X^{*\prime}y^*. \tag{2.41}$$

Or

$$\hat{\beta}_{GLS} = (X'PP'X)^{-1}X'PP'y. \tag{2.42}$$

Therefore,

$$\hat{\beta}_{GLS} = (X'\Sigma^{-1}X)^{-1}X'\Sigma^{-1}y. \tag{2.43}$$

The variance of the GLS estimator can be obtained as follows:

$$E\left[(\hat{\beta}_{GLS} - \beta)(\hat{\beta}_{GLS} - \beta)'\right] = E[(X^{*\prime}X^*)^{-1}X^{*\prime}\varepsilon^*\varepsilon^{*\prime}X^*(X^{*\prime}X^*)^{-1}]. \tag{2.44}$$

$$\therefore \quad E\left[(\hat{\beta}_{GLS} - \beta)(\hat{\beta}_{GLS} - \beta)'\right] = (X^{*\prime}X^*)^{-1}X^{*\prime}X^*(X^{*\prime}X^*)^{-1}. \tag{2.45}$$

Hence,

$$Var(\hat{\beta}_{GLS}) = (X^{*\prime}X^*)^{-1} = (X'\Sigma^{-1}X)^{-1}. \tag{2.46}$$

The GLS estimator is more efficient than the OLS estimator because the GLS is a model that fulfils the classical assumptions based on the Gauss-Markov theorem, but the OLS does not due to the presence of autocorrelation and heteroscedasticity.

The GLS estimator is more efficient than the OLS estimator due to the fact that

$$Var(\hat{\beta}) - Var(\hat{\beta}_{GLS}) = (X'X)^{-1}X'\Sigma X(X'X)^{-1} - (X'\Sigma^{-1}X)^{-1} = A\Sigma A',$$

since $A = [(X'X)^{-1}X' - (X'\Sigma^{-1}X)^{-1}X'\Sigma^{-1}]$ (Creel, 2014, pp.121–176).

Estimation of MPC, MPI, technology and innovation

We find that all the saving motives are psychological saving motives. As a result, the empirical findings show that the psychological savings motive determines the planned level of consumption C^*_{nt} in period t, measured in terms of the level of consumption and savings $(C_{nt-1} - S_{t-1})$ in period $t-1$. The savings motive hypothesis (SMH) generates a psychological consumption-savings relationship given by $C^*_{nt} = C_{nt-1} - S_{t-1}$.

Meanwhile, in the SMH, the level of savings (S_{t-1}) is constant and identical to the level of the observed initial investment in the annual investment series $(C_0 = S_{t-1} \equiv I_1)$ It is true that the consumption function $(C_{nt-1} = C_0 + Y_t)$ arising from the SMH is more accurate than the usual Keynesian consumption function $(C_{nt} = C_0 + Y_t)$, when it comes to providing more accurate estimates for the Thus, regression of annual time series of C_{nt-1} on Y_{at} provides a regression-line. Here, H_T is a t used in testing for heteroskedasticity. (See Appendix 12.1 for details.)

$$\frac{\hat{C}_{nt-1}}{d(d(C^2_{nt-1}))} = \frac{1.41\times10^{10}}{d(d(C^2_{nt-1}))} + \frac{0.628115Y_t}{d(d(C^2_{nt-1}))}. \quad (2.47)$$

$$t \qquad 28.73 \qquad 48.22$$

$$R^2 = 1.0000 \quad DW = 1.90 \quad N = 41 \quad H_T = 0.04 \quad \text{period: 1974–2014}$$

By using the GLS method, the marginal propensity to invest (MPI) was obtained as follows:

$$\frac{\log(\widehat{Y_t/Cn_{(t-1)}})}{d(d(Y^2_{dt}))} = \frac{0.155753(\log(10))}{d(d(Y^2_{dt}))}. \quad (2.48)$$

$$t \qquad 256.53$$

$$R^2 = 0.999 \quad DW = 2.00 \quad N = 42 \quad H_T = 0.11 \quad \text{period: 1973–2014}$$

(See Appendix 12.2. for details.) And it can be verified that the log of GDP to lag of consumption $[log(Y_t/C_{nt-1})]$ equals the $MPI = \alpha$. Hence, the annual levels of technology and innovation were respectively estimated by the formulae given in Equation (2.50).

$$A_t = \frac{Y_t}{[K_t^{\alpha}.L^{\beta}]} = \frac{Y_t}{[K_t^{0.155753}.L^{0.628115}]}. \quad (2.49)$$

$$Z_t = Y^{1-\alpha-\beta}. \quad (2.50)$$

Explanation of the parameter values obtained from data

Given that the parameters on capital is defined as, say, capital elasticity of income.

Thus, $[\partial(log(Y))/\partial(log(K))]$. (2.51)

This expression demonstrates that, given the Cobb-Douglas production function as provided in Equation (2.14), the capital coefficient (parameter) can be expressed as follows:

$$\alpha = \frac{\alpha}{1} = \frac{dY}{dK} = \frac{\partial Y}{\partial K}.\frac{K}{Y} = \frac{\partial Y/Y}{\partial K/K} = \frac{\partial(\log(Y))}{\partial(\log(K))} = \epsilon. \quad (2.52)$$

(Varian, 2010, pp.190–191). Thus, a 1% increase in the growth of capital $[\partial(log(K))]$ causes economic growth output to increase by by $\alpha = \partial(log(Y))/1\%$ yearly, other things being equal. Therefore, all the parameter values of concern were found to be significantly different from zero, while the H_T & DW indicated no cases of heteroskedasticity and autocorrelation.

Results

First, we find that a 1% increase in higher school education GER had the potential of causing economic growth, innovation advancement, growth in capital, labour, technological progress and total factor (TF) advancement to increase by 0.82, 0.10, 1.56, 0.53, 0.27 and 0.56%, respectively, during the given period (see Tables 1, 2 and 3).

Table 1: Effects of higher school education on (1) technology and (2) innovation

Regression Model 1			**Regression Model 2**		
Dependent Variable: **d(log(A))**/d(d((A/H			Dependent Variable: **d(log(Z))**/d(d((TF/H		
Independent Variable	Coeff.	t-Stat.	Independent Variable	Coeff.	t-Stat.
d(log(H(-1)))/d(d((A/H	0.27	57.21	**d(log(H(-1)))**/d(d((TF/H	0.10	6.77
d(d(log(A)))/d(d((A/H	0.74	8.540	**d(d(log(Z)))**/d(d((TF/H	1.21	6.99
Adjusted Sample: 1973-2014			Adjusted Sample: 1973-2014		

Data source: Models 1 and 2 were obtained from the GLS regressions conducted.

NB: Regressions 1 to 2 were found to be free from autocorrelation and heteroscedasticity.

Table 2: Effects of higher school education on (3) total factor and (4) income

Regression Model 3			Regression Model 4		
Dependent Variable: **d(log(TF))**/d(d((Y/H			Dependent Variable: **d(log(Y))**/d(d((Y/H		
Independent Variable	Coeff.	t-Stat.	Independent Variable	Coeff.	t-Stat.
d(log(H(-1)))/d(d((Y/H	0.56	12.58	**d(log(H(-1)))**/d(d((Y/H	0.82	19.87
d(d(log(TF)))/d(d((Y/H	0.65	8.039	**d(d(log(Y)))**/d(d((Y/H	0.20	1.75
Adjusted Sample: 1973-2014			Adjusted Sample: 1974-2014		

Data source: Models 3 and 4 were obtained from the GLS regressions conducted.

Table 3: Effects of higher school education on (5) capital and (6) labour

Regression Model 5			Regression Model 6		
Dependent Variable: **d(log(K))**/d(d(			Dependent Variable: **d(log(L))**/d(d(		
Independent Variable	Coeff.	t-Stat.	Independent Variable	Coeff.	t-Stat.
d(log(H(-1)))/d(d(	1.56	22.50	**d(log(H))**/d(d(	0.53	58.15
d(d(log(K)))/d(d(	0.59	6.371	**d(d(log(L)))**/d(d(	0.03	0.399
Adjusted Sample: 1974-2014			Adjusted Sample: 1973-2014		

Data source: Models 5 and 6 were obtained from the GLS regressions conducted.

Second, empirical evidence shows that a 1% increase in economic growth, innovation advancement, capital accumulation, labour generation, technological progress and TF growth had the potential of causing higher education GER growth to increase by 1.08, 5.02, 0.45, 1.84, 1.36 and 1.42%, respectively, during the given period (see Tables 4, 5 and 6).

Table 4: Effects of (7) technology and (8) innovation on higher school education

Regression Model 7			Regression Model 8		
Dependent Variable: **d(log(H))**/d(d(			Dependent Variable: **d(log(H))**/d(d(		
Independent Variable	Coeff.	t-Stat.	Independent Variable	Coeff.	t-Stat.
d(log(A(-1)))/d(d(	1.36	123.3	**d(log(Z(-1)))**/d(d(	5.02	4.76
d(d(log(H)))/d(d(	1.07	31.81	**d(d(log(H)))**/d(d(	0.47	9.21
Adjusted Sample: 1973-2014			Adjusted Sample: 1973-2014		

Data source: Models 7 and 8 were obtained from the GLS regressions conducted.
NB: Regressions 7 to 8 were free from autocorrelation and heteroscedasticity.

Table 5: Effects of (9) TF and (10) innovation on higher school education

Regression Model 9			Regression Model 10		
Dependent Variable: **d(log(H))**/d(d((TF/H			Dependent Variable: **d(log(H))**/d(d(		
Independent Variable	Coeff.	t-Stat.	Independent Variable	Coeff.	t-Stat.
d(log(TF(-1)))/d(d((TF/H	1.42	29.59	**d(log(Y(-1)))**/d(d(	1.08	6.77
d(d(log(H)))/d(d((TF/H	0.44	5.103	**d(d(log(H)))**/d(d(	0.47	6.99
Adjusted Sample: 1973-2014			Adjusted Sample: 1973-2014		

Data source: Models 9 and 10 were obtained from the GLS regressions conducted.

Table 6: Effects of (11) labour and (12) capital on higher school education

Regression Model 11			Regression Model 12		
Dependent Variable: **d(log(H))**/d(d((A/H			Dependent Variable: **d(log(H))**/d(d(		
Independent Variable	Coeff.	t-Stat.	Independent Variable	Coeff.	t-Stat.
d(log(K))/d(d((TF/H	0.45	32.18	**d(log(L))**/d(d(	1.84	77.65
d(d(log(H)))/d(d((A/H	0.59	4.05	**d(d(log(H)))**/d(d(	0.15	2.437
Adjusted Sample: 1973-2014			Adjusted Sample: 1973-2014		

Data source: Models 11 and 12 were obtained from the GLS regressions conducted.

Third, over the given period, a 1% growth in innovation, technical progress and total factor productivity growth had the potential of causing economic growth to increase by 4.63, 1.33 and 1.14 %, respectively (see Tables 7 and 8).

Table 7: Effects of (13) technology and (14) innovation on income

Regression Model 13			Regression Model 14		
Dependent Variable: **d(log(Y))**/d(d(			Dependent Variable: **d(log(Y))**/d(d(		
Independent Variable	Coeff.	t-Stat.	Independent Variable	Coeff.	t-Stat.
d(log(A(-1)))/d(d(	1.33	4.589	**d(log(Z(-1)))**/d(d(	4.63	7
d(d(log(Y)))/d(d(	0.71	22.73	**d(d(log(Y)))**/d(d(	1.00	3
Adjusted Sample: 1974-2014			Adjusted Sample: 1974-2014		

Data source: Models 13 and 14 were obtained from the GLS regressions conducted.

Table 8: Effects of (15) total factor on income; and (16) innovation on labour

Regression Model 15			Regression Model 16		
Dependent Variable: d(log(Y))/d(d((A/H			Dependent Variable: d(log(L))/d(d((		
Independent Variable	Coeff.	t-Stat.	Independent Variable	Coeff.	t-Stat.
d(log(TF(-1)))/d(d((A/H	1.14	8.448	d(log/d(d((	3.14	38.91
d(d(log(Y)))/d(d((A/H	0.54	2.596	d(d(log(L)))/d(d((	0.26	11.65
Adjusted Sample: 1973-2014			Adjusted Sample: 1974-2014		

Data source: Models 15 and 16 were obtained from the GLS regressions conducted

Table 9: Effects of innovation on (17) capital, and (18) technology

Regression Model 17			Regression Model 18		
Dependent Variable: **d(log(K))**/d(d(			Dependent Variable: **d(log(A))**/d(d(		
Independent Variable	Coeff.	t-Stat.	Independent Variable	Coeff.	t-Stat.
d(log(Z(-1)))/d(d(	4.60	10.34	**d(log(Z(-1)))**/d(d(	1.97	21.84
d(d(log(K)))/d(d(	-0.39	-3.658	**d(d(log(A)))**/d(d(	0.65	3.586
Adjusted Sample: 1973-2014			Adjusted Sample: 1973-2014		

Data source: Models 17 and 18 were obtained from the GLS regressions conducted.
NB: All the regressions were found to be free from autocorrelation and heteroscedasticity.

Fourth, a 1% increase in innovation advancement had the potential of causing a rise in labour generation, capital accumulation and technological growth by 3.14, 4.60 and 1.97%, respectively (see Tables 8 and 9 above).

Fifth, a 1% increase in higher school enrolment growth could have caused growth in labour productivity and capital productivity to rise by 0.55 and 0.28 %, respectively, in Uganda during the given period (see Tables 19 and 20).

Last, a 1% increase in innovation advancement could have caused growth in labour productivity and capital productivity to rise by 3.75 and 1.81 %, respectively, in Uganda during the given period (see Tables 20 and 21). The study is important for informing the innovation and higher education policies of Uganda. See Appendix 12.3 for summary.

Table 10: Effects of higher school education on (19) labour productivity and (20) capital productivity.

Regression Model 19			Regression Model 20		
Dependent Variable: **d(log(LP))**/d(d(			Dependent Variable: **d(log(KP))**/d(d(		
Independent Variable	Coeff.	t-Stat.	Independent Variable	Coeff.	t-Stat.
d(log(H(-1)))/d(d(	0.55	7.19	**d(log(H(-1)))**/d(d(	0.28	5.25
d(d(log(LP)))/d(d(	-1.00	-17.13	**d(d(log(KP)))**/d(d(	0.40	4.72
Adjusted Sample: 1973-2014			Adjusted Sample: 1973-2014		

Data source: Models 19 and 20 were obtained from the GLS regressions conducted.

NB: Regressions 19 to 20 were free from autocorrelation and heteroscedasticity.

Table 11: Effects of innovation on (21) labour productivity and (22) capital productivity

Regression Model 21			**Regression Model 22**		
Dependent Variable: **d(log(LP))**/d(d(			Dependent Variable: **d(log(KP))**/d(d(		
Independent Variable	Coeff.	t-Stat.	Independent Variable	Coeff.	t-Stat.
d(log(Z(-1)))/d(d(	3.75	7.92	**d(log(Z(-1)))**/d(d(	1.81	4.37
d(d(log(LP)))/d(d(	-0.65	50.29	**d(d(log(KP)))**/d(d(	0.43	4.55
Adjusted Sample: 1973-2014			Adjusted Sample: 1973-2014		

Data source: Models 21 and 22 were obtained from the GLS regressions conducted.
NB: Regressions 21 to 22 were free from autocorrelation and heteroscedasticity.

Discussion

There is evidence of long-term relationships in developed countries, usually unidirectional causal relationships from economic growth to innovation. This implies that innovation is simply a consequence of rapid economic growth.

This evidence indicates that a strong economy is appropriate for innovative activities. The relationship between innovation and economic growth emerged in recent years (Pradhan et al., 2016). In the case of Uganda, evidence shows that there is bidirectional causality between (a) innovation advancement and economic growth, (b) innovation advancement and higher education gross enrolment ratio (HGER), (c) technological progress and HGER growth, (d) economic growth and HGER growth, (e) growth in capital and HGER growth, (f) growth in labour, capital, capital productivity, labour productivity and HGER growth and (g) total factor growth and HGER growth within the given period, ceteris paribus.

Nowadays, this relationship has become a central and topical theme in research in innovation economics. Studies on the relationship between innovation and economic growth can be done under any of the four themes (Maradana et al., 2017) by assuming: (a) unidirectional causality from innovation activities to economic growth; (b) unidirectional causality from economic growth to innovation activities; (c) bidirectional causality between innovation activities and economic growth; and (d) no relationship between economic growth and innovation activities (Maradana et al., 2017; Pradhan et al., 2016). Theme (c) is appropriate for our study because the study rests on the causal principle that if event A occurs before event B, then event A must be the cause of B. As a result, all the dependent variables were regressed on the lags of the respective independent variables. We also examined the unidirectional causality running (i) from innovation advancement to individual growth in technology, capital to labour as well as (ii) from total productivity to economic growth, by regressing the dependent variables on the first lags of the independent variables.

The discussion focuses on the effects of higher school education on economic growth, innovation advancement and technological progress. According to the World Economic Forum (2016), education is defined as the stock of skills, competencies and other productivity-enhancing characteristics. In every country, education is an important part of human capital because it (a) increases the efficiency of each individual worker and (b) stimulates the economy to move up the value chain beyond manual tasks (World Economic Forum, 2016). A lot of empirical works, including our empirical findings, have shown empirically that education affects productivity growth.

Generally, in every country, education affects productivity through three channels (World Economic Forum, 2016). One, it enhances the collective ability of the workforce to carry out existing tasks more quickly. Two, through secondary and especially tertiary education, it facilitates the transfer of knowledge about new information, products and technologies created by others (Barro & Lee, 2010). Lastly, education increases the creativity of each country and enhances the capacity of the country to create new knowledge, products and technologies (Grant, 2017). Education plays a leading role in enhancing economic growth, innovation advancement and technological progress. This finding is supported by Woessman (2014) and UNESCO (2012).

Woessman (2014) argues that education is a leading determinant of economic growth and employment. Meanwhile, UNESCO (2012) finds that for each US$1 spent on education, about USD10 to USD15 is generated as an outcome of economic growth (UNESCO, 2012). Moreover, if 46 of the poorest countries in the world could attain the lowest Organisation of Economic Cooperation and Development (OECD) benchmark for mathematics among 75% more 15-year-olds, economic growth could improve by 2.1% from its baseline and 104 million people could be lifted out of extreme poverty (UNESCO, 2012). Our finding is also supported by empirical evidence that Tilak (2003) provides by using data from 49 countries in the Asia Pacific region.

Tilak (2003) finds a significant effect of HE (gross enrolment ratio, GER) on the level of economic development (as measured by Gross Domestic Product [GDP] per capita). Tilak (2003) allows a time lag for HE to cause economic development. The rapid economic rise of India on the world economic stage is attributed partly to its long decades of successful efforts to provide high-quality, technically orientated HE to a significant number of its citizens (Bloom et al., 2006). Bloom et al. (2006) finds that expanding higher education (HE) may promote faster technological catch-up and improve a country's ability to maximise its economic output. Bloom et al. (2006) show, that the Sub-Saharan Africa production level in 2006 was about 23% below its production possibility frontier. A one-year increase in the HE stock could have increased the growth rate of GDP per capita by 0.24 percentage points and African output growth by an additional 0.39 percentage points in the first year. Thus, a one-year increase in HE stock could have boosted incomes by roughly 3% after 5 years and ultimately by 12 % (Grant, 2017).

Our empirical findings show that in Uganda during the 1973 to 2014 period, a 1% increase in higher education growth could have caused technological progress, innovation, total factor, income, capital, labour, labour productivity and capital productivity to rise by 0.27, 0.10, 0.56, 0.82, 1.56, 0.53, 0.55 and 0.28% per annum, respectively. This particular empirical finding indicates that higher school education growth could have been the most important factor in enhancing capital accumulation and a very important factor in boosting incomes in Uganda during the given period (see Tables 1 to 6, 21 and 22 above for more details).

Meanwhile, in Uganda during the given period, a 1% increase in growth of technology, innovation, total factor, income, capital and labour could have caused higher education growth to rise by 1.36, 5.02, 1.42, 1.08, 0.45 and 1.84% yearly, respectively. From this particular empirical finding, it can be discerned that innovation advancement had the highest potential to enhance higher school education, followed by the generation of employment (see Tables 7–12).

Moreover, in Uganda during the given period, a 1% increase in innovation advancement could have caused income, labour, capital, technology, labour productivity and capital productivity to rise by 4.63, 3.14, 4.60, 1.97, 3.75 and 1.81% yearly, respectively. From this particular empirical finding, it can be observed that in the country, innovation advancement had spectacular potential of enhancing growth in income, labour, capital, technology, labour productivity and capital productivity (see Tables 14, 16, 17, 18, 21 and 22 for details). Lastly, from Tables 13 and 15, it can be observed that in the real economy, economic growth can be enhanced sufficiently, by technological progress and total factor productivity.

Policy Implications

Among the several national policies of higher education that the Government of Uganda is required to execute are four major strategies: (a) the promotion of research and strengthening regional universities; (b) improving college/university admission policy; (c) improvement of the overall college/university education system; and (d) constructing a sound vocational and technical education. Second, the Government of Uganda must focus on seven key technology areas: industrial technologies; emerging industrial technologies; knowledge-based service technologies; state-led technologies; national issues-related technologies; global issues-related technologies; and basic and convergent technologies. Third, research and development (R&D) investments as a share of GDP should be increased. Four, innovation advancement through economic growth, employment generation, capital accumulation, growth in higher school education, total factor growth and technological progress should be promoted. Five, innovation advancement should be used to enhance economic growth, employment generation, capital accumulation, growth in higher school education, total factor growth and technological progress. Six, economic growth, capital accumulation and economic growth should be promoted through innovation advancement. Seven, intellectual property rights should be promoted. Eight, innovation should be driven mainly through the private sector. Nine, the rapid-learning cycle in technology development should be improved. Ten, manufacturing capacity should be increased to grow an innovation-based economy. Last, a knowledge-based economy should be created.

Below is a summary of broader policy implications, regarding the role of higher school education in enhancing economic growth, innovation and technological progress in Uganda:

(1) Uganda will need to promote new drivers of economic growth to address its major technological advancement challenges. Sustained growth in the long run will depend on continuous technological progress. To promote continuous technological progress and cultivate new drivers of growth, Uganda could pursue policies to enhance the structural and institutional reforms that promote the removal of distortions, accelerate diffusion and foster discovery.

First, reducing distortions in the allocation of resources has been a key driver of growth in the past, and continuing reforms would allow Uganda to reach its maximum potential production frontier, and the removal of distortions requires reforms of financial, labour and land markets to ensure that resources are allocated competitively and efficiently to their most productive uses in the economy. Second, accelerating diffusion of more advanced existing technologies, products and management techniques will help Uganda extend its current production frontier to the global frontier. Accelerating diffusion requires innovation and science and technology policies that promote the diffusion of technology, as well as an upgrading education and training system that prepares workers to adopt and use new technologies. Third and last, fostering the discovery of new innovation and technology will help Uganda to extend its global production frontier.

(2) The Government of Uganda will continue supporting specific technologies and industries, particularly by targeting R&D. For instance, government will provide the national institutes of health with critical financing for key technologies that contribute to the growth of the biotechnology industry, and the internet. Government will also follow the industry policy strategy, such as improving the information and communications technology (ICT) infrastructure as well as intellectual property rights, and upgrading the workforce. These policies shall be complemented by the provision of support to key enabling technologies and industries such as the automotive and steel industries, including support through various funds, such as national industry promotion strategies, that can promote manufacturing upgrading by increasing the digitisation and interconnection of products, value chains and business models.

(3) Government aims at strengthening the innovation capacity of firms. Uganda has extensive innovation support policies that are in line with economic objectives (productivity, diversification, human capital, entrepreneurship and inclusion) and science, technology and innovation objectives (research excellence, technology transfer, and R&D and non-R&D innovation) that are commonly seen in other countries. The policies employ a wide range of instruments to support innovation, such as fiscal incentives, grants, loan guarantees, vouchers, equity, public procurement, technology extension services, incubators, accelerators, competitive grants and prizes, science and technology parks, collaboration and networks.

(4) Higher school education, in particular, is essential for promoting the removal of distortions, for accelerating diffusion and for fostering discovery. It facilitates the diffusion of innovation and technology by enhancing the capability of the workforce to use, adopt and disseminate technologies. A more capable workforce will assist in fostering new discoveries and innovations and strengthen the research capabilities of Uganda’s universities, research institutes and enterprises.

Prioritising human capital investments and strengthening Uganda’s education and training system will be essential for transitioning to innovation-led and productivity-led growth.

(5) Government regulatory authorities encourage commercial banks and other financial service providers to expand lending to small and medium enterprises. They encourage the implementation of differentiated monetary and credit policies, risk compensation funds, and government guarantee funds and tax incentives.

(6) International trade and investments can continue to be an important source of growth for Uganda. Uganda will continue to improve its international competitiveness and raise the quality and innovativeness of its exports. Thus, Uganda needs to continue to pursue policy and institutional reforms to open up its economy and integrate and engage in free trade. These actions would provide critical new drivers of growth for Uganda’s economy by promoting market competition, access to global frontier technologies, collaboration with globally leading firms, and integration into and upgrading within global value chains (World Bank, 2019).

Conclusion

We find that a 1% increase in higher school education GER had the potential of causing economic growth, innovation advancement and technological progress to increase by 0.82, 0.10, and 0.27%, respectively, in Uganda during the given period. Meanwhile, empirical evidence shows that a 1% increase in economic growth, innovation advancement and technological progress had the potential of causing annual higher school education GER growth to increase by 1.08, 5.02 and 1.36%, respectively, during the given period. Government should promote research at universities and strengthen regional universities, improve tertiary admission policy, improve the overall tertiary education system and construct a sound vocational and technical education.

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Relevant data was collected from the United Nations and World Bank websites.

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Appendix

Deriving Alani consumption function from national income accounting

Consumer behaviour in the national income accounting consists of aggregate disposable income (Y_{dt}), which is the addition of household consumption (C^*_{nt}), and the aggregate household investment I_t where the mental consumption (C^*_{nt}) function is given by (C^*_{nt}) = $C_{nt-1} - C_0$.

$$C_{nt} + I_t = Y_{dt}. \qquad (12.1)$$

Substituting (C^*_{nt}) = $C_{nt-1} - C_0$ in Equation (A.1.1) where (C^*_{nt}) = $C_n + u_t$, provides

$$-C_0 + C_{nt-1} + I_t = Y_{dt}. \ (12.2)$$

Equation 1 can be rewritten in terms of MPC (β) and marginal propensity to invest, MPI (α)

$$-C_0 + C_{nt-1} + I_t = \alpha Y_{dt} + = \beta Y_{dt}. \qquad (12.3)$$

Since $\alpha + \beta = 1$ (12.4)

the MPC equals the APC, implying that $I_t = \alpha Y_{dt}$ making Equation (12.3) reduce to Equation (12.10) as follows:

$$\alpha Y_{dt} + \beta Y_{dt} = Y_{dt} \qquad (12.5)$$

$$\left(\frac{I_t}{Y_{at}}\right) Y_{dt} + \left(\frac{C_{nt}}{Y_{dt}}\right) Y_{dt} = Y_{dt} \qquad (12.6)$$

$$\alpha Y_{dt} = I_t \qquad (12.7)$$

Rewriting Equation (12.3) by substituting I_t for αY_{dt} gives

$$-C_0 + C_{nt-1} + I_t = I_t + \beta Y_{dt} \qquad (12.8)$$

Thus $-C_0 + C_{nt-1} = \beta Y_{dt}$ (12.9)

∴ $C_{nt-1} = C_0 + \beta Y_{dt}$ (12.10)

Preparing for robustness checks by using MPC derived from the neoclassical production function

The neoclassical production function for the households could be expressed by

$$Y_{dt} = I_t^{\alpha}\, C_{nt}^{\beta} \qquad (12.11)$$

Where Y_{dt} is output, I_t is capital formation, quantity of labour is estimated by aggregate level of consumption C_{nt}, and α, β are parameters of returns to scale on capital and labour, respectively. Equation (12.11) can be rewritten as follows:

$$Y_{dt} = I_t^{\alpha} C_{nt}^{1-\alpha} = I_t^{\alpha} C_{nt} C_{nt}^{-\alpha} \qquad (12.12)$$

Manipulation of Equation (12.12) provides the following:

$$\frac{Y_{dt}}{C_{nt}} = + \left(\frac{I_t}{C_{nt}}\right)^{\alpha}. \qquad (12.13)$$

Transformation of Equation (12.13) in logarithm form gives

$$\therefore \qquad \log \frac{Y_{dt}}{C_{nt}} = \alpha \log\left(\frac{I_t}{C_{nt}}\right) \quad (12.14)$$

$$\therefore \qquad \log(10).\log\left(\frac{Y_{dt}}{C_{nt}}\right) = \alpha \log(10).\log\left(\frac{I_t}{C_{nt}}\right). \qquad (12.15)$$

Rewriting Equation (12.15) in double log form provides

$$\log[\log\left(\frac{Y_{dt}}{C_{nt}}\right)] - [\log(10).] = -\alpha[\log(10)] + log\,[\log\left(\frac{I_t}{C_{nt}}\right). \qquad (12.16)$$

Manipulation of Equation (12.16) yields a reduced form of Equation (6) as follows:

$$log\,[\log\left(\frac{Y_{dt}}{C_{nt}} \times \frac{C_{nt}}{I_t}\right)] = (1-\alpha).\, log\,[\log(10)]. \qquad (12.17)$$

$$\therefore \qquad log\left(\frac{Y_{dt}}{I_t}\right) = \beta \log(10) \qquad (12.18)$$

Table 12: Effect of a 1% increase in growth of an independent variable on the rise in growth of a given dependent variable in Uganda (1970 -2014): A summary

Dependent Variable (Effect)		Independent Variable (Cause)	
Technology	0.27%	Higher Education	1%
Innovation	0.10%	Higher Education	1%
Total Factor	0.56%	Higher Education	1%
Gross Domestic Product	0.82%	Higher Education	1%
Capital Stock	1.56%	Higher Education	1%
Quantity of Labour	0.53%	Higher Education	1%
Higher Education	1.36%	Technology	1%
Higher Education	5.02%	Innovation	1%
Higher Education	1.42%	Total Factor	1%
Higher Education	1.08%	Gross Domestic Product	1%
Higher Education	0.45%	Capital Stock	1%
Higher Education	1.84%	Quantity of Labour	1%
Gross Domestic Product	1.33%	Technology	1%
Gross Domestic Product	4.63%	Innovation	1%
Gross Domestic Product	1.14%	Total Factor	1%
Quantity of Labour	3.14%	Innovation	1%
Capital Stock	4.60%	Innovation	1%
Technology	1.97%	Innovation	1%

Dependent Variable (Effect)		Independent Variable (Cause)	
Labour Productivity	0.55%	Higher Education	1%
Capital Productivity	0.28%	Higher Education	1%
Labour Productivity	3.75%	Innovation	1%
Capital Productivity	1.81%	Innovation	1%

In Table 12 above we summarise the effects of growth in higher school education on economic growth, innovation advancement and technological progress in Uganda during the 1970–2014 period. Firstly, from the table it can be observed that the empirical findings show that a 1% increase in higher school education gross enrolment ration (GER) growth could have caused technological progress, innovation advancement, total factor growth, economic growth, capital accumulation and labour generation to increase annually by 0.27, 0.10, 0.56, 0.82, 1.56 and 0,53%, respectively, in Uganda during the given period. Secondly, empirical evidence shows that a 1% increase in technological progress, innovation advancement, total factor growth, economic growth, capital accumulation and labour generation could have propelled higher school education GER growth to increase yearly by 1.36, 5.02, 1.42, 1.08, 0.45 and 1.84 %, respectively, during the given period.

Thirdly, over the given period, a 1% rise in technical progress, innovation and total factor growth could have driven economic growth to increase by 1.33, 4.63, and 1.14 % annually, respectively. Fourthly, a 1% increase in innovation advancement could have generated a rise in growth of labour quantity, capital stock and technology by 3.14, 4.60 and 1.97% yearly, respectively. Fifthly, a 1% growth in higher school education GER could have produced a rise in growth of labour productivity and capital productivity by 0.55 and 0.28% annually, respectively. Lastly, a 1% increase in innovation advancement could have stimulated a rise in growth of labour productivity and capital productivity by 3.75 and 1.81% yearly, respectively.