The Growth Effect of Education for Low and Middle-Income Countries: The Quantity or the Quality of Education Matters Most?

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I. Introduction

This paper examines the economic growth impacts of the quantity of primary education, the quantity of secondary education, and the quality of education using a panel data of African countries. Whether primary education, secondary education, or tertiary education has the most impact on economic growth and development is an ongoing question in the literature. The answer to this question is particularly relevant for developing countries where educational resources are scarce and mean years of schooling (measured quantity of enrollment in primary, secondary, and tertiary school) is low compared to those of the rest of the world; for example, the mean years of schooling of adults above age 25 for most African countries is, on average, still below the primary school level. Yet, education of the labor force, and thus the development of human capital is one of the key drivers of economic growth.

The growth empirics fail to provide conclusive answers to the question of whether a) the quantity of primary or secondary education has more impact on economic growth, b) the quantity of education or the quality of education has more impact on economic growth. With regard to the quantitative impact of education on growth, while Kocourek and Nodemlelova (2018) and others argue that years of schooling has a significant correlation with economic growth, others such as Delgado and Henderson (2014) contend otherwise. Others such as Barro and Sala-i-Martin (2004) argue that enrollments in primary education have a more profound effect on growth than enrollments secondary education. With regard to the quality of education, while most of the empirical results in the literature suggest not only a positive correlation between the quality of education and growth, but also show that it has a stronger impact on growth than the quantity of education. Still, the empirical evidence is far from being conclusive; for example, Breton (2011) argues that the quantity of education is the most important factor in economic growth.

This paper investigates the economic growth effects of the quantity and quality of education on economic growth using a panel data of 34 low and middle-income African countries covering 2003 to 2016 period.

We maintain the basic assumption of the augmented Solow model developed by Mankiw et al. (l992) which adds human capital to the basic Solow model; the latter proxy human capital accumulation by quantity of education (enrollments in school); our paper examines both the quantity and the quality effects of education using different data sets, additional control variables, and different estimation technique. As in Barro (1991), Barro and Sala-i-Martin (2004), and others, our empirical analysis uses school enrollment (primary and secondary school) as a proxy for quantity of education. In the empirical literature, international test scores on science and mathematics is the proxy widely used for quality of education; our empirical model depart from this trend. We use the quantity of per capita scientific and technical journal articles as a proxy for quality of education.

We estimate a set of panel data models for a) low income, and b) combined low- and middle-income African countries using various control variables, the number of countries included in the study determined by the availability of data. We use dynamic generalized method of moments (DGMM), applying first differencing to remove fixed effects, to estimate the parameters of the empirical models. Our findings suggest that a) both the quantity and quality of education have statistically significant positive impact on economic growth; b) primary education has a stronger impact on economic growth than secondary education, and c) the quantity of education measured by school enrollments have stronger impact than the quality of education which are proxied by the number of scientific and technical journal articles.

The rest of the paper is organized as follows. Section II presents a brief review of the literature; section III explains the theoretical framework; section IV describes the data and methodology; section V discusses the empirical results; and section VI provides concluding remarks.

II. A Brief Overview of Previous Studies

Romer (1986), Baumol (1986), Lucas (1988), Barro (1991), and Mankiw et al., (1992) exhibit renewed interest in the economic growth effects of human capital. However, while these and others in the literature posit that education as a form of human capital plays a vital role in economic growth and development, the empirical literature in general has failed to exhibit conclusive correlation between the two variables.

Mankiw et al. (1992) augment the Solow growth model by introducing a human capital variable, and using percent of population in secondary school as a proxy for human capital conclude that human capital plays a positive role in economic growth; this finding underscores the importance of education in economic growth. In addition, Easterly and Levine (1997), Krueger and Lindahl (2001) and Barro and Sala-i-Martin (2004) show positive correlation between years of schooling and growth in GDP per capita; however, Barro and Sala-i-Martin (2004) conclude that primary enrollment, rather than secondary and tertiary enrollments, has a robust effect on the rate of growth of per capita income. Also, others such as Gemmell (1996), Tsamadias and Prontzas (2012), Pegkas and Tsamadias (2014), Mariana (2015), and Kocourek and Nodemlelova (2018) confirm that quantity of education plays a positive role on economic growth. However, the empirical evidence on the correlation of education and per capita economic growth has not been conclusive. For example, Barro and Lee (l994) indicate a statistically significant correlation between the level of male secondary education and the growth rate of per capita income, but a statistically significant and negative correlation with respect to the effect of female secondary education. Barro and Lee (1994) state that the negative correlation between female education and economic growth may be explained by the discrimination practice that many countries follow toward well-educated females that prevent them from getting fully involved in the labor market. Furthermore, Hoeffler (2002), Bloom et al. (2006), and Delgado and Henderson (2014) reveal that years of schooling do not have a statistically significant effect on GDP per capita growth.

While the above studies focus on the quantity of education effects, others have expanded the literature to include the quality of education effects. Barro (2001), Altinok (2007), Hanushek and Woessmann (2008), Breton (2011), Hanushek (2013 and 2016), and Jin and Jin (2014) focus on the quality of education as a determinant of economic growth rather than the quantity of education. Barro (2001) examine the effects of both the *quantity* of schooling (measured by secondary and tertiary attainment) and the *quality* of education (using results on test scores for science, mathematics, and reading as a proxy); his findings reveal that the quality of education is more important than quantity of education in promoting economic growth. Barro (2013) reemphasize that scores on international examination (as a proxy of education quality) have a stronger correlation than quantity measures of education. Altinok (2007) shows a statistically significant correlation between the quality of education and GDP per capita growth for developing countries using test scores on mathematics and science for primary and secondary students (as a proxy for quality of education); and this author argues that the quality rather than the quantity of education is more important in determining economic growth. Similarly, Hanushek and Woessmann (2008) show that the quality of education (proxied by achievement tests) rather than years of schooling has a more profound positive effect on the growth of GDP per capita. Furthermore, Hanushek (2013, 2016) reemphasizes achievement test scores are more important for economic growth rather than years of schooling. Jin and Jin (2014), using an original proxy for quality of education (published articles in science and engineering fields) confirms that the quality of education is a driver of economic growth for developed countries. However, Breton (2011) concludes that rather than the quality of education (proxied by average test scores) the quantity of schooling (measured by average schooling attainment) is more significantly correlated with economic growth. However, Pritchett (2001) states that neither change in average years of schooling nor international test scores have a statistically significant association with GDP per capita growth.

Our paper examines the relationship between education and economic growth for African countries focusing on the effect of the quality of education. Other studies that have examined this relationship (for African countries) include Gyimah-Brempong (2006), Hassan and Ahmed (2008), and Seetanah (2009), each focusing on the effect of the quantity of education on economic growth. Gyimah-Brempong (2006) reveals that all three levels of education (measured by average years of primary, secondary and tertiary education) have a statistically significant and positive effect on per capita income growth. Likewise, (using the number of students who attained higher education as a measure of the quantity of education). Hassan and Ahmed (2008) shows that primary and secondary schooling enrollment, literacy rate, and average years of schooling have significant (and positive) correlation with GDP per capita growth; likewise, Seetanah (2009) exhibits that secondary enrollment ratio promotes economic growth.

While the above studies on African countries focus on the quantity measure of education, in this paper we examine the effects of both the quality and quantity of education on the economic growth of 34 low and middle-income African countries. This paper departs from previous empirical growth literature in three different aspects. First, we introduce per capita technical and scientific journal articles as a new proxy for quality of education (and thus the quality of human capital); to the best of our knowledge no one has used this proxy before in the empirical study of the augmented Solow-growth model. Second, none of the empirical literature on African countries mentioned above examine the effect of the quality of education, and in particular this proxy in assessing the effect of education on economic growth. Furthermore, our empirical analysis relies on more recent (and larger-time-series) data: 2003 to 2016 panel data of 34 African countries.

In addition, our empirical analysis for examining the effect of education on economic growth relies on estimating African countries' dynamic panel data using difference GMM. Using this estimation method helps for emending possible endogenity in the regression equation, and using suitable instruments that is not correlated with the equation transformed error term. GMM used before by Hoeffler (2002), Gyimah-Brempong (2006), and Seetanah (2009). However, Gyimah-Brempong (2006) exclusively estimate his model using IV and fixed effect GMM. Using fixed effect GMM in dynamic models does not have any estimates inconsistency problem, but it requires precisely searching for suitable instruments to be used in the model. Also, Seetanah (2009) introduce his empirical evidence relying on pooled OLS and random effect GMM. Hoeffler (2002) examines her empirical model using OLS and system GMM, but she does not find significant effect for education on economic growth. She has to use system GMM since she relies, as most previous empirical literatures, on the data constructed by Barro and Lee (1994), which covers five years' time periods, so, using difference GMM could magnify any gaps in her panel data. While our panel data constructed from long time series without panel gaps, part of our paper contribution carried out by introducing its empirical evidence through estimating the correlation between education and economic growth using difference GMM.

III. The Theoretical framework

It has been long recognized that education, and thus human capital determine economic growth. Each level of education, vocational, primary, secondary, and tertiary are expected raise not only the productivity of workers, but also the quality of their work. As expressed by Ozturk (2001), education alone would not lead to economic growth; the quantity and quality of investment, and the overall policy environment are other key ingredients that determine economic growth; but ultimately, these other factors are influenced by the level of human capital in the economy. Thus, our paper investigates the role of both the quantity and quality of education in economic growth applying the augmented Solow model which is developed by Mankiw et al. (1992). Following Mankiw et al. (l992), Islam (l995), Bloom et al., (2006), and Vinod and Kaushik (2007) we use education as a measure of human capital. The Mankiw et al. (l992) augmented Solow model is given by,

$$Y(t) = K(t)^{\alpha} H(t)^{\beta} \left[A(t)L(t)\right]^{1-\alpha-\beta} \tag{1}$$

where Y, K, H, L, and A refer to output, the stock of physical capital, the stock of human capital, labor, and the level of technology respectively. The model assumptions include diminishing marginal returns to the factors of production, constant returns to scale, and an exogenous growth of labor and technology, that is, labor, $L(t) = L(0)e^{nt}$ and technology, $A(t) = A(0)e^{gt}$; the technology-augmented labor, $A(t)L(t)$, is expected to grow at the rate of $n + g$.

The production function exhibited in (1) can be expressed in terms of effective labor as,

$$y(t) = k(t)^{\alpha} h(t)^{\beta} \tag{2}$$

where $y(t) = \frac{Y(t)}{A(t)L(t)}$, $k(t) = \frac{K(t)}{A(t)L(t)}$, and $h(t) = \frac{H(t)}{A(t)L(t)}$

and assuming that a constant share of output is invested in human and physical capital s_h and s_k respectively, Mankiw et al. (1992), express the evolutions of $k(t)$ and $h(t)$ as,

$$\dot{k}(t) = S_k y(t) - (n+g+\delta)k(t) \tag{3}$$

$$\dot{h}(t) = S_h y(t) - (n+g+\delta)h(t) \tag{4}$$

where δ is the rate of depreciation for both physical and human capital. In steady state, the left-hand-side variables of (3) and (4) approach zero implying,

$$\frac{y(t)}{n+g+\delta} = \frac{k(t)}{S_k} = \frac{h(t)}{S_h} \tag{5}$$

The steady state values of k and h can be calculated using (3), (4) and the values $h(t) = k(t)\frac{S_h}{S_k}$, $k(t) = h(t)\frac{S_k}{S_h}$, $k(t) = \frac{S_k y(t)}{(n+g+\delta)}$ and $h(t) = \frac{S_h y(t)}{(n+g+\delta)}$ from (5) giving us:

$$k^* = \left[\frac{S_k^{\ 1-\beta} S_h^{\ \beta}}{n+g+\delta}\right]^{\frac{1}{1-\alpha-\beta}} \quad , \quad h^* = \left[\frac{S_k^{\ \alpha} S_h^{\ 1-\alpha}}{n+g+\delta}\right]^{\frac{1}{1-\alpha-\beta}} \tag{6}$$

Substituting this steady state values of physical and human capital in (2) and taking the natural log gives,

$$\ln\frac{Y(t)}{L(t)} - \ln A_0 - gt = \frac{\alpha}{(1-\alpha-\beta)}\ln S_k + \frac{\beta}{(1-\alpha-\beta)}\ln S_h - \left[\frac{(\alpha+\beta)}{(1-\alpha-\beta)}\right]\ln(n+g+\delta) \tag{7}$$

Thus, in steady state, per capita output, $y^* \equiv \frac{Y(t)}{L(t)}$, is given by,

$$\ln y^* = \ln A_0 + gt + \frac{\alpha}{(1-\alpha-\beta)}\ln S_k + \frac{\beta}{(1-\alpha-\beta)}\ln S_h - \left[\frac{(\alpha+\beta)}{(1-\alpha-\beta)}\right]\ln(n+g+\delta) \tag{8}$$

To determine the dynamic growth rather than steady state value of per capita output growth, Mankiw et al. (1992), Islam (1996) and others, start with the speed of convergence to steady state:

$\frac{d \ln y(t)}{dt} = \lambda\left[\ln y^* - \ln y(t)\right]$, where y^* is the steady state output per effective labor ($Y(t)/(A(t)L(t))$, $y(t)$ is the actual output per effective labor, and $\lambda = (n+g+\delta)(1-\alpha-\beta)$, and show the following dynamic model:

$$\ln y(t_2) = (1-e^{-\lambda\tau})\ln y^* + e^{-\lambda\tau}\ln y(t_1) \tag{9}$$

where t_2 represents the current period and t_1 a previous period, and $\tau = t_2 - t_1$.

Substituting for the value of $\ln y^*$ from (8) into (9) and subtracting $\ln y(t_1)$ from both sides gives,

$$\begin{aligned} \ln y(t_2) - \ln y(t_1) &= \left[1-e^{-\lambda t}\right]\frac{\alpha}{1-\alpha-\beta}\ln S_k + \left[1-e^{-\lambda t}\right]\frac{\beta}{(1-\alpha-\beta)}\ln S_h \\ &-\left[1-e^{-\lambda t}\right]\frac{\alpha+\beta}{(1-\alpha-\beta)}\ln(n+g+\delta) - \left[1-e^{-\lambda t}\right]\ln y(t_1) \end{aligned} \tag{10}$$

Rearranging (10) and expressing y as output per worker (instead of per effective worker) gives the dynamic growth model,

$$\begin{aligned} \ln y(t_2) &= (1-e^{-\lambda t})\ln A(0) + g(t_2 - e^{-\lambda t}t_1) + (1-e^{-\lambda t})\frac{\alpha}{1-\alpha-\beta}\ln S_k \\ &+(1-e^{-\lambda t})\frac{\beta}{(1-\alpha-\beta)}\ln S_h - (1-e^{-\lambda t})\frac{\alpha+\beta}{(1-\alpha-\beta)}\ln(n+g+\delta) + e^{-\lambda\tau}\ln y(t_1) \end{aligned} \tag{11}$$

where $(1-e^{-\lambda t})\ln A(0)$ represents the individual time-invariant country effect, and $g(t_2 - e^{-\lambda t})$ represents the time varying exogenous technology effect common to all countries. The empirical model we estimate uses the level of human capital instead of the rate of human capital growth implying that the coefficients will differ from those expressed in (11). Thus, the basic dynamic panel data model we estimate is given by,

$$\ln y_{it} = \gamma_1 \ln y_{it-1} + \gamma_2 \ln S_{k,it} + \gamma_3 \ln h_{it} - \gamma_4 \ln\left(n_{it} + g + \delta\right) + \mu_i + \eta_t + \varepsilon_{it} \quad (12)$$

where y is per capita output, μ_i is the individual (time-invariant) country fixed effect, η_t is time effect, ε is the random error term, the γ 's are the parameters to be estimated, and the remaining variables are as defined earlier.

IV. Data and Methodology

We base our empirical analysis based on a panel data of thirty-four cross-section units and a time series of fourteen years using a general form of dynamic panel data model, $y_{it} = \gamma y_{it-1} + x_{it}^{'}\beta + \alpha_i + \varepsilon_{it}$ where $i = 1,...,n$ and $t = 1,...,T$, y is the dependent variable, and x is a vector of explanatory variables, α_i represents unobserved time-invariant individual effect, ε_{it} a random error term and γ a parameter associated with the lagged dependent variable, and β is vector of parameters associated with the explanatory variables other than the lagged dependent variable. We assume $E(\varepsilon_{it}) = 0$, $E(\varepsilon_{it}\varepsilon_{jp}) = \sigma_\varepsilon^2$ for $i = j$ and $t = p$, and zero serial correlations, that is, $E(\varepsilon_{it}\varepsilon_{jp}) = 0$ for $t \neq p$. The specification of the lagged dependent variable on the right-hand side of the equation suggests a violation a strict exogeneity assumption (regarding the explanatory variables); this violation implies that estimators such as the least square dummy variable estimator (the fixed-effects estimator) are inconsistent and biased (for small T and large n).

Furthermore, most likely x_i is correlated with α_i (factors correlated with x_i but unobserved by the researcher) resulting in problematic multicollinearity effects. We apply the dynamic generalized method of moments (DGMM) technique which is expected to be consistent and asymptotically normal, to estimate our empirical model. The DGMM technique is assumed to exploit all of the information available in the sample to construct efficient estimates (Arellano and Bond, 1991; Baum, 2013). We estimate our empirical model applying the first differencing technique to remove the individual-fixed effects and using lagged levels of the model variables as instruments (as suggested by Arellano and Bond, 1991) and the White method of standard errors adjustment to overcome heteroskedasticity. We use the J-test to test the validity of the instruments.

The panel data we use for our study covers 34 cross-section units (low and middle-income African countries) over 14 years (2003 to 2016). The dependent variable, per capita economic growth ($Growth$), is measured by log of real GDP per capita. Per capita real GDP is constructed as $\frac{GDP_i}{p_i \times pop_i}$ where GDP is nominal GDP, p is the GDP deflator, pop is total population, and i refers to cross-section unit. Following Mankiw et al., (1992), Gyimah-Brempong (2006), Barro (2013) and others we use the ratio of foreign-direct investment to GDP as a proxy for physical capital accumulation (Inv). The empirical analysis in this paper uses both qualitative and quantitative measures of education as an indicator of human capital accumulation; we use enrollments in a) primary ($Primary$) and b) secondary ($Secodary$) education as a measure of quantity education, and per capita scientific and technical journal articles ($Articles$) as a measure of the quality of education. The index of trade openness ($Openness$) is constructed as $\frac{X_i + M_i}{GDP_i}$ where X is total export, M is total import, GDP stands for nominal GDP and i refers to the cross-section unit. The population variable (Pop) is represented by total population. Institutional impact on economic growth is proxied by rule of law index (Law).

Data on nominal GDP per capita, GDP deflator, foreign direct investment, total population, and scientific and technical journal articles are gathered from the World-Bank database of World Development Indicators. Enrollment in primary and secondary education obtained from World Bank education statistics. Data for rule of law obtained from Worldwide Governance Indicators database. Data on export and import of goods and services are obtained from national accounts main aggregates database, of United Nations statistics division (UNSD).

V. Empirical Results

The primary aim of our empirical analysis is to assess the contribution of education quantity (school enrollment) and education quality (the cognitive skills of the population) to economic growth for low- and middle-income African countries. We test the hypothesis that the quality of education rather than the quantity of education is a driver of economic growth. The quality of education rather than mere schooling is expected to contribute to the development of human capital (the stock of skills, knowledge, and innovative capacity of the labor force), a key variable in the augmented Solow model of economic growth. Since we find that data on tertiary enrollment for most of the African countries in this study is sparse and limited our empirical analysis relies on primary and secondary enrollment as quantitative measures education.

We present three sets of regression results. The first set focuses on the impact of education *quantity* on economic growth (measured by per capita real GDP) using primary school enrollment as a proxy (presented in Table 1); the second set also focuses impact of education *quantity* on economic growth, but uses secondary school enrollment as a proxy (presented in Table 2).[1] The third set of regression (presented in Table 3) focuses on the impact of education *quality* on economic growth; we use per capita scientific and technical journal articles as a proxy for quality of education.

We estimate parameters for two sets of samples: 1) a panel data 34 combined low -income African countries covering the years 2003 to 2016, and 2) a panel data 26 low-income African countries covering the years 2003 to 2016. A separate regression for middle-income (and high income) African countries is precluded due to data limitation. We estimate parameters by dynamic GMM using lags of the explanatory variables as instruments, first-differencing to remove unobserved individual effects (and associated omitted variable bias), and the White technique to remove heteroscedasticity. As stated above, Table 1 exhibits results associated with quantity of education measured by enrollments in primary schools, and Table 2 exhibits results associated with quantity of education measured by enrollments in secondary schools; and Table 3 exhibits the results associated with quality of education. The P-values for the Hansen J-statistics in all three tables indicate that there is no enough evidence to reject the validity of the instrumental variables. Columns (1) and (2) in each table below present the results of the baseline model which uses population growth, investment to GDP ratio and lagged dependent variable (used to capture dynamic effects) as control variables.

[1] Enrollment in tertiary education is not included in this study due to lack of reliable and consistent data for the sample countries and periods covered by this paper.

1. The Growth Effect of Quantity of Education: Enrollment in Primary Schools

Results of the baseline model, Columns (1) and (2) in Table 1, shows that the estimated coefficient associated with enrollment in primary is 0.40 (significant at the 1% level) for the combined sample of low- and middle-income African countries and 0.25 (significant at the 1% level) for the sample of low-income-African countries, suggesting that the *quantity* of education in the form of primary school enrolment has a positive and a statistically significant effect on human-capital development and thus per capita economic growth for the sample countries included in the study. The positive correlation between quantity of education and economic growth is consistent with others who have done similar work on African countries: Gyimah-Brempong (2006), Hassan and Ahmed (2008), and Seetanah (2009). It is also consistent with other studies, including Easterly and Levine (1997), Krueger and Lindahl (2001) and Barro and Sala-i-Martin (2004), Tsamadias and Prontzas (2012), Pegkas and Tsamadias (2014), Mariana (2015), and Kocourek and Nodemlelova (2018). However, it is not consistent with Hoeffler (2002), Bloom et al. (2006), and Delgado and Henderson (2014), studies that show that years of schooling do not affect GDP per capita growth significantly.

Supporting the augmented Solow growth model, the results of the baseline model (in Columns (1) and (2), Table 1) show population growth has a statistically significant negative effect on economic growth, and growth in physical capital (proxied by investment ratio) has a statistically significant positive effect: the parameter estimate associated with population growth is -0.99 for the combined sample of low and middle-income African countries, and -0.87 for the sample of low-income African countries, both parameters statistically significant at the 1% level; the parameter associated with investment ratio is 0.14 (statistically significant at the 1% level) for the combined low- and middle-income countries, and 0.18 (statistically significant at the 1% level) for the low-income group.

The results in columns (3) and (4), Table 1 include trade openness as an additional control variable; the estimation results show that the baseline estimates are robust in direction and statistical significance to the inclusion of this control variable. The magnitudes of the coefficients are also close to the baseline results. The estimated coefficient associated with primary school enrollment in columns (3) and (4) is 0.38 (statistically significant at the 1% level) for the combined low- and middle-income group, and 0.27 (statistically significant at the 1% level) for the low-income group. The estimated coefficient of the trade-openness variable, 0.06 (statistically significant at the 1% level) for both income groups supporting the theory that trade openness induces knowledge and technological spillovers that help derive economic growth.[2]

Table 1. The Link between Quantity of Primary Education and Growth.
Method: Dynamic GMM
Dependent Variable: Per Capital Real-GDP Growth, log($Real\_GDP_{it}$)

	(1)	(2)	(3)	(4)	(5)	(6)
	Low & Middle Income	**Low Income**	**Low & Middle Income**	**Low Income**	**Low & Middle Income**	**Low Income**
Log (Population$_{it}$)	-0.9926	-0.8676	-0.9367	-0.8700	-0.9167	-0.8049
	(0.038)	(0.0242)	(0.0259)	(0.1061)	(0.0285)	(0.1112)
	[26.1]***	[35.1]***	[36.1]***	[8.21]***	[32.2]***	[7.24]***
Log (Primary$_{it}$)	0.4029	0.2539	0.3834	0.27399	0.3682	0.24058
	(0.0267)	(0.0178)	(0.0293)	(0.0526)	(0.0289)	(0.0520)
	[15.1]***	[14.3]***	[13.1]***	[5.21]***	[12.7]***	[4.63]***
(Invest/GDP)$_{it}$	0.14066	0.18158	0.1182	0.1504	0.1143	0.14406
	(0.0266)	(0.0080)	(0.0355)	(0.0268)	(0.0267)	(0.0417)
	[5.28]***	[22.5]***	[3.33]***	[5.61]***	[2.27]***	[3.46]***
Openness$_{it}$			0.0548	0.0591	0.0654	0.06641
			(0.0102)	(0.01421)	(0.0138)	(0.0095)
			[5.36]***	[4.16]***	[4.71]***	[7.01]***
Rule_of_Law$_{it}$					0.0087	0.0385
					(0.0076)	(0.0151)
					[1.149]	[2.549]**
Log(real_GDP)$_{it-1}$	0.7350	0.6919	0.7237	0.6729	0.7314	0.6683
	(0.0132)	(0.0046)	(0.0093)	(0.0097)	(0.0077)	(0.0067)
	[55.6]***	[151.6]***	[77.3]***	[69.7]***	[94.3]***	[99.8]***
Hansen J-Statistic	32.891	24.891	32.635	24.257	33.653	25.002
P-Value	(0.3273)	(0.3559)	(0.29267)	(0.2807)	(0.2522)	(0.2471)
No. of Observations	374	278	374	278	374	278

Note: (***, **, *) denotes significance level at 1%, 5%, and 10% respectively. Standard error in parentheses ( ), and absolute value of t-statistic in brackets [ ]. The instrument variables used for estimating the model are the first lag of each explanatory variable, and the second lag for the dynamic factor in the model.

[2] Theoretically, trade openness induces knowledge and technological spillovers that elevate a country's capacity to create new products and adapt more efficient production processes and thereby contribute to economic growth.

The regression results in Columns (5) and (6) exhibit rule-of-law as an additional control variable. The parameter estimates remain robust in sign and statistical significance. The results in Columns (5) and (6) show a positive correlation between primary school enrollment and per capita economic growth with a coefficient of 0.37 and 0.24 for the combined low-and middle-income countries and low-income countries respectively, both statistically significant at the 1% level. The results show that the estimated coefficient of the rule of law variable is 0.06 (statistically significant at the 5% level) for the low-income African countries supporting the theory that rule of law, which includes the provision of personal security, protection of property rights, contract enforcement, checks and limits on executive discretion, and the absence of corruption, and so forth, promotes economic growth. The coefficient associated with the rule of law variable for the combined low- and middle-income group is not statistically significant.

2. The Growth Effect of Quantity of Education: Enrollment in Secondary Education

The results in Table 2 focus on the impact of *quantity* of education measured by *enrollments in secondary school*. Columns (1) and (2) in Table 2 report the parameter estimates of the baseline model which specifies *enrollment in secondary school*, population growth, investment share in GDP and lagged dependent variable as explanatory variables; the results show that the parameter estimate associated with enrollments in secondary education is 0.19 (statistically significant at the 1% level) for the combined sample of low- and middle-income African countries, and 0.11 (statistically significant at the 1% level) for the low-income African countries. Similar findings (positive correlation between economic growth and secondary education) are generated by Mankiw et al. (1992), Easterly and Levine (1997), Krueger and Lindahl (2001) and Barro and Sala-i-Martin (2004) and also by Gyimah-Brempong (2006), Hassan and Ahmed (2008), and Seetanah (2009) whose studies focus on African countries. However, the results are not consistent with Hoeffler (2002), Bloom et al. (2006), and Delgado and Henderson (2014); the latter fail to show statistically significant correlation between quantity of education and economic growth. Interestingly, the results of the baseline model in Tables 1 and 2 indicate that the economic growth effect of primary education is larger than the growth effect of secondary education: the coefficient of enrollments in primary schools (0.40 and 0.25 for the combined low- and middle-income and low-income group respectively) is larger than the coefficient associated with secondary school enrollment (0.19 and 0.11 for the combined low- and middle-income and low-income group respectively). These latter finding are consistent with Barro and Sala-i-Martin (2004).

Table 2. The Link between Quantity of Secondary Education and Growth.
Method: Dynamic GMM
Dependent Variable: Per Capital Real-GDP Growth, log ($Real\_GDP_{it}$)

	(1)	(2)	(3)	(4)	(5)	(6)
	Low & Middle Income	**Low Income**	**Low & Middle Income**	**Low Income**	**Low & Middle Income**	**Low Income**
Log ($Population_{it}$)	-0.9567	-0.7922	-0.8842	-0.8502	-0.8854	-0.8072
	(0.018)	(0.066)	(0.0284)	(0.0511)	(0.0322)	(0.1753)
	[53.1]***	[12.1]***	[31.1]***	[16.7]***	[27.5]***	[4.60]***
Log ($Secondary_{it}$)	0.1899	0.1073	0.1663	0.1383	0.1678	0.12696
	(0.0068)	(0.0226)	(0.0141)	(0.0203)	(0.014)	(0.0592)
	[27.8]***	[4.75]***	[11.8]***	[6.81]***	[11.1]***	[2.144]**
$(Invest/GDP)_{it}$	0.1695	0.2292	0.1420	0.1491	0.1369	0.1621
	(0.0112)	(0.0241)	(0.0272)	(0.0385)	(0.0256)	(0.0594)
	[15.1]***	[9.49]***	[5.21]***	[3.87]***	[5.36]***	[2.73]***
$Openness_{it}$			0.0404	0.00644	0.0429	0.0304
			(0.0059)	(0.00845)	(0.0040)	(0.0172)
			[6.79]***	[0.76290]	[10.6]***	[1.77]*
$Rule\_of\_Law_{it}$					0.0279	0.0558
					(0.005)	(0.009)
					[5.57]***	[6.19]***
$Log(real\_GDP)_{it-1}$	0.7231	0.6827	0.7232	0.7540	0.7269	0.67386
	(0.0068)	(0.0049)	(0.0076)	(0.0092)	(0.00726)	(0.0136)
	[105.3]***	[138.7]***	[94.9]***	[82.4]***	[100.1]***	[49.7]***
Hansen J-Statistic	34.925	20.161	33.034	21.830	23.834	23.024
P-Value	(0.2868)	(0.6322)	(0.32103)	(0.4700)	(0.73703)	(0.2876)
No. of observations	357	261	357	261	357	261

Note: (***, **, *) denotes significance level at 1%, 5%, and 10% respectively. Standard error in parentheses ( ), and absolute value of t-statistic in brackets [ ]. The instrument variables used for estimating the model are the first lag of each explanatory variable, and the second lag for the dynamic factor in the model.

The remaining coefficients of the baseline model in Table 2 are statistically significant and carry the expected signs: the estimated parameter associated with population growth is -0.96 for the combined sample and -0.79 for the low-income group, both statistically significant at the 1% level; the coefficient of the investment ratio is 0.17 for the combined sample and 0.23 for the low-income group, both statistically significant at the 1% level.

The regressions in Columns (3) and (4), Table 2, include trade openness as an additional control variable and confirms that the estimated coefficients of the baseline model are robust in direction and statistical significance. The estimated coefficient of secondary school enrollments is still positive and statistically significant at the 1% level: 0.17 and 0.14 for the combined group and the low-income group respectively. The parameter estimate associated with the trade openness is 0.04 (statistically significant at the 1% level) for the combined low- and middle-income group; the coefficient is not statistically significant for the low-income group.

The last two regressions in Table 2 (Columns (5) and (6)) add the rule of law variable as an additional control variable; the coefficient associated with this variable is 0.03 and 0.06 (both statistically significant at the 1% level) for the combined sample and for the low-income country group respectively. The regression results in Columns (5) and (6) confirm a positive and statistically significant correlation between enrollments in secondary school and economic growth: a coefficient of 0.17 (statistically significant at the 1%) for the combined sample and 0.13 (statistically significant at the 5% level) for the low-income group. The results also confirm the robustness of the baseline results in terms of signs and statistical significance with regard to the coefficients of population growth and investment ratio. The coefficient of trade openness in Columns (5) and (6), Table 2, is 0.04 (significant at the 1% level) for the combined sample and 0.03 (significant at the 10% level) for the low-income group. The coefficient of the rule of law variable is 0.03 and 0.06 (both statistically significant at the 1% level) respectively for the combined sample and for the low-income country group.

3. The Growth Effect of Quality of Education

We run our last regression of economic growth on the same regressors as in tables 1 and 2, except here we use qualitative measure of education instead of quantitative measure. The set of regression results in Table 3 focus the growth impact of human capital development using education *quality as a proxy*. The baseline regression results on education quality, Columns (1) and (2) in Table 3, show that quality of education is positively correlated with economic growth; the estimated coefficient associated with the quality of education is 0.01 for the combined sample of low- and middle-income African countries, and 0.02 for the low-income African countries; both statistically significant at the 1% level. The positive correlation between these two variables is consistent with Barro (2001), Altinok (2007), Hanushek and Woessmann (2008), Barro (2013), Jin and Jin (2014) and others, but inconsistent with Pritchett (2011) who concludes otherwise.

Table 3. The Link between Quality of Education and Growth.

Method: Dynamic GMM
Dependent Variable: Per Capital Real-GDP Growth

	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
	Low & Middle Income	**Low Income**	**Low & Middle Income**	**Low Income**	**Low & Middle Income**	**Low Income**
Log (Population$_{it}$)	-0.4581	-0.4881	-0.4229	-0.4707	-0.4318	-0.4677
	(0.0076)	(0.0205)	(0.0044)	(0.0244)	(0.0089)	(0.0339)
	[59.9]***	[23.8]***	[97.1]***	[19.3]***	[48.3]***	[13.8]***
Log (Quality$_{it}$)	0.0087	0.0233	0.0087	0.02458	0.007	0.0235
	(0.0012)	(0.0035)	(0.0021)	(0.0059)	(0.0026)	(0.0105)
	[7.49]***	[6.62]***	[4.09]***	[4.14]***	[2.73]***	[2.23]**
(Invest/GDP)$_{it}$	0.231	0.2676	0.2269	0.23317	0.2303	0.2564
	(0.0388)	(0.01787)	(0.0388)	(0.0252)	(0.0383)	(0.0561)
	[5.94]***	[14.9]***	[5.84]***	[9.24]***	[6.01]***	[4.57]***
Openness$_{it}$			0.0642	0.04217	0.0671	0.05166
			(0.0084)	(0.0059)	(0.0081)	(0.01062)
			[7.65]***	[7.10]***	[8.29]***	[4.86]***
Rule_of_Law$_{it}$					0.0223	0.0252
					(0.0033)	(0.0108)
					[6.64]***	[2.334]**
Log(real_GDP)$_{it-1}$	0.7859	0.7590	0.7695	0.74203	0.7711	0.7383
	(0.006)	(0.0057)	(0.004)	(0.0062)	(0.0041)	(0.0105)
	[129.6]***	[133.9]***	[190.3]***	[119.9]***	[188.1]***	[70.1]***
Hansen J-Statistic	54.212	29.0362	30.344	24.3072	31.615	29.386
P-Value	(0.0061)	(0.1791)	(0.4481)	(0.3313)	(0.33701)	(0.10503)
No. of observations	408	312	408	312	408	312

Note: (***, **, *) denotes significance level at 1%, 5%, and 10% respectively. Standard error in parentheses ( ), and absolute value of t-statistic in brackets [ ]. The instrument variables used for estimating the model are the first lag of each explanatory variable, and the second lag for the dynamic factor in the model.

The positive correlation between educational quality and economic growth hints that to amplify the quantity effect of education resources need to be devoted to the quality of education as well. The coefficients of population growth and investment ratio remain robust in sign and statistical significance as in Tables 1 and 2; however, their magnitudes change slightly. In Table 3 (Columns (1) and (2)), compared to the results in Tables 1 and 2, population growth appears to have a less dampening effect on per capita economic growth (the absolute value of the coefficient is lower in Table 3) and growth in physical capital measured by investment ratio appears to have a larger impact than what Tables 1 and 2 exhibit.

Regressions (3) and (4) in Table 3 add a trade-openness variable to the baseline model (regressions (1) and (2) in Table 3) to check the robustness of the results; as expected this control variable has a positive effect on per capita economic growth: the estimated coefficient of trade openness is 0.06 (significant at the 1% level) for the combined sample and 0.04 (significant at the 1% level) for the low-income African countries. However, the results of the baseline model (of Table 3) are robust in statistical significance and direction; that is, adding trade openness as a control variable did not alter the results of regressions (1) and (2) in Table 3. In results in (5) and (6), Table 3 include a rule of law variable as an additional control variable. The coefficient associated with the rule of law variable is 0.02 for the combined sample and 0.3 for the low-income group, both statistically significant at the 1% level, indicating that the rule of law has impact on economic growth. In regressions (5) and (6), the parameter estimates of population growth, investment ratio, and trade openness are robust in sign and statistical significance; the coefficient of the quality of education variable is robust in sign (positive) and also in statistical significance but at a lower level of significance for lower-income group (5% level instead of 1% level).

Table 4. The Growth Impacts of the Quantity and Quality of Education

Standardized Coefficients*

	(1)	(2)	(3)	(4)	(5)	(6)
	Low & Middle Income	**Low Income**	**Low & Middle Income**	**Low Income**	**Low & Middle Income**	**Low Income**
Log(Primary)	1589.93	1001.94	1512.97	1081.22	1452.99	949.38
Log(Secondary)	324.61	183.41	284.27	236.40	286.83	217.02
Log(Quality)	0.0001	0.0002	0.0001	0.0002	0.0001	0.0002

*Computed using coefficients Log(Primary), Log(Secondary) and Log(Quality) Tables 1-3 respectively.

The standardized coefficients in Table 4 suggest that enrollments in primary education have a stronger impact than enrolments in secondary education and the quality of education variables; and both, enrolments in primary and secondary education have stronger impact on economic growth than the quality of education. These results are not consistent with Barro (2001), Hanushek and Woessmann (2008), and Barro (2013). In this context, their finding indicate that the quality of education has much stronger impact on economic growth rather than the quantity of education. As pointed out in the literature review, they use different proxies for the quantity and the quality of education than the proxies we use in our empirical model. However, our findings in this part are consistent with Breton (2011), who argues that the quantity of education has a stronger effect on economic growth rather than the quality of education.

Overall, the results imply that both the quantity of education and the quality of education are key drivers of economic growth for the sample countries included in the study. In addition, the results further indicate that the quantity of primary education has a stronger impact on economic growth than the quantity of secondary education and the quality of education.

VI. Summary and Conclusions

This paper uses panel data from 34 low- and middle-income African countries over the 2003-2016 period, and DGMM-regression technique to investigate the contribution of education quantity and quality to economic growth. The previous literature in general has failed to exhibit conclusive findings on the relative significance of these variables. Moreover, previous studies on African countries have focused on only the quantity effect of education; this paper examines both the quantity and the quality effects of education on economic growth.

The estimation results (of the augmented Solow model) show that a) both the quantity of education (primary and secondary school enrolment) and the quality of education have a statistically significant positive effect on per capita real GDP growth; b) the quantity of primary education has stronger impact on economic growth than the quantity of secondary education; c) the quantity of primary and secondary school enrollment have a stronger impact on per capita real GDP growth than the quality of education.

It noteworthy to state that there are number of caveats that need to be considered regarding our empirical findings. The first constraint lies in the fact that our sample of the middle-income

African countries is too small to estimate by DGMM precluding a separate analysis for middle-income African countries. Second, we use enrollments in primary and secondary education as proxies for quantity of education rather than average years of schooling because data on the latter is not adequately available. Third, the proxy we used for the quality of education may not adequately reflect the quality of education. Future research can expand on this paper using alternative measures of quality of education including test scores on international mathematics and science exams

Notwithstanding these caveats, our findings about the quantity and quality of education in low- and middle-income African countries generate both policy implications. The results suggest that for Low- and middle-income African countries increasing investment in education to increase enrollments and policies designed to improve the quality of education, including support for the research and development sector could promote economic growth.

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