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Human Capital-Economic Growth Nexus in Africa: Heterogeneous Panel Causality Approach

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ABSTRACT

This paper examines the causal relationship between human capital (HC) and economic growth (EG) for a panel 29 African countries. In particular, the study applied theoretically consistent panel unit root procedures and panel co-integration tests that account for the presence of cross-sectional dependency among the members of a panel. To ascertain the direction of causality between HC and EG, the study applies the heterogeneous panel causality test proposed by Dumitrescu and Hurlin. This test has the ability to control for the presence of both heterogeneity and cross-sectional dependence that might be present in the panel. To determine the signs of the relationship between the two variables, the study applied the dynamic ordinary least square (OLS). The results from the heterogeneous panel causality test provide evidence in support of bidirectional causality between HC and EG for the sample countries. The results from the dynamic OLS indicate that HC and EG have significantly positive effect on each other. This finding reinforces the need for the sample countries to work in tandem in promoting education as an engine of EG.

Keywords: Human Capital, Economic Growth, Panel Data Causality, Africa
JEL Classifications: C33, O40, O55

1. INTRODUCTION

Economic growth (EG), as measured by growth in the gross domestic product (GDP) or growth in the per capita GDP, varies from country to country. These variations explain why some countries are characterized as rich, thus ensuring high standards of living than poor countries. The implication therefore is that while the level of real GDP is a good measure of economic prosperity, the growth of real GDP (EG) is a good gauge of economic progress (Mankiw, 2008). Understanding what accounts for the differences in EG and standard of living as a consequence among the countries has become very crucial as countries construct their sustainable economic development strategies and policies. Over the years, developing/poor countries have attempted to increase their capital base as part of their development efforts. Many a time, this is achieved through International Trade Liberalization through which multinational corporations act as the conduit for technological and capital transfers to the countries. This posits an argument that may infer that EG can mostly be achieved through capital accumulation.

There has been the need to decompose capital between physical capital and human capital (HC). Traditionally, research has concentrated on the role of physical capital accumulation via improvements in productivity. However, the issue of labor-augmenting characteristics of HC has ushered in new debates on HC as a supply factor (Awel, 2013; Adekola, 2014; Abbas, 2000). There is a tremendous body of knowledge that tends to provide evidence for the nexus between HC and EG given that HC, in economics, is defined as "the knowledge and skills that workers acquire through education, training, and experience" (Mankiw, 2008). As such, effective investment in HC becomes an increasingly important element in long-term EG and development strategies. This notion is supported by the World Bank study reported by Awe and Ajayi (2010). The study reported that HC on the average, accounts for 64% of total wealth versus 16% and 29% for physical and natural capital respectively of the 192 countries sampled. Moreover, not only does an increase in HC improve worker productivity, it is also necessary for optimum utilization of physical capital (Qadri and Waheed, 2011). As a result, countries position their stock of HC a one area that they may possess some comparative advantage in vying for foreign investments.

The relationship between EG and HC has been extensively explored by researchers. However, most of the earlier studies on this issue have produced mixed results in the literature. For instance, Adekola (2014) explores the relationship between public expenditure on HC and EG for Nigeria using data from 1961 through 2012. Applying the co-integration procedures proposed by Johansen (1988) and the vector error correction model of Engle and Granger (1987), he finds that public expenditures of federal and states governments have significantly positive impact on HC in Nigeria. Krueger and Lindahl (2001) argue that education has positive effect on EG mainly for countries with low education levels. Engelbrecht (2003) investigates the impact of HC on EG for Organization for Economic Co-operation and Development (OECD) countries. He finds that HC has a positive effect on EG for the sample of OECD countries under study. Jorgenson and Fraumeni (1992) examined the relation of HC to EG for the United States for the time period from 1948 through 1986. They find that HC has positively significant effect on EG for the United States.

De la Fuente and Domenéch (2000), using their own compiled data, find that changes in educational attainment have significantly positive effect on EG for OECD countries. Benhabib and Spiegel (1994), using the Cobb–Douglas aggregate production function, examined the relationship between HC and EG. They find that HC is not a determinant of EG, as the regression coefficient on HC is negative and statistically insignificant. They attribute the negative regression coefficient on HC to the fact that most of the countries in their sample, especially those from the continent of Africa, started the period with unusually low stocks of HC.

Pritchett (2001) examined the relationship between EG and HC. He finds that increases in HC do not promote EG for the sample of developing countries under study. Pritchett attributes his finding to the fact that the political and institutional environment could be bad enough that the accumulation of HC weakens EG. He further suggests that the quality of education could be so low that years of schooling fail to create any level of HC. Finally, he maintains that returns on education may have rapidly declined due to an increase in the supply of - and stagnant demand for - educated labor. Mankiw et al. (1992) explore the relationship between EG and HC for a group of 98 countries. They find that HC accounts for approximately 49% of the variations in EG for the countries under study.

Reza and Valeecha (2012) examined the relationship between education and EG for Pakistan using regression analysis. They failed to find supportive evidence that education promotes EG in Pakistan. They attribute their finding on the inability of the Pakistan government to provide employment opportunities for its students. Most students who complete their education fail to secure jobs that would enable them to meaningfully contribute to the national economy. Lack of jobs in Pakistan forces some of its graduates to go abroad in search of employment an opportunity which leads to brain drain in the country. Barro (2001) examined the relationship between education and EG for a group of 100 countries using data running from 1965 through 1995. He finds that EG is positively related to starting level of average years of school attainment of adult males at the secondary and higher levels. He attributes this finding to the fact that educated employees tend to complement new technologies. He, however, did not find similar results between school attainment and EG for females at the secondary and higher levels.

From the preceding literature review, it is apparent that African countries have not received adequate attention with regard to the relationship between EG and HC. Most of the studies in the literature focused attention on the relation of HC to EG in the context of the OECD countries. To this effect, the present study extends the debate on the relationship between HC and EG for a panel of 29 African countries using more recent econometric techniques in panel data approach. Specifically, the study applies the heterogeneous panel causality test proposed by Dumitrescu and Hurlin (2012). This testing procedure is adopted by the study because it has the ability to control for the presence of both heterogeneity and cross-sectional dependence that might be present in the panel.

The remainder of the paper is organized as follows: Following the present introduction, Section 2 discusses the methodology. Section 3 presents the data and empirical results. Section 4 furnishes the conclusions and policy implications of the study.

2. METHODOLOGY

The empirical analysis of the study begins with the application of a battery of cross-sectional dependency tests such as those proposed by Breusch and Pagan (1980), Pesaran (2004) and Pesaran et al. (2008). It is important to account for the presence of cross sectional dependency in the data generating process, as this has implications for the validity of panel unit root and heterogeneous Granger causality test results. For instance, O'Connell (1998) argues that failure to control for contemporaneous correlations between series in a panel could lead to the rejection of the joint unit root hypothesis. The implantation of the Breusch and Pagan (1980) Lagrange multiplier (*LM*) procedure requires the estimation the following panel data model:

$$y_{it} = \alpha_i + \beta' x_{it} + \mu_{it} \tag{1}$$

In Equation (1), y is the depend variable (in our case HC or EG), i represents the cross-sectional dimension, t is the time index, x_{it} represents $k \times 1$ vector of independent variables. α_i and β_i respectively, stand for individual intercepts and the slope coefficients that are permitted to vary across panel members. Under the *LM CD* test, the null hypothesis of no cross-sectional dependence (i.e., H_0: $Cov(u_{it}, u_{ij}) = 0$, for all t and $i \neq j$) is tested against the alternative, H_1: $Cov(u_{it}, u_{jt}) \neq 0$, for at least one pair of $i \neq j$. The *LM* test statistic for cross sectional dependency is calculated as follows:

$$LM = T\sum_{t=1}^{N-1}\sum_{j=i+1}^{N}(\hat{\rho}_{ij}^{2}) \tag{2}$$

In Equation (2), N is the number of cross sections, T is the sample size and $\hat{\rho}_{ij}$ stands for the correlation coefficient between the residuals obtained from individual ordinary least square (OLS) estimations. The test statistic is distributed as $\chi^{n(n-1)/2}$. The LM test statistic is valid in the cases where N is small and T is sufficiently large. To mitigate this shortcoming, Pesaran (2004) proposed a scaled version of the Breusch and Pagan (1980) LM test statistics which is applicable if $T\rightarrow\infty$ and $N\rightarrow\infty$. The scaled version of the LM procedure is as follows:

$$CD_{lm} = \sqrt{T/N(N-1)}\sum_{t=1}^{N-1}\sum_{j=i+1}^{N}(\hat{\rho}_{ij}^{2}) \tag{3}$$

The CD_{lm} statistic is assumed to be asymptotically normally distributed. However, CD_{lm} can be applied when either $T > N$ or $N > T$. Although the CD_{lm} test can be applied even when N and T are large, it however exhibits size distortions in the cases where N is large and T is small. To overcome this weakness, Pesaran (2004) advanced the following test:

$$CD = \sqrt{2T/N(N-1)}\sum_{t=1}^{N-1}\sum_{j=i+1}^{N}(T\hat{\rho}_{ij}^{2}-1) \tag{4}$$

Pesaran (2004) shows that the CD test has exactly mean zero for fixed T and N and that the procedure is robust to heterogeneous dynamic models including multiple breaks in slope coefficients and/or error variances, provided the unconditional means of y_{it} and x_{it} are time-invariant and their innovations have symmetric distribution. The null hypothesis under each of the procedures is that there is no cross-sectional dependence among the members of the panel. The null hypothesis is rejected if the calculated test statistic is greater than the critical value at the conventional levels.

However, Pesaran et al. (2008) have shown that the conventional CD tests tend to lack power, especially when the population average pair-wise correlations are zero while the underlying individual population pair-wise correlations are non-zero. To overcome this drawback, Pesaran, et al. (2008) proposed the bias-adjusted LM test which is given by:

$$LM_{adj} = \sqrt{2/N(N-1)}\sum_{t=1}^{N-1}\sum_{j=i+1}^{N}(\hat{\rho}_{ij})\frac{(T-k-1)\hat{\rho}_{ij}^{2}-\mu_{Tij}}{v_{Tij}} \tag{5}$$

In Equation (6), μ_{Tij} and v_{Tij} represent the exact mean and variance of $(T-k-1)\hat{\rho}_{ij}^{2}$. The LM_{adj} test follows asymptotically standard normal distribution. The null hypothesis under the LM_{adj} is that there is no cross-sectional dependence among the members of the panel.

This paper next applies the panel unit root test proposed by Hadri–Kurozumi (2012). The Hadri–Kurozumi panel test can be implemented in situations where both $T > N$ and $T < N$. The test accounts for cross-sectional dependency that might be present in the panel. It also allows for serial correlation. The null hypothesis under the Hadri–Kurozumi panel test is that the series do not contain unit root. The alternative hypothesis is that the series in the panel are unit root processes. Under the Hadri–Kurozumi panel unit root test, the long-term variance is estimated in two-ways namely — Z_A^{SPC} and Z_A^{LA}. The seemingly unrelated regression technique is used for the Z_A^{SPC} test and as such the bootstrap techniques is used to obtain the test statistic and the associated P value. In the Z_A^{LA} method, t-statistics and P value are taken into account. The Z_A^{SPC} method is preferred over the Z_A^{LA} if there is evidence of cross-sectional dependence in the panel. On the other hand, Z_A^{LA} is preferred over the Z_A^{SPC} technique if there is evidence against cross-sectional dependence in the panel. In the interest of brevity, details pertaining to Hadri–Kurozumi panel unit root test will not be discussed here. However, the interested reader is referred to Hadri–Kurozumi (2012) for detailed description of the procedure.

2.1. Panel Granger Non-Causality Tests

The study applies the panel Granger non-causality test (homogenous non-causality [HNC]) proposed by Hurlin (2004; 2008) and Dumitrescu and Hurlin (2012). The test is implemented under the assumption of no cross-sectional dependency. Nevertheless, the procedure has been shown through Monte Carlo simulations to produce unbiased results even in the presence of cross sectional dependency. The test consists of two distributions namely asymptotic and semi-asymptotic. The asymptotic distribution is valid when $T > N$. On the other hand, the semi-asymptotic distribution is appropriate when $N > T$. The bootstrap critical values, obtained through simulations are used when there is evidence of cross-sectional dependency among the series in the panel.

The Dumitrescu and Hurlin (2012) panel Granger non-causality test is given by:

$$y_{1,t} = \alpha_{1,1} + \sum_{k=1}^{k}\gamma_i^k y_{1,t-k} + \sum_{k=1}^{k}\beta_i^k, x_{1,t-k} + \mu_{i,t} \tag{6}$$

Where, y and x are two stationary series (in our case, EG and HC).

H_0: $\beta_i = 0$ $\quad\forall i = 1, 2, \ldots\ldots\ldots\ldots\ldots N$ with
$\beta_i = (\beta_i^{(1)} \ldots\ldots \beta_i^{(k)})$ (7)

H_1: $\beta_i \neq 0$ $\quad\forall i = 1, 2, \ldots\ldots\ldots\ldots\ldots N$ (8)

$\beta_i \neq 0$ $\quad\forall i = N, +1, N_1 + 2, \ldots\ldots, N$ (9)

Under the HNC, the alternative hypothesis permits some of the individual vectors (β_i) to be equal to zero. The Dumitrescu–Hurlin test involves three average statistics including $W_{N,T}^{HNC}$, $Z_{N,T}^{HNC}$ and Z_N^{HNC}. The average statistic given by $W_{N,T}^{HNC}$ is expressed as follows:

$$W_{N,T}^{HNC} = 1/N\sum_{i=1}^{N}W_{i,T} \tag{10}$$

In Equation (10), $W_{i,T}$ represents the individual Wald statistical values for the cross-sections. The average statistic given by $Z_{N,T}^{HNC}$ has asymptotic distribution which is expressed as follows:

$$Z_{N,T}^{HNC} = \sqrt{N/2K}(W_{N,T}^{HNC} - K)\ \ T, N \rightarrow \infty\ N(0,1) \tag{11}$$

$$W_{i,T} = (T - 2K - 1)\left(\tilde{\varepsilon}_i \varphi_i \tilde{\varepsilon}_i \Big/ \tilde{\varepsilon}_i M_i \tilde{\varepsilon}_i\right),\ i = 1,\ldots\ldots,N \tag{12}$$

The average statistic Z_N^{HNC} has semi-asymptotic distribution associated with the null HNC hypothesis is given by the following expression:

$$Z_N^{HNC} = \frac{\sqrt{N}[W_{N,T}^{HNC} - N^{-1}\sum_{i=1}^{N} E(W_{i,T})}{\sqrt{N^{-1}\sum_{i=1}^{N} Var(w_{i,T})}}\quad N \rightarrow \infty, N(0,1) \tag{13}$$

The existence of cross-sectional dependence among the panel member requires that the 5% critical values simulated from 50,000 replications of the benchmark model and the 5% of the approximated values be utilized.

3. DATA

The data set consists of annual observations on GDP per capita and HC (proxied by index of HC per person, based on years of schooling and returns to education as suggested by Barro and Lee (2010) and Psacharopoulos (1994), respectively. The data were obtained from the Penn World Tables (PWT) version 8 provided by Feenstra et al. (2013). This study adopts the PWT data set because the GDP per capita of the sample countries are expressed in a common currency. Simply put, the PWT estimates of GDP per capita are based on purchasing power parity. The period under consideration runs from 1963 through 2010. The sample countries are Benin, Botswana, Cameron, Central African Republic, Cote d'Ivoire, Democratic Republic of Congo, Republic of Congo, Gabon, Gambia, Ghana, Kenya, Lesotho, Mali, Mauritania, Morocco, Mozambique, Mauritius, Malawi, Namibia, Niger, Rwanda, Senegal, Sierra Leone, South Africa, Tanzania, Togo, Uganda, Zambia and Zimbabwe. The EG variable is calculated as the first differences of the GDP per capita for the various sample countries. To ensure data consistency, the HC variable is expressed as changes in index of HC per person.

4. EMPIRICAL RESULTS

This section discusses the empirical results of the study. Table 1 presents the results from the various cross-sectional dependence tests. The results indicate that the null hypothesis of no cross-sectional dependency across the countries in the panel should be rejected at the conventional levels of significance. For instance, the test statistics for EG are 472.158, −6.196, −4.236, 8.398, respectively for the *LM*, CD_{lM}, *CD*, and the bias adjusted *CD* procedures. These test statistics are statistically significant at the 1% level of significance. Similarly, for HC variable, the *CD* test statistics 449.911, −5.789, 4.044%, and 8.376%, respectively for the *LM*, CD_{lM}, *CD*, and the bias adjusted *CD* procedures reject the null hypothesis of no cross sectional dependence at least at the 10% level of significance. Taken together, these results suggest that the null hypothesis of no cross-sectional dependence should be rejected. These results imply that shocks to either EG or HC in one of the sample countries can be easily transmitted to the other countries in the panel.

To account for the presence of cross-sectional dependencies in the panel, the study implements the Hadri and Kurozumi (2012) panel unit root tests. The results from the Hadri and Kurozumi (20012) procedures are displayed in Table 2. The results suggest that the null hypothesis of stationarity should not be rejected, with the exception of the results from the Z_A^{SPC} test; for HC. The test statistics 0.062 (P = 0.475) and 0.865 (P = 0.194) respectively, for Z_A^{SPC} and Z_A^{LA} are statistically insignificant in the case of EG variable, indicating the acceptance of the null hypothesis of stationarity. For HC variable, the result from the Z_A^{SPC} procedure rejects the null hypothesis while that from the Z_A^{LA} test accepts the stationarity hypothesis. The presence of cross-sectional dependence in the panel implies that the test statistics from the Z_A^{SPC} procedure are the most appropriate for the study.

Having established the order of integration for EG and HC variables, the study explores the existence of long-run relationship between them by applying the Durbin–Hausman panel co-integration test. The Durbin–Hausman panel co-integration test is adopted because it has the ability to control for cross-sectional

Table 1: Cross-sectional dependence test results

Test	Test statistics	P
Panel A: EG		
LM (Breusch and Pagan, 1980)	472.158***	0.013
CD_{lm} (Pesaran, 2004)	−6.196***	0.000
CD (Pesaran, 2004)	−4.236***	0.000
Bias adjusted *CD* test	8.398***	0.000
Panel B: HC		
LM (Breusch and Pagan, 1980)	449.911*	0.065
CD_{lm} (Pesaran, 2004)	−5.789***	0.000
CD (Pesaran, 2004)	−4.044***	0.000
Bias adjusted *CD* test	8.376***	0.000

*** and * indicate the rejection of the null hypothesis of no cross-sectional dependence at the 1% and 10% levels, respectively. EG: Economic growth, HC: Human capital

Table 2: Hadri–Kurozumi panel unit root test results

Variable	Test	Statistic	P value
EG	Z_A^{SPC}	0.062	0.475
	Z_A^{LA}	0.865	0.194
HC	Z_A^{SPC}	5.981***	0.000
	Z_A^{LA}	0.096	0.462

***Indicates the rejection of the null hypothesis of stationarity. EG: Economic growth, HC: Human capital dependencies that might exist among panel members. Furthermore, the test can be applied when $y \rightarrow I(1)$ and $x \rightarrow I(1)$ or I(0). Table 3 displays the results from the Durbin–Hausman co-integration test. The first model, EG is the dependent variable while HC is the dependent variable in the second model. The results from both the group (DH_g) and panel (DH_p) tests reject the null hypothesis of no co-integration between EG and human capita. The test statistics obtained from the equation with EG as the dependent variable are DH_g = 187.725 (P = 0.000) and DH_p = 3.603 (P = 0.000). These test statistics are statistically significant at the 1% level of significance. Similar results are indicated for the model where HC is the dependent variable. These results imply that there is long-run relationship between EG and HC.

To test for causality between EG and HC, this study applies the heterogeneous panel causality test proposed by Dumitrescu and Hurlin (2012). The appropriate lags were determined to be 5 in all of the cases by the Bayesian information criteria. For robustness, the study calculates and reports the results for 5, 6 and 7 lags. Using 5, 6, and 7 lags, the results overwhelmingly reject the null hypothesis of non-causality from EG to HC. For lag 5,

Table 3: Durbin-Hausman panel co-integration test results

Dependent variable	Test	Statistic	P value
EG	DH_g	187.725***	0.000
	DH_p	3.603***	0.000
HC	DH_g	91151.265***	0.000
	DH_p	927.490***	0.000

***Indicates rejection of the null hypothesis of no co-integration at the 1% level of significance. EG: Economic growth, HC: Human capital

Table 4: Dumitrescu–Hurlin panel granger causality test results

Test	EG↛HC	HC↛EG
Panel A: Lags (k)=5		
W^{HNC}	6.508***	7.410***
Z_{NT}^{HNC}	12.837***	20.522***
Z_{N}^{HNC}	1.7878*	3.108***
Panel A: Lags (k)=6		
W^{HNC}	8.464***	10.159***
Z_{NT}^{HNC}	22.979***	38.789***
Z_{N}^{HNC}	2.744***	4.959***
Panel A: Lags (k)=7		
W^{HNC}	10.181***	12.602***
Z_{NT}^{HNC}	32.048***	56.438***
Z_{N}^{HNC}	3.224***	6.083***

***, and * indicate levels of significance at the 1%, and 10%, respectively. The values in parentheses show t-statistics values. The approximated critical values for the average statistic are computed from Equation (30) of Dumitrescu and Hurlin (2012) for the case k=1. The simulated critical values are computed via stochastic simulations with 50,000 replications. EG: Economic growth, HC: Human capital

the test statistics are 6.508, 12.837 and 1.787, respectively for W^{HNC}, Z_{NT}^{HNC} and Z_{N}^{HNC}. These test statistics are significant at least at the 10% level. Similarly, the test statistics 7.410, 20.522 and 3.105, respectively for W^{HNC}, Z_{NT}^{HNC} and Z_{N}^{HNC} suggest that causality runs from HC to EG. The results for 6 and 7 lags corroborate those obtained from the use of 5 lags. Taken together, the results provide supportive evidence of feedback relationship between EG and HC for sample countries. The finding of bidirectional causality between EG and HC is consistent with Awel (2013).

The Granger causality tests are designed to determine which variable causes the other. These tests are not however designed to determine the sign (positive or negative) of the relationship between the variables in the model. To this effect, this study uses the panel-dynamic OLS (PDOLS) method proposed by Mark and Sul (2003) to ascertain the sign of the long-run relationship between economic and HC. The PDOLS framework allows for individual heterogeneity through disparate short-run dynamics, individual-specific fixed effects and individual-specific time trends. The framework also allows a limited degree of cross-sectional dependence through the presence of time-specific effects (Mark and Sul, 2003. p. 656).

Table 5 displays the estimates from the PDOLS framework. Panel A of Table 5 displays the estimates for individual panel members. The results show that the impact of HC on EG and *viz*. varied from country to country. The results show that in all of the cases EG and HC have significantly positive effect on each other. However, these results should be taken with caution as there are obtained from the single-equation DOLS with limited number of observations. In addition, Mark and Sul (2003) point out that the cross-sectional variation in the estimates obtained from single-equation DOLS framework is an indicative of the inherent difficulty in obtaining good estimates rather the evidence of disparate economic behavior. Panel B of Table 5 presents the estimates from the PDOLS. According to the results, EG and HC have significantly positive influence on each other. For instance, in the equation for EG, the coefficient on HC (0.999) is positive and statistically significant at the 1% level. This implies that a unit increase in HC will increase EG by approximately 0.999. Similarly, a unit increase in EG promotes HC by roughly 0.999. Taken together, the results from this study reinforce the importance of HC investment in nascent economies, especially those in the African continent.

5. SUMMARY AND IMPLICATIONS

This paper has used the heterogeneous panel causality approach to ascertain the relationship between EG and human for group of 29 African countries for the time period running from 1963 through 2010. Specifically, the study first tests for the presence of cross-sectional dependence in panel by applying a battery of procedures including Pesaran (2004) CD_{lm}, CD, and the bias adjusted CD test advanced by Pesaran et al. (2008). To determine the order of integration for the two variables, the study employed the Hadri–Kurozumi panel unit root which has the capacity to correct for the

Table 5: PDOLS long-run estimates

Member	Effect of HC on EG		Effect of EG on HC	
	Coefficient	Standard error	Coefficient	Standard error
Panel A: Results for individual panel members				
Benin	1.013***	0.004	0.993***	0.003
Botswana	0.999***	0.003	1.003***	0.002
Central African Republic	0.997***	0.004	1.003***	0.003
Cote d'Ivoire	1.005***	0.003	0.995***	0.002
Cameron	1.005***	0.003	0.997***	0.002
Democratic Republic of Congo	0.999***	0.003	1.001***	0.002
Republic of Congo	0.997***	0.003	1.005***	0.002
Gabon	1.012***	0.003	0.987***	0.003
Ghana	1.004***	0.003	0.992***	0.002
Gambia	1.006***	0.003	0.996***	0.002
Kenya	1.002***	0.003	0.999***	0.002
Lesotho	1.006***	0.002	0.997***	0.002
Morocco	1.000***	0.003	0.996***	0.002
Mali	0.997***	0.003	0.996***	0.002
Mozambique	0.988***	0.003	1.000***	0.002
Mauritania	0.987***	0.003	1.002***	0.002
Mauritius	0.996***	0.003	1.002***	0.002
Malawi	1.001***	0.002	0.999***	0.002
Namibia	0.999***	0.004	1.002***	0.003
Niger	1.012***	0.003	0.987***	0.003
Rwanda	0.990***	0.004	0.999***	0.004
Senegal	0.991***	0.004	1.004***	0.003
Sierra Leone	0.979***	0.004	1.018***	0.003
Togo	1.010***	0.004	0.993***	0.003
Tanzania	1.007***	0.005	0.990***	0.004
Uganda	0.995***	0.004	1.007***	0.003
South Africa	0.989***	0.004	1.010***	0.003
Zambia	0.987***	0.004	1.012***	0.003
Zimbabwe	0.990***	0.004	1.007***	0.004
Panel B: Pooled OLS				
All countries	0.999***	0.001	0.999***	0.001

***Indicates significance at the 1% level. The PDOLS was estimated with 4 lead and lags. Common time effect was also controlled. PDOLS: Panel dynamic ordinary least square, EG: Economic growth, HC: Human capital

presence of cross-sectional dependence among panel members. To examine the long-run relationship between EG and HC, the study implemented the panel co-integration tests advanced by Durbin–Hausman. For Granger causality, the study utilized the heterogeneous panel causality test proposed by Dumitrescu and Hurlin (2012). Finally, to determine the sign of the relationship between EG and HC, the PDOLS technique proposed by Mark and Sul (2003) was applied.

The results from the various *CD* tests indicate that there is evidence of cross-sectional dependence in the panel. The results from the panel unit root tests indicate the EG variable is stationary process while the results for HC were mixed. The results from both the group and panel co-integration tests suggest that the two variables share long-run relationship. In other words, the two variables are found to be co-integrated. The results from the heterogeneous panel causality tests reveal that EG and HC have bidirectional causality. Simply put, EG and HC influence each other. The results from the PDOLS show that EG and HC have significantly positive effect on each other. The results from this study support the notion that educated labor force is crucial in the creation, application, and adoption of new technologies, all of which engender EG. The findings of this study call for the authorities of the sample countries to increase their public expenditures on education.

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