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THE FOURTH INDUSTRIAL REVOLUTION AND ECONOMIC GROWTH IN SUB-SAHARAN AFRICA

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Abstract

This study aimed at investigating the relationship between the fourth industrial revolution proxied by total factor productivity and economic growth in sub-Saharan Africa during the period 1986-2016. To achieve this, static and dynamic models were estimated. This study found that the total factor productivity is not significantly impacted economic growth as expected. This is an indication that the region has not fully tap from industrial revolutions which have transformed many economies across the world. The region needs to maximise its benefits from industrial revolutions by taking advantage of the current technological progress and innovations. The study also found that institutional quality and gross capital formation are crucial to economic growth in sub-Saharan Africa.

Keywords: industrial revolution, economic growth, panel data

1. INTRODUCTION

The world has witness series of industrial revolutions in time past, and their benefits are documented in the literature. For instance, the first industrial revolution that started in mid of the 18th century brought about changes in the techniques of production. Attention was shifted from hand production to machine tools and mechanization as water and steam power became new engines of production. The second industrial revolution came into existence after the discovery of electric and hydroelectric power along with the development of chemical industries. The second industrial revolution brought about new power-generating tools, increasing the potential for industrialization, and increased productivity. Makridakis (2017) stated that it was an industrial revolution noted for mass production, which was made possible by rapid growth in the manufacturing, communication technology, and transportation sectors.

The invention of computers and the internet during the second part of the 20th century contributed to what is referred to as the Third Industrial Revolution. Currently, the attention is shifting towards the fourth industrial revolution all over the world. The main characteristic of the Fourth Industrial Revolution is the massive expansion in the scope of what the machines can do. According to Schwab (2016), the fourth industrial revolution will witness a series of discoveries in areas such as artificial intelligence, machine learning, robotics, and 3-D printing. In recent time, the internet is becoming faster, more accessible, and more mobile while information can easily be manipulated within a short time through the increase in data storage and processing capacity. Autor (2014) and Gibbs (2017) emphasised that computers are becoming increasingly able to perform cognitive tasks thanks to machine learning and artificial intelligence, which allow them to develop and refine their algorithms, expanding the range of automatable tasks beyond routines.

Abdychev et al. (2018) stated that *p*revious industrial revolutions have resulted in an increase in the level of productivity and general improvement of human living conditions over the long term. Before the first industrial revolution, the standard of living was stagnant across the world, and the level of output was very low. However, since that period there has been a significant improvement in the level of output, the level of international trade has been increased, urbanisation has increased, and most of the economies have transformed from agriculture to large scale production industries.

In sub-Saharan Africa, various governments and entrepreneurs are benefiting from the opportunities provided by the current industrial revolution. For instance, there has been a significant improvement in mobile baking in East Africa, and this has provided millions of people the opportunity of having access to financial services. However, the benefits of technology are not limited to finance in Africa. In Mozambique, Biscate is a phone-based recruitment solution for blue collar workers. In South Africa, the medical app Vula Mobile has been launched to connect health workers with specialist care providers for their patients. The internet penetration in Kenya, Nigeria, and Seychelles has increased to 50% which is above the global average. Also as stated by Donou-Adonsou, Lim, and Mathey (2016) that economic growth has been on the increase for the past two decades, the increase in economic growth might be due to technological progress. The relevant of technological progress in the growth process has been analysed in the Solow growth model. Solow (1956) stated that the output per worker depends mainly on savings, population growth, and technological change. Technology has been a significant driver of economic growth around the world for over decades ago. Sub-Saharan Africa is not left out as the new technological advances, such as the internet and mobile networks have enabled the region to be connected to the rest of the world. Both the internet and mobile network make it possible for sub-Saharan African countries to market their products and allows buyers to make informed decisions.

This study empirically examines the relationship between the Fourth Industrial Revolution and economic growth in Sub-Saharan Africa. Specifically, this study will examine the impact of technological progress proxy by total factor productivity on economic growth. Some studies have examined the impact of technology on economic growth in the sub-Saharan region. For example, Chavula (2013) and Donou-Adonsou, Lim, and Mathey (2016) examined technological progress and economic growth in Sub-Saharan Africa but both studies focused on the impact of telecommunications infrastructure. Donou-Adonsou (2018) examined the technology, education, and economic growth in Sub-Saharan Africa. Haftu (2019), on the other hand, examined the relationship between information communications technology and economic growth in Sub-Saharan Africa.

This study contributes to the literature in the following ways. First, this study will fill the gap in the existing literature on the growth impact of the Fourth Industrial Revolution by empirically examining the impact of technological progress on economic growth. Second, rather than focusing on one aspect of technology, this study used total factor productivity (TFP) to measure industrial revolutions as increases in TFP result usually from technological innovations or improvements.

2. THEORETİCAL BACKGROUND AND EMPİRİCAL LİTERATURE

The study by Solow (1956) started the inclusion of technology in the growth model. This was further propelled by studies such as Barro (1991), Barro and Sala-i-Martin (1991, 1992), and Mankiw, Romer, and Weil (1992). All these studies admitted that technological progress is a crucial factor that determines economic growth. After the Solow growth model, there was a new growth theory known as endogenous growth model that emerged which treated technology as an endogenous factor of growth. This is, contrary to the Solow growth model, which earlier treated technology as exogenous. The studies in this line include. Lucas (1988), Aschauer (1989), Romer (1990, 1993), Grossman and Helpman (1991), Aghion and Howitt (1992). For instance, technological progress was considered to depend on human capital by Lucas (1988). Romer's (1990) claimed that the search for new ideas influences technological progress. The author explained that firms which are usually motivated by profit maximisation are investing in research which leads to the invention of new technology. The view of Grossman and Helpman (1991) agrees with Romer's (1990) as they emphasised on innovation and improvement in the quality of the existing products as a catalyst for economic growth. Oliner and Sichel (1994) use the neoclassical framework and incorporate information technology into the growth model. In their model, they show that the growth rate of output depends not only on computing equipment (stock of computers), other types of capital, labor, and multifactor productivity but also on their respective shares of output. Oliner and Sichel (2000) in their study extend the basic model and find that the combination of hardware, software, and communication equipment are accounting for two-thirds of U.S. labor productivity growth in the second half of the 1990s, and communication equipment contributed about 0.1 percentage point annually to output growth.

Even many studies have empirically examined the relationship between technology and economic growth; however, in sub-Saharan Africa, only a few studies can be identified. Donou-Adonsou, Lim, and Mathey (2016) examined the relationship between technological progress and economic growth in sub-Saharan Africa. However, they focused on the role of telecommunications infrastructure in economic growth. The study included 47 countries in the study and covered the period 1993-2012. After using the instrumental variable-generalized method of moments, the study found that both the internet and mobile phones significantly enhanced economic growth. Also, the study concluded that the development of the telecommunications infrastructure is essential as it is a significant determinant of economic growth in the region. Donou-Adonsou (2018) was interested in determining if better access to education will influence the relationship between telecommunications infrastructure and economic growth in sub-Saharan Africa. To achieve the objective of the study, a panel data consisting of 45 sub-Saharan countries which also covered the period 1993 – 2015 were used. The study used fixed effect and two-step feasible efficient generalized method of moments techniques. The study found that the internet promotes economic growth while mobile phone produce otherwise results in the countries that have better access to education. Wamboye, Tochkov, and Sergi (2015) during the period 1975-2010, investigated the kind of relationship that exists between information and communication technologies (ICTs) and labour productivity growth in sub-Saharan Africa. Their results indicated that both the fixed-line and mobile telecommunications positively impact growth after penetration rates reach a certain critical mass.

2.1. Methodology Model and Data

This study adopts the cross-country growth model by Barro (1991) which has been modified to accommodate technology. The modified model has been used by Datta and Agarwal (2004), Chavula (2013), Donou-Adonsou et al. (2016) and Donou-Adonsou (2018). The following dynamic panel data model is estimated.

$$GDP_{i,t} = \alpha_i + \beta_1 GDP_{i,t-1} + \beta_2 TECH_{i,t} + \beta_3 INF_{i,t} + \beta_4 GCF_{i,t} + \beta_5 DEMO_{i,t} + \epsilon_{i,t} \quad (1)$$

From the equation (1), GDP is the real GDP per capita in the country i = 1, 2, …., N (N refers to the total number of countries included in the model), t = 1, 2, 3….., T (T represents the total of years). $GDP_{i,t-1}$ is the initial GDP which is expected to be consistent with the convergence hypothesis which states that the higher levels of initial GDP tend to lower growth as a result of the diminishing returns to capital. TECH represents technology which is proxy by total factor productivity. Based on the importance of technology in the growth process, its coefficient is expected to positively impact economic growth. GCF is the gross capital formation. Gross capital information aid productivity, therefore a positive relationship is expected with economic growth. DEMO represents democracy accountability. This is included as an institutional variable. Several pieces of literature, like Acemoglu and Robinson (2008), Acemoglu (2009) and Rodrik (2007) have emphasised the importance of institutions to economic growth. Therefore, democracy accountability is expected to have a positive impact on economic growth. INF is inflation. Due to the inability of governments in sub-Saharan African countries to keep the rate of inflation low over the years, inflation is expected to have a negative impact on economic growth. $\epsilon_{i,t}$ is the error term.

Equation (1) is estimated using the static estimators and dynamic GMM.

3. DATA AND DESCRİPTİVE STATİSTİCS

Data on real GDP per capita (constant 2010 U.S. dollars), technology, gross capital formation, inflation, and democracy accountability are obtained from World Development Indicators (World Bank 2019). This study covers 38 sub-Saharan African countries out of possible 48 and span through the period 1986–2016. The exclusion of some countries is due to unavailability of data. Some of the sub-Saharan African countries have ravaged by the war in time past, and this makes data unavailable. The descriptive statistics of the variables are presented in Table 1.

Table 1 Definition of variables and summary of statistics

Variables	Definition of Variables	Obs.	Mean	St. Dev.	Source
GDP per capita	GDP per capita, constant 2010 US$	1136	1.482	7.3875	WDI
GCF	Gross capital formation (% of GDP)	1107	1.249	0.258	WDI
DEMO	Democracy Accountability	863	2.965	1.163	ICRG
TECH	Total factor productivity	1140	0.568	0.269	PWT
INF	Inflation, consumer prices (annual %)	974	0.906	0.642	WDI

Note: WDI stands for World Development Indicators, PWT stands for Penn World Table and ICRG represents International Country Risk Guide

Source: Authors calculation

4. RESULTS AND DİSCUSSİON

Before the estimation of the relationship between technology and economic growth in sub-Saharan Africa, there is a need to examine the stationarity property of the variables. This is necessary to avoid spurious results. Therefore, unit root test is conducted using Levin et al. (2002), Breitung's (2000) t-statistic, Im et al. (2003), and the ADF- and PP-Fisher Chi-square (Maddala and Wu 1999). The results of the unit root test are presented in Table 2.

From the unit root test results in Table 2, aside from technology, all other variables are stationary at levels. The only exception is PP-Fisher test, which shows that democracy accountability is not stationary at levels. However, at first difference, all the variables are certified stationary by all the tests except Breitung test, which indicated that technology is not stationary at first difference.

Table 2 Panel Unit Roots Tests

Variables	LLC	IPS	ADF-Fisher	PP-Fisher	Breitung
lnGDP	-7.905***	-10.913***	257.295***	906.192***	-6.949***
ΔlnGDP	-15.345***	-25.295***	601.174***	5527.21***	-12.130***
lnGCF	-3.716***-	-2.937***	114.533***	130.150***	-2.883***
ΔlnGCF	12.912***	-17.752***	411.317***	1898.32***	-11.741***
lnINF	-2.754***	-2.635**	150.673***	215.630***	-2.211**
lnΔINF	-13.337***	-12.982***	-354.915***	1980.16***	-8.573***
lnTECH	-0.962	2.016	40.947	51.583	6.747
lnΔTECH	-0.832***	-7.322***	147.890***	751.724***	3.751
DEM	-3.559***	-3.004***	89.813**	38.663	-5.339***
ΔDEM	-12.094***	-17.005***	89.813***	320.773***	-17.005***

Note: ***, ** and * denotes 1%, 5% and 10% respectively.

Source: Author's calculation

Table 3 presents the results of the three static estimates of the panel data. In the table and subsequent tables, GCF is the gross capital formation, INF represents inflation, TECH indicates technology, DEMO is the democracy accountability. The first column of Table 3 consists the variables while the second, third and fourth columns contain the results of pooled OLS, fixed effect, and random effect respectively. In the pooled OLS, gross capital formation has the expected sign and significant at 1%. The coefficient of inflation is negative and significant as expected. Technological progress has a negative sign and insignificant. Therefore, we cannot draw a conclusion. Democracy accountability significantly impacted economic growth as its coefficient is positive. In the fixed effect estimation, gross capital formation has a positive sign and significant. Inflation and technology negatively impact economic growth while democracy accountability has a positive impact on economic growth. The result of the random effect is not different from the earlier estimations. The coefficients of the gross capital formation and democracy accountability are positive and are statistically significant at 1%. Inflation and technology have negative signs. However, while the coefficient of inflation is significant at 1%, the coefficient of technological progress is not significant. Hausman test provides prob > chi2 = 0.0002 indicating that the fixed effect estimation is preferable to random effect. This implies that the fixed effect result is preferred to explain the relationship between technological progress and economic growth. The Lagrange Multiplier test produce a prob > chi2 = 0.0000, which specifies that the random effects result is better than that of ordinary least squares. The Wooldridge test for autocorrelation is not significant, which indicates that the estimations are free from serial autocorrelation.

Table 3 Results of Static Panel Data

Dependent Variable: GDP per capita	Pooled OLS	Fixed Effect	Random Effect
C	-5.223*** (0.000)	-3.634** (0.016)	-4.601*** (0.000)
GCF	4.854*** (0.000)	3.922*** (0.000)	4.367*** (0.000)
INF	-0.548** (0.042)	-1.423*** (0.000)	-0.857*** (0.003)
TECH	-0.284 (0.686)	-1.103 (0.436)	-0.411 (0.629)
DEM	0.362** (0.020)	0.646*** (0.001)	0.472*** (0.005)
R^2	0.09	0.14	0.22
Hausman test			0.0002
LM			0.0000
WA			0.2227
No of countries	38	38	38
No of observations	713	713	713

Note: ***, ** and * denotes 1%, 5% and 10% respectively. WA stands for Wooldridge Autocorrelation test.

Source: Author’s calculation

However, in order to provide a robust check for the panel static estimations, this study employs dynamic GMM to further investigate the relationship between technological progress and economic growth in sub-Saharan Africa. The result of the dynamic GMM is presented in table 4. The first column consists of the explanatory variables. These include initial GDP per capita, gross capital formation, inflation, technology and democracy accountability. The second column of the table consists of the one-step difference GMM. The initial GDP per capita has a positive impact on the current GDP per capita. The coefficient of gross capital formation is positive and statistically significant at 1%. Inflation negatively impacted economic growth at 1% level of significance. The variable of interest, which is technological progress is negative but not significant, while the coefficient of democracy accountability is positive as expected and statistically significant.

Regarding the diagnostic tests, the first order autocorrelation admits the existence of autocorrelation while the second order autocorrelation is rejected. The Sargan test is significant which implies that the null hypothesis is not rejected and hence the general instruments used is not valid. The third column of Table 4 presents the result of the estimation of two-step difference GMM. Contrary to column one, the initial GDP per capita has a negative sign but not significant at any levels. The coefficients of gross capital formation and democracy accountability are positive. However, the coefficient of gross capital formation is not significant while democracy accountability is significant at 10%. Inflation and technology have an inverse relationship with economic growth. Like in column 2, the first order autocorrelation is not rejected and the second order autocorrelation is rejected. The Sargan test does not reject the null hypothesis which means that the model specification is not supporting the general validity of the instruments. Column 4 of Table 4 consists of the result of the system GMM in one step. The coefficient of initial GDP per capita has a positive impact on the current GDP per capita and statistically significant at 1%. Gross capital formation and democracy accountability are significantly impacted economic growth as their coefficients are positive. The sign of the coefficient of technology is negative like in previous models. However, its coefficient is not significant. Inflation produces a negative impact on economic growth. The diagnostic tests confirm that the model is valid. For instance, the null hypothesis of no first-order autocorrelation is rejected at 1% significance level as expected. However, the second order autocorrelation is rejected. The Sargan test is not significant. This implies that the instrument used in the estimation is valid and the validity of the instruments is an indication that the model is correctly specified. The fifth column presents the result of the two-step system GMM. From the model, the initial GDP per capita is positive and significant and 5%. The gross capital formation and democracy accountability show a positive sign and significant at 1% and 5% respectively. Technology is positive but insignificant while inflation is negative. Like in column 4, the diagnostic tests confirm the validity of the model. As expected, the first order autocorrelation is not rejected while the second order autocorrelation is rejected. The Sargan test indicates the validity of the instrument.

The one-step system GMM and two-step system GMM estimates are preferred, and more appropriate than other estimates judge by the various diagnostic tests. Therefore, they are the models that will be used to explain the impact of technological progress on economic growth since they are the best fitting models. The positive impact of initial GDP per capita on current capita is contrary to neoclassical growth theory perspective, where a negative relationship is expected as a result of the convergence hypothesis. But Donou-Adonsou (2018) explained that the convergence hypothesis might not hold due to rapid technological progress, which can continuously shift the production function by increasing productivity in several ways. The insignificant effect of technological progress on economic growth in both the static and dynamic models is not surprising as Michael (2018) stated that total factor productivity is abysmal in sub-Saharan Africa as the region has yet to take the full advantage of the industrial revolutions. The dominance of the informal sector in sub-Sahara African countries is a hindrance to the significant impact of technological progress in the region. The informal sector is generally characterised by small and micro enterprises such as petty-trading, food-sellers, craftsmanship, small-holder farming, and small agro-processing businesses according to Potts (2008), Osei-Boateng and Ampratwum (2011) and Herrera et al. (2012) and hence, does not permit the use of advanced technology which can boost the productivity in the economy. Another reason for the insignificant impact of technological progress on economic growth can be the poor government investment and involvement in technology adoption. Amankwah-Amoah, Osabutey, and Egbetokum (2018) emphasied that governments' policy in sub-Sahara Africa have failed to chart innovation and technology trajectories and the lack of innovation and technology prioritisation in national development policy framework will limit the impact of technological progress. To this effect, there is the need for the region to maximise the benefit of technology and innovations as well as exploiting technological catch-up through the combination of different existing technologies and adapting them in such a way to promote economic growth. Though the coefficient of inflation is negative but it is insignificant in dynamic estimations; however in static models, it is significant. Studies like Kodongo and Ojah (2016) and Zahonogo (2017) also found a significant negative impact of inflation on economic growth in sub-Saharan Africa. The institutional quality variable which is democracy accountability is significantly impacted economic growth. This is an indication that institutional quality matter for economic growth in sub-Saharan Africa. The significant positive impact of gross capital formation on economic growth from both the static and dynamic GMM is consistent with several theoretical arguments and empirical studies. Studies like Perkins, Roemer Gillis, and Snodgrass (1987), King and Levine (1994) and Easterly and Levine (2001) concluded that the rate of capital formation is a significant determinant of economic growth of an economy. Harrod (1939) declared that for any country to experience growth and development, it must invest in capital formation through the diversion of current consumption for capital formation.

Table 4 Technological Progress and Economic Growth

	Difference GMM (One step)	Difference GMM (Two steps)	System GMM (one step)	System GMM (two-step)
GDP_{-1}	0.039 (0.348)	-0.087 (0.445)	0.261*** (0.000)	0.183* (0.079)
GCF	4.791*** (0.000)	3.797 (0.110)	3.751*** (0.000)	7.263** (0.032)
INF	-1.393*** (0.000)	-0.955 (0.076)	-0.352 (0.169)	-0.439 (0.409)
TECH	-1.009 (0.592)	-6.340 0.257	-0.063 (0.925)	0.621 (0.910)
DEM	0.709*** (0.003)	1.637* 0.079	0.293** (0.049)	1.974** (0.074)
AR(1)	0.000	0.022	0.000	0.013
AR(2)	0.856	0.458	0.369	0.539
Sargan Test	0.003	0.003	0.606	0.103
No of countries	38	38	38	38
No of observations	619	619	694	694

Note: ***, ** and * denotes 1%, 5% and 10% respectively.

Source: Author's calculation

4. IMPLICATION AND CONCLUSION

In this study, we examined the relationship between the Fourth Industrial Revolution (technological progress) proxied by total factor productivity on economic growth in sub-Saharan Africa. The evidence from this study shows that technological progress does not significantly impact economic growth in sub-Saharan Africa during the study period. This is might be due to the inability of the region to take the full advantage of the industrial revolutions which has significantly transformed the economies of the developed countries. Evidence from the previous industrial revolutions has also shown that industrial revolutions lead to increase in productivity and economic growth in which this study cannot establish in case of sub-Saharan Africa. The implications of this is that for sub-Sahara African countries to benefit from the Fourth Industrial Revolution, they must look into the followings. First, in line with Ayentimi and Burgess (2018) the government must reorganise the educational system to be able to produce the workforce that will possess the necessary skill sets needed to meet the skills demand of the Fourth Industrial Revolution. Second, the governments must strengthen the available infrastructure and as well and spread services and infrastructure across the countries, particularly the rural areas for the smooth take-off of the Fourth Industrial Revolution. Third, different policy approaches that will focus on the key capacity building services of high quality of education, training, health, small businesses, agriculture, energy, satellite technology must be adopted to improves the capacity to realise the benefits of the Fourth Industrial Revolution in the sub-Saharan African region.

REFERENCES

Abdychev, A. Alonso, C. Alper, E,. Desruelle, D., Kothari, S., Liu,Y, Perinet, M., Rehman, S., Schimmelpfennig, A and Preya Sharma (2018) The Future of Work in Sub-Saharan Africa. No. 18/18.

Acemoglu, D, and Robinson, J. A. (2008). "The Role of Institutions in Growth and Development." Working Paper 10. Washington: World Bank, Commission on Growth and Development.

Acemoglu, D. (2009) *Introduction to Modern Economic Growth* Princeton: Princeton University Press.

Acemoglu, Daron. (2009). Introduction to Modern Economic Growth. Princeton, NJ: Princeton University Press

Aghion, P., & Howitt, P. (1992). A model of growth through creative destruction. Econometrica, 60(2), pp.323–351.

Amankwah-Amoah, J., Osabutey, E.L.C and Egbetokum, A. (2018). "Contemporary Challenges and Opportunities of Doing Business in Africa: The Emerging Roles and Effects of Technologies." Technological Forecasting and Social Change 131: 171–174.

Aschauer, D. A. (1989). Is public expenditure productive? Journal of Monetary Economics, 23(2), pp.177–200.

Autor, D (2014). "Polanyi's Paradox and the Shape of Employment growth." NBER Working Paper 20485, National Bureau of Economic Research, Cambridge, MA.

Ayentimi, D. T & Burgess, J. (2018): Is the fourth industrial revolution relevant to sub-Sahara Africa? Technology Analysis & Strategic Management, 31(6), 641-652.

Barro, R. J. (1991). Economic growth in a cross-section of countries. Quarterly Journal of Economics, 106(2), pp.407–443.

Barro, R. J., & Sala-i-Martin, X. (1991). Convergence across states and regions. Brookings Papers on Economic Activity, 1991(1), pp.107–182.

Barro, R. J., & Sala-i-Martin, X. (1992). Convergence. Journal of Political Economy, 120(21), pp.364–386.

Breitung J (2000) The local power of some unit root tests for panel data. In: Baltagi B (ed) Advances in econometrics, vol. 15: nonstationary panels, panel cointegration, and dynamic panels. JAI Press, Amsterdam, pp 161–178

Chavula, H. K. (2013). Telecommunications development and economic growth in Africa. Information Technology for Development, 19(1), pp.5–23.

Datta, A., & Agarwal, S. (2004). Telecommunications and economic growth: a panel data approach. Applied Economics, 36(15), pp.1649–1655.

Donou-Adonsou, F (2018). Technology, education, and economic growth in Sub-Saharan Africa. https://doi.org/10.1016/j.telpol.2018.08.005

Donou-Adonsou, F., Lim, S., & Mathey, S. A. (2016). Technological progress and economic growth in sub-Saharan Africa: Evidence from telecommunications infrastructure. International Advances in Economic Research, 22(1), pp.65–75.

Donou-Adonsou1, F., Sokchea Lim, S and Mathey, S. A (2016). Technological Progress and Economic Growth in Sub-Saharan Africa: Evidencefrom Telecommunications Infrastructure. Int Adv Econ Res (2016) 22:65–75

Easterly, W., and R. Levine. 2001. "What Have We Learned from a Decade of Empirical Research on Growth? It's not Factor Accumulation: Stylized Facts and Growth Models." The World Bank Economic Review 15 (2): pp.177–219

Gibbs, M. (2017). "How is New Technology Changing Job Design?" *IZA World of Labor* 344.

Grossman, G., & Helpman, E. (1991). Innovation and growth in the global economy. Cambridge, MA: MIT Press.

Haftu, G. G (2019). Information communications technology and economic growth in Sub-Saharan Africa: A panel data approach. *Telecommunications Policy* Vol.43(1), pp.88-99.

Harrod, R. F. (1939). "An Essay in Dynamic Theory." The Economic Journal 49 (193): pp.14–33.

Herrera, J., Kuépié, M, Nordman, C.J, Oudin, X and Roubaud. F (2012). "Informal Sector and Informal Employment: Overview of Data for 11 Cities in 10 Developing Countries." Wiego Working Paper No 9. http://www.wiego.org/ sites/wiego.org/files/publications/files/Herrera_WIEGO_WP9.pdf.

Im KS, Pesaran H, Shin Y (2003). Testing unit roots in heterogeneous panels. J Econom 115, pp.53–74

King, R. G., and R. Levine. (1994). "Capital Fundamentalism, Economic Development, and Economic Growth." Carnegie-Rochester Conference Series on Public Policy 40, pp.259–292.

Kodongo, O and Ojah, K. (2016). Does infrastructure really explain economic growth in Sub-Saharan Africa? Review of Development Finance 6 (2016) pp.105–125

Levin A, Lin C-F, Chu C-SJ (2002). Unit root tests in panel data: asymptotic and finite-sample properties. J Econom 108(1):pp.1–24

Lucas, R. E. (1988). On the mechanics of economic development. Journal of Monetary Economics, 22(1), pp.3–42.

Maddala Gangadharrao Soundalyarao, Wu Shaowen (1999) A comparative study of unit root tests with panel data and a new simple test. Oxf Bull Econ Stat 61, pp.621–652

Makridakis, S. (2017). "The Forthcoming Artificial Intelligence (AI) Revolution: Its Impact on Society and Firms." Futures 90:46–60.

Mankiw, G., Romer, D., & Weil, D. (1992). A contribution to the empirics of economic growth. Quarterly Journal of Economics, 107(2), pp.407–437.

Michael, Y. (2018) The Determinants of the Level and Growth of Total Factor Productivity in Sub-Saharan Africa in A. Heshmati (ed.), *Determinants of Economic Growth in Africa*. Palgrave Macmillan imprint is published by the registered company Springer International Publishing AG part of Springer Nature, pp.199-236

Oliner, S. D., and Sichel, D. E. (1994). Computers and output growth revisited: How big is the puzzle? Brookings Papers on Economic Activity, 1994(2), pp.273–334.

Oliner, S. D. and Sichel, D. E. (2000). The resurgence of growth in the late 1990s: Is information technology the story? The Journal of Economic Perspectives, 14(4), pp.3–22.

Osei-Boateng, C., and Ampratwum, E. (2011). The Informal Sector in Ghana. Accra: Friedrick Ebert Stiftung-Ghana office. http://library.fes.de/pdffiles/ bueros/ghana/10496.pdf.

Perkins, D.W., M. Roemer Gillis, and D.R. Snodgrass. 1987. Economics of Development, 2nd ed. W.W. Norton.

Potts, D. (2008). "The Urban Informal Sector in sub-Saharan Africa: From bad to Good (and Back Again?)." Development Southern Africa 25 (2): 151–167.

Psacharopoulos, G. (1994). Returns to investment in education: A global update. World Development, 22(9), pp.1325–1343.

Rodrik, D. (2007) *One Economics Many Recipes: Globalization, Institutions, and Economic Growth* Princeton: Princeton University Press.

Rodrik, Dani. 2007. One Economics, Many Recipes: Globalization, Institutions, and Economic Growth. Princeton, NJ: Princeton University Press.

Romer, P. (1993). Idea gaps and object gaps in economic development. Journal of Monetary Economics, 32(3), pp.543–573.

Romer, P. M. (1990). Endogenous technological change. Journal of Political Economy, 98(5), pp.71–102.

Schwab, Klaus. 2016. *The Fourth Industrial Revolution*. New York: Crown Publishing Group.

Solow, R. (1956). A contribution to the theory of economic growth. Quarterly Journal of Economics, 70(1), pp.65–94.

Wamboye, Tochkov, and Sergi (2015). Technology Adoption and Growth in sub-Saharan African Countries. Comparative Economic Studies 57(1), pp.136-167.

Zahonogo, P (2017) Trade and economic growth in developing countries: Evidence from sub-Saharan Africa. Journal of African Trade 3 (2016), pp. 41–56