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The Role of Endogenous Technology in Making Sustained Economic Growth in Sub–Saharan Africa: Panel GMM and VECM Approaches

Urgaia R. Worku

Ambo University, Ethiopia

E-mail: urgaia.rissa@gmail.com

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Abstract

This study examines the role of endogenous technology in making sustained economic growth in a panel of 36 Sub-Saharan Africa (SSA) countries over the period 1990-2020. We derive total physical capital, total employment productivity (TEP), total factor productivity (TFP) and terms of trade (TOT) growth rates using various concepts. In this sense, the panel of short-run vector error correction model (VECM) and panel of long–run generalized method of moments (GMM) are applied and the estimation results are obtained. The empirical results reveal that there are significantly positive impacts of the growth rates of TFP, TEP and terms of trade (TOT) on real GDP growth rate in the long -run. These are profoundly important indicators for SSA today that timely using endogenous technology can play the central role in succeeding economic growth. And hence, without a greater supply of home–grown talent in the areas of the economic sector, it may be hard to break down the vicious circle of poverty, build prosperous, inclusive and resilient economies that can be feeding the people and enabling the countries to compete with trade globally.

Keywords: Economic growth, Panel VECM, GMM, SSA

JEL Classification Number: C33, O15, O47 & O55.

1. Introduction

Sub-Saharan Africa (SSA) is a region consisting of 49 states, including South Africa. It is a habitat to more than one billion people, a diverse sub-continent offering potential human and natural resources. The region has a potential to make sustainable and inclusive economic growth. However, as the economy is characterized by subsistence and aid dependence (IMF 2013), many of the countries in the region are based on commodity exports, making them bound to the ups-and-downs of global commodity prices. Even trade among SSA countries makes up an insignificant proportion of the region's total commerce, adding to the poor infrastructure investments, which represent the most significant limitations to economic growth (Christian, 2011). For the region, there is no option to take a step forward to make strong, viable and inclusive economic growth so as to improve the living standards of the people.

The importance of long-run economic growth over time, even small rates of growth has large effects (Worku, 2016). The small difference in economic growth rates among countries result in very different living standards if that difference continues for many years (DFID, 2004). In this regard, because of many factors such as economic stagnation and limited factor of production, the African continent in gerela and the Sub-Saharan (SSA) Africa in particular lagged behind for many years now.

As human beings, people who live in SSA must deserve better living standards and this can be achieved by making the economy inclusive and sustained growth through total factor productivity. Encouraging total factor productivity is extremely important for achieving the designed targets of the 2030 Agenda for Sustainable Development Goals (SDGs). One of the targets in SDGs is poverty reduction. The poverty reduction in SSA countries can be addressed by enhancing inclusive sustainable economic growth (World Bank, 2001 and UNRISD, 2010). This target is different from the late 19th and early 20th centuries in Germany and Great Britain used to target the working classes for maintaining the living standard.

For the individual, societies and economies, investing in human capital is essential in the context of shifting population dynamics and utilizing limited resources (World Economic Forum, 2013). From this premise, what we have drawn is that better educated people are more likely to innovate, adopt new technology and better productivity than less educated ones according to the studies by Lucas (1993) and Romer (1993). Advances in technology by human capital resources, education and incomes hold ever-greater promise of long, healthy and more secure lives (UNHP, 2014). Mobilizing savings and allocating resources to the most productive investments results in a more efficient allocation of resources, more rapid accumulation of physical and human capital, and faster technological progress (Samargandi, Fidrmuc, & Ghosh, 2015).

From the background of this study, what we understand about the major determinants that influence economic growth, are the implementation of economic policies and commitment of the governments depending on the level of development achievement at different levels. In this framework, since the statement of works by Adam Smith to the present day, many researchers have tried to find out the most important determinants of growth by formulating new models and improved theories, there is still no common consensus on the key determinants of growth and all-encompassing model (Boldeanu & Constantinescu, 2015).

The multidimensional assessment of endogenous technology is increasingly recognized as playing an important role in making better well-being. It is based on the quality of education and the relationship with public social spending whether the 2030 Agenda for Sustainable Development will be achieved or not (Paliova, McNown, & Nulle, 2019). The developments and changes in the social life have led to change in the social needs aiming to solve social problems and ensure prosperity through social policies for inclusiveness (Aravacik, 2018).

Making an introduction part of the study consistent with related literature review; we make the research hypothesis and statement of the problem as follows. In line with the research hypothesis; the better use of intensive endogenous technologies for the production of goods and services with high quality and quantity, the more magnificent and continual real GDP growth rate will be produced, thereby enhancing the living standard for the people. This enables the countries to create more additional jobs and income generation which give them a greater role in positions internationally in terms of trade. In the statement, we try to make this study a unique approach to the short-run and long-run economic analysis dynamically using panel VECM and GMM both theoretically and empirically important.

From the theoretical point of view, we are able to reveal that the only way for economic growth to be strong enough and inclusive for millions of lives to benefit, if and only if the endogenous technology is applied. This is helpful to break down the vicious circle of poverty by encouraging endogenous technological applications to the work in productive economic sectors through total factor productivity, total employment productivity, creating a conducive environment for attracting foreign direct investment toward the economy and making the economy more open to the rest of the world to trade. Therefore, in this study, as a new contributor, we try to make a unique economic analysis by taking total factor productivity as a proxy for endogenous technology and a main factor for continually increasing real GDP.

Again from the methodological aspect, we try to identify the key contributing factors of economic growth and its appropriate model, by deriving various types of formulas to generate the variables we undertake. In this sense, we intend to make a methodological contribution to the economic analysis by designing a new approach; panel vector error correction model (VECM) and panel generalized method of moments (GMM) in the spirit of dynamics with very helpful derived variables. We begin with data to set up, with transformed original data into a demeaned dataset to make sure the non–violating econometric classical assumptions such as cross–sectional independence. In fact at each stage before estimation coefficients generated, we have checked these and others with the help of their respective standard methods of tests. By these approaches we apply for the bivariate analyses by extending the standard method of the panel multivariate to ensure the dynamic inter–temporal causal effects in short-run and long–run.

Therefore, these kinds of economic analyses are new which make our study different as far as we have never seen such work published elsewhere prior to this study. Hence, we have added an important new insight as a contribution to the development of existing knowledge about economic analysis. The purpose of this study is to examine whether the application of endogenous technology in productive economic sectors through total factor productivity makes strong sustainable and inclusive economic growth for changing the lives in SSA in the framework of the 2030 Agenda for Sustainable Development Goals. While the general objective is to investigate whether the contribution of endogenous technology ensures sustained economic growth in the region. The study conducted in this area is of the most significant one. It helps to provide concrete and tangible information for the policymakers to take some actions. It also serves as a foundation that can motivate other researchers to conduct further studies.

2. The Related Literature Reviews

While doing this research study, we have seen many empirical studies which explain several factors affecting economic growth. These included first, growth rates vary in various countries over a long period due to economic policies, institutions and national characteristics Barro and Sala-i-Martin (2003). Second, economic growth has been credited to the level of human capital Mankiw, Romer, and Wei (1992). Third, growth has a positive effect on investment in human capital that would take place in economic activities Barro (1996). Fourth, political and institutional aspects could play an important role in advancing growth as suggested by Petrakos and Arvanitidis (2008).

Recent empirical studies have shown that the determinants of economic growth are of great importance. For instance, investment in both physical and human capital was necessary for economic growth in middle-income developing countries (Dewan & Hussein, 2001). In addition, Gylfason and Hochreiter (2008) explained that good governance, institutional reforms and improvements in the educational system could play a more important role in raising economic output and efficiency.

Very recently, some researchers have tried to estimate the effect of labour, human capital and technology on economic growth within the framework of social protection. These include, Stefan (2016); Alam, Sultana, & But (2010); Sezer and Abasiz (2016); Murshed, Badiuzzaman, and Pulok (2017) and Zhang, Zou, and Sha (2019). In this regard, a positive relationship between education and growth showing, higher values of employment rate by tertiary education (see Stefan, 2016). Study by Alam, Sultana, and Butt (2010) suggested the long run relationship between social expenditures and economic growth has enhanced productivity by providing infrastructure, education and harmonizing private and social interests.

The level of human development in Sub–Saharan Africa region is low, even though there has been a rapid growth of some aspects of human capital, in terms of the expansion of education in recent times. The expansion of the human capital stock itself has not been matched by a commensurate rise in physical capital due to the low level of income growth and the low returns to the education investment (Simon & Francis, 1998).

It has been argued that in the 1950s and 1960s, most of Asian economies were destined for prolonged poverty, while Africa's independence encouraged great optimism (Michael, 2011). However, the South East Asian economic performance has given rise to a large literature studying the growth 'miracle', whereas the Sub-Saharan African has attracted attention for the opposite reason that the failure of many countries to sustain per-capita income growth after the 1970s (Robin, 2011). A sustained improvement in Sub–Saharan Africa human development was found to be the lowest level in the world (UNDP, 1997, 2013 and World Economic Forum, 2013).

One of the effects of the conditional convergence term is that the growth rate rises when the initial level of real per capita GDP is relatively low compared to the starting amount. In this regard, based on panel GMM for the panel of nineteen Sub–Saharan countries from the year 1982–2000, the empirical study by Ndambiri et al. (2012) indicated that physical capital and human capital formation were substantial contributors to economic growth. “One of the policy tools that has received a growing recognition in the success of developing human capital is necessary for Uganda to sustain its economic growth rate is social protection. Similar needs across Sub-Saharan Africa, social protection programmes for sustained economic growth, expanded both in scope and coverage that can play a vital role in addressing the development issues” (UNICEF, 2016, p. 106).

The economic impact of the COVID-19 shock in SSA has been severe, falling real GDP by around 1.66% compared to the previous year (O'Neill, 2020). In addition, in recent years, despite the fact that some fastest growing economies such as Ethiopia and Ghana have remarkable registered GDP, wealth and income inequalities remain heavily concentrated in the hands of few people.

Economic growth is an increase in the value added of goods and services produced over time at a fixed price adjusted to curb inflation. This is conventionally measured as real GDP growth (IMF, 2012). The importance of long-run economic growth over time, even small rates of growth has large effects (Worku, 2016). The small difference in economic growth rates among countries result in very different living standards if that difference continues for many years. For example, a greater increase in GDP along with better living conditions in the United Kingdom has continually increased in economic growth of nearly two percent on average annually over one hundred seventy-eight years to date (DFID, 2004).

Currently, there are a number of mechanisms for sustained economic growth to be created in various nations with policies and instruments vary according to their context. For instance, in South Korea and Taiwan, governments provide extensive support for public programs, following the developmental model that social protection has been used as a tool to promote economic growth (Kwon & Huck-Ju, 2009). According to Lo and Barbeito (1998) and Ocampo and José (2008), in Argentina, Brazil and South Africa, there is a dualist structure of protected formal sector workers and marginalized informal sector workers by their governments. Another one is in countries where the agrarian sector largely dominates the economy, support is mainly provided by non-governmental organizations and individual charitable donations (UNRISD, 2010) for enhancing economic development whenever properly used.

In summary, this study tries to explain the complementarities between total factor productivity and other factors that potentially affect economic growth. Even though the issue has been quite known for many years, no one attempts it as a solution for developing countries. The related empirical studies help us to identify the key concepts for our underpinning to economic analyses.

3. Methodology of the Study

This study uses unbalanced macroeconomic annual data obtained from the UN aggregate databases, World Bank development indicators and International Monetary Fund economic outlook for the surveys ranging from the year 1990–2020 for the selected 36 panel countries in Sub Saharan Africa. These include a group of countries in a panel for this study are Angola, Benin, Botswana, Burkina Faso, Burundi, Cabo Verde, Cameroon, Central African Republic, Chad, Congo Democratic Republic, Congo Republic, Côte d'Ivoire, Equatorial Guinea, Eswatini, Ethiopia, Gabon, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Madagascar, Malawi, Mali, Mauritius, Mozambique, Namibia, Niger, Nigeria, Rwanda, Senegal, South Africa, Tanzania, Togo Uganda and Zambia.

In defining and measuring the variables as well as model specifications, firstly we use the perpetual inventory method of Berlemann and Wesselhoft (2014). Under perpetual inventory method, the net total physical capital at the beginning of the current period (TPC_t) can be expressed as the sum of one period lag in physical capital (PCS_{t-1}) and one period lag in total investment (TINV_{t-1}) minus total gross national saving (TGNS_{t-1}) mathematically as

$$TPC_t = TPC_{t-1} + \mathrm{TINV}_{t-1} - \mathrm{FCC}_{t-1} \tag{1}$$

This implies that the change in total physical capital stock (ΔTPC_t) is given by:

$$\Delta TPC_t = TPC_t - TPC_{t-1} = \mathrm{TINV}_{t-1} - \mathrm{FCC}_{t-1} \tag{2}$$

According to the neoclassical assumption of growth theory which provided by Harberger (1978) when the economy is in its steady state as a consequence, output grows at the same rate as physical capital that would be given as:

$g_{GDP} \equiv g_{TPC} = \frac{\Delta TPC_t}{TPC_{t-1}} = \frac{TPC_t - TPC_{t-1}}{TPC_{t-1}}$. Solving this equation for TPC_{t-1} and plugging into (3.1), and again solving for TPC_t, we will have got:

$$TPC_t = \frac{(1 + gGDP_t)(\mathrm{TINV}_{t-1} - \mathrm{FCC}_{t-1})}{gGDP_t}$$

Therefore, the growth rate of total physical capital over time can be found as:

$$gx_{1,t} \equiv \frac{\Delta TPC_t}{TPC_{t-1}} = \frac{TPC_t - TPC_{t-1}}{TPC_{t-1}} \tag{3}$$

where g stands for GDP growth rate can also be calculated in logarithmic form as $ln\left(\frac{GDP_t}{GDP_{t-1}}\right) = lnGDP_t - lnGDP_{t-1}$ & $gGDP_t = \frac{GDP_t - GDP_{t-1}}{GDP_t}$.

Secondly, we derive the second variable by taking the ratio of real GDP to total employment engaged in the production of real GDP, then we are able determine the growth rate of total employment productivity or total labor productivity (TEMPTP). We assume that the ratio of real GDP to total employment is represented as:

$$x_{2,t} = \frac{y_t}{\text{total employment}_t}$$

Therefore, the growth rate of total employment productivity obtained respectively as:

$$gx_{2,t} = \frac{\Delta x_{2,t_t}}{x_{2,t-1}} = \frac{x_{2,t_t} - x_{2,t-1}}{x_{2,t-1}} \quad (4)$$

Calculation for the growth rate of $\text{total employment}_t$ is based on the classical assumption for the labour force to be growing at the rate at which it has been evolved. This can be shown as the ratio of the first order derivative of labour with respect to time to its original size, but for the annual discrete data can be depicted as, n= $\frac{\Delta\text{total employment}_t}{\text{Ttotal employment}_{t_{t-1}}}$, n ≥ 0.

Thirdly, to set the foreign direct investment net inflows (FDINI) in relation to the real GDP, is an essential in the form of a growth rate of the foreign direct investment net inflows ($x_{3,t}$) that can be set as follows:

$$gx_{3,t} = \frac{\Delta x_{3,t}}{x_{3,t-1}} = \frac{x_{3,t} - x_{3,t-1}}{x_{3,t-1}} \quad (5)$$

Fourthly, total factor productivity (TFP) is calculated based on the Solow growth model with the help of calculus concepts. TFP is the most commonly used measure for technological change that relates input–output in the production function, which can be obtained through a residual approach as in (Solo, 1956, 1957). It is a measure of productivity which can be calculated as a ratio of economy-wide total production to the weighted average of inputs i.e. labour and capital. We can obtain TFP from the most widely used of the production function known as the Cobb–Douglas function as follows

$$TFP_t = A_t = \frac{y_t}{K_t^{\alpha} L_t^{\beta}}, \alpha + \beta = 1, \alpha \geq 0 \,\&\, \beta \geq 0.$$

By transformation the logarithm, the total factor productivity (TFP) over time becomes

$$ln\,TFP_t \equiv lnA_t = lnY_t - (\alpha lnK_t + \beta_t lnL_t)$$

The growth rate of total factor productivity in continuous time form of data is the difference between the proportional change in output and change in a Divisia Index of inputs, given as

$$\frac{lnT\dot{F}P_t}{ln\,TFP_t} = \frac{ln\dot{Y}_t}{lnY_t} - \left(\alpha \frac{ln\dot{K}_t}{lnK_t} + \beta \frac{ln\dot{L}_t}{lnL_t}\right)$$

The technological changes $\left(\frac{ln T\dot{F}P_t}{ln\, TFP_t}\right)$ results from intangible factors such as research and development (R&D), synergies, etc which is more useful to look at productivity increase over a period instead of the absolute value of total factor productivity. However, the growth rate of total factor productivity in terms of discrete time for the discrete annual data can be expressed as

$$gx_{4,t} \equiv \frac{\Delta\, TFP_t}{TFP_{t-1}} = \frac{TFP_t - TFP_{t-1}}{TFP_{t-1}}$$

$$gx_{4,t} = \frac{y_t - y_{t-1}}{y_t} - \left(\alpha \frac{TPC_t - TPC_{t-1}}{TPC_{t-1}} + \beta \frac{TEMPT_t - TEMPT_{t-1}}{TEMPT_{t-1}}\right)$$

$$gx_{4,t} = g\, y_t - \left(\alpha g x_{1,t} + \beta g x_{2,t}\right) \qquad (6)$$

We can obtain the values of $\alpha\ and\ \beta$ by applying the first order partial derivatives of the total profit, that is, the difference between total revenue and total costs of the economy with respect to capital and labour inputs as follows.

$$\frac{\partial \pi_t}{\partial TPC_t} = \frac{\partial (TR_t - TC_t)}{\partial K_t} = \frac{\partial (P_t y_t - r_t TPC_t - w_t TEMPT_t)}{\partial TPC_t}$$

$$= \frac{\partial \left(P_t \mathrm{A_t TPC_t}^{\alpha} \mathrm{L_t}^{1-\alpha} - r_t KTPC_t - w_t TEMPT_t\right)}{\partial TPC_t} = 0,$$

&

$$\frac{\partial \pi_t}{\partial TEMPT_t} = \frac{\partial (TR_t - TC_t)}{\partial TEMPT_t} = \frac{\partial (P_t y_t - r_t TPC_t - w_t TEMPT_t)}{\partial TEMPT_t}$$

$$= \frac{\partial \left(P_t \mathrm{A_t TPC_t}^{\alpha} \mathrm{TEMPT_t}^{1-\alpha} - r_t TPC_t - w_t TEMPT_t\right)}{\partial TEMPT_t} = 0.$$

$$\frac{\partial \pi_t}{\partial TPC_t} = \alpha P_t \mathrm{A_t TPC_t}^{\alpha-1} \mathrm{TEMPTL_t}^{1-\alpha} - r_t = 0, \& \ \frac{\partial \pi_t}{\partial TEMPT_t}$$

$$= (1-\alpha) P_t \mathrm{A_t TPC_t}^{\alpha} \mathrm{TEMPT_t}^{-\alpha} - w_t$$

$$\Rightarrow \alpha = \frac{\partial y_t}{\partial TPC_t} \frac{TPC_t}{y_t} = \frac{r_t TPC_t}{y_t} \cong \left(\frac{\Delta y_t}{\Delta TPC_t}\right)\left(\frac{TPC_t}{y_t}\right) \ \ \& \ \beta = 1 - \alpha.$$

Endogenous growth model assumes the allocation of resources used for the creation of new technologies in the economy is divided between the R&D conducting sector and goods-producing sector by the engagement of employment and capital inputs (see Romer, 2012).

Fifthly, with multi-commodity, index of openness can be expressed mathematically as the total sum of exports and imports of the country to its GDP ratio (Kotcherlakota & Sack-Rittenhouse, 2000). Another kind of measurement for openness is terms of trade (TOT) in which we can obtain the difference between price on commodities in foreign and domestic markets. It was first discussed and studied by Obstfled and Rogoff (1996) and then considered as measuring the trade openness in (Lloyd & MacLaren, 2002).

The empirical investigation on economic growth in cross-country (Halit, 2003) and dynamic measurement of economic openness in (De Lombaerde, 2009) can be used as a foundation for this study. Noteworthy, trade is the difference between monetary value of exports and imports of output in an economy over a certain period.

Let the net export be defined as $NX_t \equiv \left(\frac{1}{Y_t}\right)\left(Y_t - \frac{P_t^F}{P_t^H}C_t\right)$ in terms of domestic output, expressed as a fraction of steady state output Y. Then we use the first order approximation of Gali and Monacelli (2005) in the form of logarithmic function that leads to:

$$\ln(Y_t.NX_t) \equiv \ln\left[Y_t\left(\frac{1}{Y_{it}}\right)\left(Y_t - \frac{P_t^F}{P_t^H}C_t\right)\right] = lnY_t - ln\left(\frac{P_t^F}{P_t^H}C_t.Y_t\right) \Rightarrow lnY_t + lnNX_t$$

$$= lnY_t - lnC_t - lnY_t + lnP_t^H - lnP_t^F$$

$$\Rightarrow \ln NX_t = -\ln Y_t - \ln C_t - (p_t^F - p_t^H) \Rightarrow \ln NX_t = -\ln Y_t - \ln C_t - TOT_t$$

$$\Rightarrow \ln TOT_t = -(\ln Y_t + \ln C_t + \ln NX_t)$$

$$x_{4,t} = \ln TOT_t = \ln IMP_t - (\ln Y_t + \ln C_t + \ln EXP_t)$$

Thus the growth rate of terms of trade is calculated as

$$gx_{5,t} = \frac{\Delta x_{5,t}}{x_{5,t-1}} = \frac{x_{4,t} - x_{5,t-1}}{x_{5,t-1}} \quad (7)$$

Under the multi-commodity and multi-country model, terms of trade is a negative overall sum of the real GDP and domestic consumption and net exports. If export price over import price times 100 exceeds over 100% in the process of dynamic output production then the economy is doing net capital accumulation since more money coming in than going out from the economy (Reinsdorf, 2009). Therefore, the economic growth or the growth rate (for a panel of 36 Sub–Saharan can be modelled as

$$lne^{gy_{it}} = lnf\left(e^{gx_{1,it}\cdot gx_{2,it}\cdot gx_{3,it}\cdot gx_{4,it}gx_{5,it}\cdot \varepsilon_{it}}\right) \quad (8)$$

After transforming logarithmic function into linear, we are able to show the linear relationship between the dependent and explanatory factors in the model as

$$gy_{it} = \psi_0 + \psi_1 gx_{1,it} + \psi_2 gx_{2,it} + \psi_3 gx_{3,it} + \psi_4 gx_{4,it} + \psi_5 gx_{5,it} + \varepsilon_{it} \quad (9)$$

where ε_{it} stands for error therm.

These explanatory factors can contribute to economic growth only when sufficient absorptive capability of advanced technologies is available for economic growth modelling with a continuum of agents indexed by their level of ability (Alfaro et al., 2000). The production function in the real environment tends to increase returns to scale with an augmented neoclassical model framework and there exist a technological spill–overs (Schmidt-Hebbel, 1994; Easterly & Levine, 1994 and Barro & Sala-i-Martin, 2003).

In the specification of dynamic panel econometric model, we employ the panel vector error correction mode (VECM) and panel generalized method of moments (PGMM) for the short-run and long-run estimation coefficients, respectively. With regard to the model specification some key points must be noted. When the variables are non–stationary in their levels but stationary in differences, we take the differences and estimate short–run using a vector error correction model (VECM) that allows consistent estimation of the relationships among the series. More precisely, under the specification of restricted parameters, the panel VECM allows the interactions of short–run dynamics between cross–sections and influence of one cross–section's temporary long–run equilibrium error on other members of the panel and the difference in cointegration ranks across cross–sections and cross–sectional cointegration (Anderson et al., 2006). If the variables in each series are cointegrated, we use the system of panel vector error correction model (VECM) instead of vector autoregressive (VAR) to estimate the short–run relationship between dependent and explanatory variables that can be set as follows

$$\Delta y_{it} = \lambda_0 + \lambda_{it}\big(y_{it-1} - \varPhi_1 x_{1,it-1} - \varPhi_2 x_{2,it-1} - \varPhi_3 x_{3,it-1} - \varPhi_4 x_{4,it-1} - \varPhi_5 x_{5,it-1}\big) + \sum_{j=0}^{m} \varPi_j \Delta x_{1it-j} + \sum_{j=0}^{n} \varPi_j \Delta x_{2it-j} + \sum_{j=0}^{r} \varPi_j \Delta x_{3,it-j} + \sum_{j=0}^{n} \varPi_j \Delta x_{4,it-j} + \sum_{j=0}^{r} \varPi_j \Delta x_{5,it-j} + \vartheta_{it} \quad (10)$$

where λ_{it} are parameters of the error correction terms which estimate the speed of adjustment or error-correction towards the long–run equilibrium for country i over time t. If the parameter of the error correction term is negative in sign and significant, there is a long–run association, or integrated of the same order of the variables; otherwise, no long-run relationship. $\boldsymbol{\lambda_0}$, Φ and Π are parameters to be estimated, ϑ_{it} is the White noise random disturbances and p, q and r denote the optimal lag length. The model is flexible which provides both the short–run elasticities, in addition to being consistent in dealing with non-stationary data at level.

One of the most widely used and efficient methods of estimation for the differenced equations is the generalized method of moments (GMM) of Arellano and Bover (1995). The GMM

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system form developed and studied by Arellano and Bover (1995) and discussed in Ahn and Schmidt (1995) and Hahn (1999) is not only lagged levels used as instruments for first differences but also lagged first differences are used as instruments for levels which corresponds to extra set of the moment conditions. There is an over–identified with GMM used with lags two and three in a dependent variable as instruments, but, this method we require a large number of time variable sets which loses some observations in time series and macro panel data (see Harris & Matyas, 1998)

The method of moment is an estimation technique which suggests the unknown parameters should be estimated by matching population moments with appropriate sample moments. The main difference between the maximum likelihood(ML) and GMM techniques is that ML requires the complete specification of the model and its probability distribution, but GMM doesn't require such sort of full knowledge and it only demands the specification set of moment condition which the model should satisfy (Harris & Matyas, 1998).

The GMM estimator is used when the parameters are over-identified by the moment conditions for the linear regression method with number of equation exceeds number the parameters to be estimated valid instruments, the moment conditions can be expressed as

$$E(z_{it}u_{it}) = E(z_{it}(y_{it} - x_{it}'\beta)) = 0$$

And the sample moments are

$$f_T(\beta) = T^{-1}\sum_{t=1}^{T} z_{it}(y_{it} - x_{it}'\beta) = T^{-1}(Zy_{it} - Z'x_{it}'\beta) \qquad i = 1,2 \dots . n$$

Suppose we choose:

$$A_T = \left(T^{-1}\sum_{t}^{T} x_t z'_t\right)^{-1} = T(Z'Z)^{-1},$$

And assume we have a weak law of large numbers for $z_t z'_t$, so that $T^{-1}\, Z'Z$ converges in probability constant matrix A. Therefore, the criterion for this function is:

$$Q_T(\beta) = T^{-1}(Zy_{it} - Z'x_{it}'\beta)'(Z'Z)^{-1}(Z'y_{it} - Z'x_{it}'\beta)$$

Differentiating with respect to β gives the first order condition as:

$\frac{dQ_T(\beta)}{d\beta} = 2T^{-1}X'Z(Z'Z)^{-1}(Zy_{it} - Z'x_{it}'\beta) = 0$, and due to unbiasdness $\beta \equiv \hat{\beta}$ solving for $\hat{\beta}$ which gives

$$\hat{\beta} = (X'Z(Z'Z)^{-1}Z'X)^{-1}X'Z(Z'Z)^{-1}Z'y \tag{11}$$

where X consists of the explanatory variables $gx_{1,it}, gx_{2,it}, gx_{3,it}, gx_{4,it}, and\ gx_{5,it}$.

This is the standard IV estimator for the case where there are more instruments than regressors. Panel data allow the correction for measurement error without assuming a known measurement error covariance matrix or using additional validation/replication data to estimate the measurement error covariance matrix. Griliches and Hausman (1986) proposed using the generalized method of moments (GMM) or optimal weighting to efficiently combine instrumental variable (IV) estimators. The panel GMM can be linear or nonlinear two-stage least squares (2SLS)/instrumental variables (IV) and estimation with AR and SAR errors.

The reason why we have used the panel data as Baltagi (2005) describes the following advantages. First, we can address a broader range of issues and tackle more complex problems with panel data than would be possible with pure time series or cross-sectional data alone. Second, it is often of interest to examine how the relationship between variables changes dynamically over time. Third, we can remove the impact of certain forms of omitted variables bias in regression results and allow controlling for unobserved omitted variables. Fourth, panel data usually give the researcher a large number of data points (N*T), increasing the degrees of freedom and reducing the collinearity among explanatory variables–hence improving the efficiency of econometric estimates.

According to the study Alonso–Borrego and Arellano (1996), based on the lagged observations used as explanatory variables, the dynamic estimators are designed to address the problems of the unobserved specific effects and the joint endogeneity of explanatory variables. Furthermore, in the dynamic panel estimators, we apply the differenced equation to remove any bias and potential parameter inconsistency arising from the simultaneity bias created by the unobserved country–specific effects and the use of lagged values of the original regressors. In cases where the cross sectional dimension is small and the time dimension is relatively large, the standard time series techniques are applied to the systems of equations and the panel aspect of the data should not pose new technical difficulties (Breitung and Pesaram ,2005).

4. Empirical Results and Discussions

Here in the empirical results and discussions section, we present the analysis made using different techniques and methods specified under the study of the methodology and the interpretations for results obtained and presented in tables and graphs.

4.1 Choosing Optimal Lag Length from Vector Autoregressive, VAR Method

The cross-equation restrictions and information criteria are the two possible approaches for choosing optimal lag length, commonly known under the VAR environment. In the spirit of the unrestricted VAR modelling, each equation should have the same lag length to a restriction that the coefficients on lags are jointly zero. This can be done using a likelihood ratio (LR) test which follows that the test statistic is asymptotically distributed as a c^2 with degrees of freedom equal to the total number of restrictions. For example, restricting 4 lags of two variables in each of the two equations equal a total of 4*2 *2 = 16 restrictions. However, the disadvantage for conducting the LR test is cumbersome and requires a normality assumption for the disturbances (Pesaran, Shin, & Smith, 2001) and hence, we use the more popular approach which is the information criteria.

One of the most important considerations with macroeconomic panel data is making an appropriate set of dynamics equations with the most appropriate lag structure. A possible source of a problem in the functional form of the model is lack of lagged structure which results in a problem of autocorrelation. In this case, one way of overcoming an autocorrelation is to add a lagged variable in the system. The optimal lag length in ARDL model can be determined by the Akaike information criterion (AIC) among many others, with the lowest error value indicating the most appropriate model to be used in the analysis. So, as can be seen from the results from Table 1, the chosen optimal lag length based on all criteria is **2.**

Table 1. Optimum Lag Length

Lag	AIC	BSIC	HIQ
0	18.416	18.446	18.428
1	17.635	17.847	17.716
2	14.539*	14.934*	14.689*

Note. * indicates lag order selected by the criterion with the least values of Akaike information criterion(AIC), Bayesian Schwarz information criterion(BSIC) and Hannan-Quinn information criterion(HIQ) VAR Lag Order Selection Criteria Endogenous variables: $gy_{it}, gx_{1,it}, gx_{2,it}, gx_{3,it}, gx_{4,it}, gx_{5,it}$ Exogenous variables: C and Included observations: 964.

4.2 Unit Roots and Stationarity Tests

The stationarity and stability conditions are one of the most important considerations in assumptions for the model estimation. If a process is said to be an integrated order of one, I(1), then its first difference would be I(0). This means each series level of the dataset has a unit root process. The validation for model estimation is verified when the roots of the characteristics equation lie on or within the unit circle. We include the intercept in the test equation and take the obtained maximum lag length of 2 in the process of conducting the tests. The stochastic process is said to be stationary if the majority roots in the characteristic equation lie outside the unit circle, otherwise, non-stationary.

The Pesaran, Shin and Smith (2001) study does not a priori impose stability in lag polynomials as cointegration exists; thereby the model is in fact stable. As can be seen from (Table 2 and Figure 1), all the five series of data have unit roots or they are non-stationarity in the level. Because the modulus and autoregressive (AR) characteristic polynomial inverse roots confirms that the characteristic polynomial roots which include six real roots six and six complex or imaginary roots lie within a unit circle. In this regard, a stability condition exists due to the fact that the results of each root are less than one or they are contained within a unit circle and conclude that the model is stable.

Table 2. Unit Roots and Stationarity Tests (AR Roots Table& Graph)

AR Roots of Characteristic Polynomial	
Roots	Modulus
-0.9784	0.9784
0.9445	0.9445
0.5524	0.5524
-0.0206 - 0.4058i	0.4064
-0.0206 + 0.4058i	0.4064
-0.2259 - 0.2545i	0.3403
-0.2259 + 0.2545i	0.3403
0.0034 - 0.3206i	0.3207
0.003417 + 0.3206i	0.3207
0.2112	0.2112
-0.1117	0.1117
0.1106	0.1106

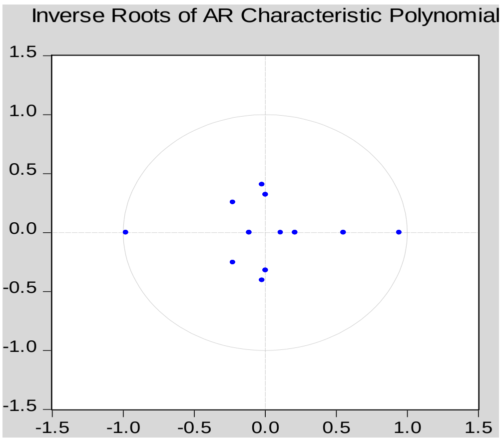

Figure 1. Inverse Roots of AR Characterisic Polynomial

4.3 Tests of Cointegration Using Pedroni Method

After conducting tests for stationarity and stability conditions we look for cointegration tests. Based on the existence of unit roots, the long–run cointegrating relationship analyses have to be made, which received remarkable attention in various methods. The methods include dynamic OLS estimation of (Pablo, 2010), panel fully modified OLS estimators of (Phillips & Moon, 1999, 2000; and Kao & Chiang, 2000), panel vector error correction models of (Anderson, Qian, & Rasch, 2006) and fully modified OLS estimators of (Pedroni, 2000; and Mark & Sul, 2003) are the most important ones.

Cointegration refers to the condition when linear combinations of nonstationary panel series data are stationary after their first differences. This suggests an existence of long–run relationship in the equilibrium among variables. Furthermore, we look into the determinants of economic growth for the cross–country according to Barro (1998) that the estimated coefficients obtained by these methods are asymptotically unbiased and normally distributed.

In the Pedroni residual cointegration test, there is a demeaning for each observation variation over time within an individual which involves subtracting the time-mean of each entity away from the values of the variable by the individual-specific mean eliminating the need to create dummy variables. An alternative to this demeaning would be to simply run a cross-sectional regression on the time-averaged values of the variables, which is known as the between estimator. An advantage of running the regression on average values (the between estimator) over running it on the demeaned values (the within estimator) is that the process of averaging is likely to reduce the effect of measurement error in the variables on the estimation process.

From the Pedroni test, we would reject the null hypothesis of no cointegration in common autoregressive (AR) coefficients on the Panel- , Panel- PP and Panel- ADF as well as on the Panel- ρ and Panel- PP under the weighted statistics at any conventional level of significance. Furthermore, we also would reject the null hypothesis on the Group- and Group-PP statistics in the between-dimension of individual AR coefficients whereas all others remain insignificant. Thus based on the majority rule decision, we conclude that the Pedroni residual cointegration test shows all the six series data have a common long–run relationship (see Table 3). On top of the hypothesis tests, there is much displayed information about variables included in the series such as the sample period for data used, number of included observations, cross-section and automatic lag length selection based on AIC with a maximum lag of two are presented under the table.

Table 3. Pedroni Residual Cointegration Test

Common AR coefficient Within-Dimension					**Individual AR coefficient Between Dimension**		
Alt.st. H_0	Statistic	Prob.	W. Stat	Prob.	Alt.st. H_0	Statistic	Prob.
Panel- $\boldsymbol{v}$	0.6066	0.2720	-3.6586	0.9999	Group- ρ	10.652	0.0000*
Panel- $\boldsymbol{\rho}$	-4.5742	0.0000*	-8.5522	0.0004*	Group-PP	-12.757	0.0000*
Panel- PP	-19.166	0.0000*	-9.5267	0.0000*	Group- ADF	1.6465	0.9502
Panel- ADF	-5.3275	0.0000*	1.2901	0.9015			

Note. Alt.st. H_0 stands for alternative hypothesis and W.Stat denotes weighted statistic. In Pedroni residual cointegration test Null Hypothesis: No cointegration, Trend assumption: No deterministic trend, Use d.f. corrected Dickey-Fuller residual variances, Automatic lag length selection based on AIC with a max lag of 2.

4.4 Cross -Section Dependence Test for Panel

We consider the standard augmented Dickey–Fuller (ADF) regression with cross–section averages of the lagged levels and first-differences of the individual series for the cross–sectional dependence test of (Pesaran, 2007). Based on an autoregressive order of (AR( )) error specification, the relevant individual cross sectional augmented Dickey–Fuller (CADF) statistics are computed from the th order cross-section. The limited distribution of this test is different from the Dickey–Fuller distribution due to the presence of cross–sectional lagged level in which Pesaran (2003) uses as a truncated version of the Im-Pesaran and Shin (1997) test to avoid the problem of moment calculation(Baltagi,2005).

Here in this paper, as the number of cross sections exceeds the number of periods, we apply the panel corrected standard error (PCSE) instead of generalised least squares (GLS) method to make the data to be cross-sectional independent before estimation. Since the estimation in the presence of cross–sectional dependence causes bias, inconsistency, inefficient parameters estimation and invalid test statistics as (Andrew, 2005) points out, we employ this and we conduct a test for the cross-sectional dependence.

Table 4 displays the test hypothesis and information about the number of cross-section and period observations. The first line of the table contains the results for the Breusch-Pagan lagrangian multiplier (LM) test which shows the test statistic value, test degree-of-freedom, and the associated p-value. The value of the test statistic of 65.22 is well into the upper tail of a 325 that we don't reject the null hypothesis of no cross-section dependence in residuals at 5% significance levels. In the meantime, the remaining two lines present the results for the scaled Pesaran LM and the Pesaran CD in which the test statistic results of 54.49 and 37.76 respectively. We wouldn't also reject the null hypothesis at the conventional 1% level of significance because the probability values of both the two tests exceed 0.01.

Finally, we don't reject the null hypothesis of no cross-section dependence (correlation) in residuals because the probability value of Pesaran CD is larger than any conventional level of significance. Thus we conclude that there is no cross sectional dependence among variables in all six series of a panel countries. As these test results confirm that there is no cross-section dependence in the variables; now it is possible to proceed for the model estimation after other tests are being carried out (Pesaran, 2007).

Table 4. Cross-sectional Dependence Tests

Test	Statistic	d.f.	Prob.
Breusch-Pagan LM	65.2247		0.0580
Pesaran scaled LM	54.4901	325	0.0347*
Pesaran CD	37.7592		0.9826

* denote rejection of the hypothesis at the 5% level of significances, Residual Cross-Section Dependence Test. Null hypothesis: No cross-section dependence (correlation) in residuals.

4.5 Short-Run and Long-Run Parametric Estimations

Once we have conducted the necessary tests such as cointegration and some diagnostics tests for the data being fitted into the specified models, the next step is to estimate the short-run and long–run coefficients. We estimate the short-run coefficients using a vector error correction model (VECM) and we report the results in Table 5. First, we generate the error correction term denoted by ECT_{it-1} is an expected negative sign but insignificant at any conventional level of significance for a panel countries. It would be vital for a single country in the time series data in order to measure the speed of adjustment in a year towards the long-run equilibrium once the disequilibrium happened in the short-run.

Second, the results show that the change in the first two periods lags in the growth rate changes of total physical capital ($\Delta gx_{1,it-1}$ and $\Delta gx_{1,it-2}$) each has a positive effects on growth rate of real GDP, while others remain constant in the short-run. Third, the changes in growth rate of the foreign direct investment net inflows in the first and second period lags in each ($\Delta x_{3,it-1}$ and $\Delta x_{3,it-1}$) has negative impacts on growth rate of real GDP for a panel of 36 countries in the short-run, while other factors being constant. Fourth, holding all others remain constant, the change in the growth rate of total factor productivity in one and two years back in each ($\Delta x_{3,it-1}$ and $\Delta x_{3,it-1}$) has a positive contribution for the growth rate of real GDP for a panel countries in the short-run.

Table 5. Short-run Estimation Coefficients using Vector Error Correction model

Variable	Coefficient	t-Statistic	Prob.
ECT_{it-1}	-0.0384	-1.3123	0.1897
Δgy_{it-1}	-0.3377	-5.6189	0.0000**
Δgy_{it-2}	-0.2028	-3.5973	0.0003**
$\Delta gx_{1,it-1}$	5.84E-05	5.8119	0.0000**
$\Delta gx_{1,it-2}$	2.51E-05	2.6587	0.0080**
$\Delta gx_{2,it-1}$	-0.0600	-1.4269	0.1539
$\Delta gx_{2,it-2}$	-0.0559	-1.3518	0.1767
$\Delta gx_{3,it-1}$	-0.0001	-4.7282	0.0000**
$\Delta gx_{3,it-2}$	-7.86E-05	-2.6572	0.0080*
$\Delta gx_{4,it-1}$	0.0047	1.5460	0.1224
$\Delta gx_{4,it-2}$	0.0102	4.2419	0.0000**
$\Delta gx_{5,it-1}$	-1.5458	-3.3681	0.0008**
$\Delta gx_{5,it-2}$	-0.6913	-1.8814	0.0602*
constant	-0.0007	-0.3259	0.7446
	-0.0008	-0.3259	0.7446
R^2	0.3102		
$\overline{R}^2$	0.3007		
F-sat	32.865		
Prob(F-sta)	0.0000		

Note. p-values and any subsequent tests do not account for model selection; where Δ stands for differences and the* denote significance values of probability at the 5% level of significances.

Using the generalized method of moments (GMM), we estimate the coefficients of dynamic long-run for the panel of 36 economies in Sub-Sahara African countries as reported in Table 6. All other factors being constant, a one unit increase in growth of total employment productivity ($gx_{2,it}$) that increases the economic growth of a panel countries by 0.06 units in the log-run. Moreover, the growth rates of both total factor productivity ($gx_{4,it}$) which represents endogenous technology and that of terms of trade (($gx_{5,it}$) that measures openness of the economy to interact with the rest of the world each of them has a positive contribution to the economic growth in Sub-Sahara African countries in the long-run while other factors held to be constant.

Last but not least, in both the difference and orthogonal panel GMM estimation, the J-test is a measure of over- identifying restrictions. As far as we don't reject the probability value of the J-statistic at any conventional level of significance, there is enough restriction to make sure constancy of the model and we have more instruments that we can exploit the over-identification to test the joint validity of all instruments. In addition, the post-estimation diagnostic Arellano-Bond Serial Correlation Test confirms that there is no serial auto-correlation problem as can be seen from Table 7. At 5% level of significance we reject the null hypothesis of no serial correlation at the auto-regressive of first order(AR(1)), however, at its second order which equals the appropriate chosen optimal lag length of 2 we can't reject the null hypothesis of nor serial correlation at any conventional level of significance. Therefore, it has been concluded that there is serial correlation according to the Arellano-Bond serial correlation diagnostic test.

The Granger causality test in Table 8 shows that there is a unidirectional causality running from the growth rate of total physical capital to the real GDP growth rate; from real GDP to the growth rate of total employment productivity and from the growth rate of total foreign direct investment inflows towards the economy to the real GDP growth on the one hand. There are also a bi-directional causality running from the growth rate of total factor productivity and that of terms of trade to the real GDP rate and vice versa, on the other hand.

Table 6. Long-run Estimation Coefficients using Generalized Method of Moments (GMM)

Variable	Coefficient	t-Statistic	Prob.
gy_{it-1}	0.1769	8.1584	0.0000*
gy_{it-2}	0.0045	0.3023	0.7625
$gx_{1,it}$	1.95E-05	3.0575	0.0023*
$gx_{2,it}$	0.0571	12.413	0.0000*
$gx_{3,it}$	1.05E-05	0.2318	0.8168
$gx_{4,it}$	0.0112	8.0944	0.0000*
$gx_{5,it}$	4.2316	16.759	0.0000*

Note. The* denote significance values of probability at the 5% level of significances, Dependent Variable: GY Method: Panel Generalized Method of Moments, Transformation: First Differences, Sample (adjusted): 1993 2018, Periods included: 26, Cross-sections included: 36, Total panel (unbalanced) observations: 930, White period instrument weighting matrix. White period standard errors & covariance (d.f. corrected), Instrument specification: @DYN(GY,-2) GX1 GX2 GX3 GX4 GX5 and constant added to instrument list. J-statistic 33.306 and Prob(J-statistic) 0.2655.

Table 7. Diagnostic Arellano-Bond Serial Correlation Test

Test order	m-Statistic	rho	SE(rho)	Prob.
AR(1)	-2.4758	-2.7401	1.1068	0.0133*
AR(2)	0.0616	0.0167	0.2715	0.9509

Note. The null hypothesis is no serial correlation and the* denote significance value of probability at the 5% level of significances for the rejection, Sample: 1990 -2020 and included observations: 930.

Table 8. Pairwise Granger Causality Tests

Null Hypothesis:	Obs	F-Statistic	Prob.
$glnx_{1it}$,it does not Granger Cause $glny_{it}$	971	18.053	0000**
$glny_{it}$ does not Granger Cause $glnx_{1it}$		0.0199	0.9802
$glnx_{2,it}$does not Granger Cause $glny_{it}$	970	0.6895	0.5021
$glny_{it}$ does not Granger Cause $glnx_{2,it}$		166.02	0000**
$glnx_{3,it}$ does not Granger Cause $glny_{it}$	1003	10.754	0000**
$glny_{it}$ does not Granger Cause $glnx_{3,it}$		0.2713	0.7624
$glnx_{4,it}$ does not Granger Cause $glny_{it}$	1005	4.0481	0.0177*
$glny_{it}$ does not Granger Cause $glnx_{4,it}$		39.957	0000**
$glnx_{5,it}$ does not Granger Cause $glny_{it}$	1008	9.3438	0.0001*
$glny_{it}$ does not Granger Cause $glnx_{5,it}$		42.077	0000**

Note. The null hypothesis of doesn't Granger cause and the* denote significance value of probability at the and 1% and 5% level of significances for the rejection.

5. Conclusion

This study tries to examine the important role of endogenous technology for making strong enough and inclusive economic growth in the Sub-Sahara African (SSA) in a panel of 36 countries over the period 1990–2020. Based on the data originally obtained from the United Nations aggregate database, World Bank development indicators and International Monetary Fund economic outlook, we derive total physical capital, total employment productivity, total foreign direct investment inflows, total factor productivity (TFP) and terms of trade growth rates using various concepts.

As the main determinants among others for real GDP, dealing with the role of TFP; the skills, knowledge and innovation that people accumulate domestically are the greatest economic resources which could bring a better living standard. In this sense, the panel of short-run vector error correction model (VECM) and panel of long–run generalized method of moments (GMM) are applied and the estimation results are obtained. The empirical results reveal that there are significantly positive impacts of the growth rates of TFP and terms of trade (TOT) on real GDP growth rate in the long -run. These are profoundly important indicators for SSA today that timely using endogenous technology can play the central role in succeeding economic growth. Since recently there has been a very large rapidly growing youth population and changing skills demands for technological change, countries in the region must use this opportunity to apply the endogenous technology in the productive sector of the economy. And hence, without a greater supply of home–grown talent in the areas of the economic sector, it may be hard to break down the vicious circle of poverty, build prosperous, inclusive and resilient economies that can be feeding the people and enabling the countries to compete with trade globally.

In the end, the dynamics inter-temporal Granger causality test shows there is a unidirectional causality running from the growth rate of total physical capital to the real GDP growth rate; from real GDP to the growth rate of total employment productivity and from the growth rate of total foreign direct investment inflows towards the economy to the real GDP growth on the one hand. There are also a bi-directional causality running from the growth rate of total factor productivity and that of terms of trade to the real GDP rate and vice versa, on the other hand.

To these end, we only focus on endogenous technological applicability for the economic growth through total factor productivity. However, further studies are required to conduct such as the impact of corruption, the economic policy in each country and the interaction among each country when it comes to trade on this area which can potentially affect the living standards

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Data Availability

Data used in this study can be found with the author and upon request, will be available.

Declarations and Competing Interests

Ethics approval and consent to participate is the core principle which this study follows all ethical practices during writing. Consent to participate and for publication are not applicable. The author states that there is no competing interest.

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Appendix

Appendix I: Important Notes and Equations

Suppose that $\{z_{it}\}$ follows an autoregressive process of order p (AR(p)) to verify the roots of the characteristics equation whether lie on or within the unit circle:

$$z_{it} = \rho_1 z_{i,t-1} + \rho_2 z_{i,t-2} + \cdots + \rho_p z_{i,t-p} + u_{it},$$

Using the lag operator as $z_{it} - \rho_1 L z_{it} - \rho_2 L^2 z_{it} - \cdots - \rho_p L^p z_{it} = u_{it}$.

After taking y_{it} as a common factor and multiplying both sides by expected values, we have the following polynomial equation.

$$E_{it}\left(z_{it}\left(1 - \rho_1 L - \rho_2 L^2 - \cdots - \rho_p L^p\right) = u_{it}\right)$$

$$\Rightarrow 1 - \rho_1 L - \rho_2 L^2 - \cdots - \rho_p L^p = 0.$$

This equation is a polynomial in L that we are able to get the characteristic roots from the characteristic equation.

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