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The Complementary Role of Quality Education and Technology on the Economic Growth of South Africa

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ABSTRACT:- There are innumerable number of literature on the thesis of education, technology and economic growth. Almost all the literature address the issue of the relationship between education and economic growth or as it may, the causality between technology and economic growth. Few of the existing literature have gone a step further to look at the role of education and innovation in economic growth and development.
It is an undisputable fact that education contributes to the human capital needed for economic growth by a country. This study looked at the roles quality education and technology play in contributing to economic growth of an economy, and the means through which the two can be deployed in a symbiotic manner to boost the economic growth of South Africa (SA).
Firstly, this paper evaluated the current state of South Africa's education system and ascertained whether the current education system has had a positive impact on the economic growth of South Africa. Secondly, the paper provided an analysis about whether technology has contributed to the economic growth of South Africa. Lastly, the paper employed the Cobb Douglas Production Model and the time series analysis to determine whether there exist a positive interaction between Total Factor Productivity and the Education proxies to the GDP of South Africa..

Keywords:- Education, Technology, Economic Growth, Development, South Africa

I. INTRODUCTION

Education is undoubtedly one of the indispensable assets for a nation's development and economic growth. In contemporary times, there have been considerable headway made by developing countries towards closing in on the developed countries in matters relating to access and affordability (Dumciuviene, 2015). Doing so has contributed to diverting focus from top quality education thus making developing countries unsuccessful in their quest to bridge the gap with the developed counterparts. By quality education, we mean an education that equips students with cognitive skills, creative abilities as well as problem solving techniques and skills needed by industries for production, which thereby increases the economic production of a country.

While talking about the economic success of South Korea in relation to human capital, Professor Ju-Ho Lee (Professor in Labour Economics, Korea Development Institute) maintained, "although Korea began the process of industrialization, much later than the West, Korea has simultaneously achieved astonishing economic development and democratic political system thanks mainly to its investment in people."

It is recognizable that the solution to the relationship between education and economic growth puzzle lies not in the quantity but in the quality of education attained as asserted by Hanushek and Woessmann (2009). Developing countries may have difficulties in experiencing economic growth without an improvement in the quality of education (Hanushek, 2009).

Economists that are proponents of growth have asserted that miscellany of per capita income among countries cannot be expatiated in seclusion from underlying factor of their human capital development varieties. The preliminary classical economists associated economic growth with physical capital while the neo classical linked economic growth to human capital. Scholars, who are endogenous growth proponents, connect economic growth with technology, which is considered dependent on human capital.
Notwithstanding the arguments of human capital and economic growth, economic growth in contemporary times, cannot only be related to human capital. Technology has usually had a hand in the economic growth of countries in recent times. Therefore, this research addresses the question, how can education and technology together contribute to the economic growth of South Africa?

II. 1.1. Outlook of Current Education System of South Africa

An The education system of South Africa (SA) that has constantly aimed at producing graduates for non-existent 'white collar' jobs has not been successful. The education system must be redesigned to target the skills in shortage in SA in order to meet the needs of the labour market. The science, technology, engineering and mathematics (STEM) education system should be targeted to produce the labour force endowed with the skills that are crucial and needed as the anchor for economic growth.

According to the Labour Market Review (2005), one of the most prominent skills, lacking in South Africa is Information Technology (IT) skills. Some other reports such as that of Reddy et al (2016) that used data from StatsSA LFSs and HEMIS found that South Africa lacked labour force in the occupations of STEM associates and professionals, administrative and commercial managers, business and administrative professionals.

The Global Talent Shortage Survey by ManpowerGroup (2017) also showed that among the top ten jobs that employers in SA were having difficulty in filling included skilled trades (electricians, carpenters, welders, plumbers etc.), management and executive, engineers, accounting and finance staff, technicians, and IT staff.

For a long time, South Africa's education system has focused on the sole aim of producing graduates for 'non-existent white collar' jobs. This has led to the surging unemployment rate in the country and the high level of skills mismatch.

The current dismal level of the South African economy is a true revelation of the failure and ill strength of the education system. Unlike countries such as Brazil, Poland, Germany, Canada, Japan and Sweden (to mention but a few), South African government has failed to implement coherent policies to redesign and strengthen the education system that has been pontificated continually. In the 2015 (OECD) rankings, which rates students at the age of 15 of countries, on the levels of math and science, South Africa finished second from bottom, in 75th place. In the Programme for International Student Assessment (PISA) rankings, it was a similar story, with the country failing to reach the top 40 for either reading or mathematics.

Education has recently come under the spotlight in South Africa, with primary and secondary schools failing to show significant improvements and exacerbating the country's high unemployment rate. Indeed, in early 2016, South Africa's minister of education Angie Motshekga commented that the country's schools were in a state of 'crisis', with less than half of students who enrolled in grade 1 in 2002 passing the school-leaving exam 11 years later.

For a long time, South Africa's education has focused its energy on research in the social sciences area with less attention given to the STEM. This point is buttressed by what (Kem Ramdass, Senior Lecturer in the Faculty of Arts, Design and Architecture, University of Johannesburg) cited in his paper "The Challenges facing education in South Africa".

According to the recent OECD (2017) report on the topic of Getting Skills Right: South Africa, the study found significant imbalances between supply and demand where cognitive skills are in short supply while manual and physical skills are in surplus after conducting a series of country studies. Also in line with the OECD (2017) report on "Getting Skills Right: Skills for Jobs indicators" , it was brought to light that South Africa had the lion's share of mismatched skills of 52% and also the highest mismatch on the field of study mismatch of 33%. This field of study mismatch is parallel with the results of Reddy et al (2016) as cited in the Labour Market Intelligence Partnership report (LMIP, 2018). Also consistent with the above findings is the work of Grapsa (2017) which carried out an in-depth analysis of skills and qualification mismatches in South Africa. The results showed that there was a high incidence of educational mismatch in South Africa.

Naledi Pandor, South Africa's former Minister of Education in 2007 claimed that South Africa is be faced with shortage of skills in various sectors of the economy. This echoes the thought of Maria Ramos, CEO of Absa Group Limited and former CEO of Transnet that there is a dreadful potentially paralyzing skills challenge in South Africa as the country aim to develop sustainable levels of economic growth. Ramos also postulated that almost 50% of firms in developing countries are also faced with the dilemma of skills shortages. The findings of the Manpower Global Talent Shortage Survey (2015) conducted by the Manpower Group disclosed that 31% of South African employers claim having difficulties in filling vacant positions with the biggest difficulties occurring for jobs related to skilled trades, engineering and management. The findings of Manpower Group supports the claims of Ramdass (2007).

The IMD World Talent Ranking carried out by IMD World Competitiveness Center (2015) also found that South Africa ranks amongst the bottom five countries for the availability of skilled labor, the implementation of apprenticeships, the ability of the education system to meet the needs of a competitive economy and the emphasis on science in schools. South Africa's ranking of the global competitiveness index on all the pillars is shown in Appendix C. They indicated that their findings are based on replies received from executives in top and middle management to an executive opinion survey. (Kem, 2007) showed his paper that SA is short in skills in the areas of business and financial managers, engineering skills and IT skills. He also said, there is a demand for generic skills like planning and communication skills.

According to a publication made on "The Economist" in 2017, South Africa has the worst education systems in the world. The major reason was cited from the apartheid regime during which the Bantu Education Act that was put forth to regulate education. The Act ensured that whites received a better education in relation to the blacks, making education inequitable. This system has had a toll on the education system of South Africa since. Even though education was expanded to reach the rural areas after Nelson Mandela assumed presidency in 1994, South Africa does not seem to have overcome the challenges of its education system.

The South Africa Schools Act 1994, Act 84, which has an aim of making quality education accessible to all learners, seems not to get right what is meant by 'quality education.' The current economic situation reflects the consequences of South Africa's education system and the need for review of the policy that underpins the education system. South Africa recorded the higher number of young people who are neither employed and not in education or training (NEET). South Africa had about 38% of people who fell in the bracket of NEET. The OECD in their Reviews on Vocational Education and Training: A Skills beyond Review of South Africa, 2014 made this revelation.

World Bank's data on the South Africa Economic (Innovation for Productivity and Inclusiveness, pp. 22) update divulged that the lack of skilled workers in South Africa accounted for the loss of productivity in the country in recent periods. This was reflective in the surge in unemployment by skill data of South Africa recorded from 2008-2017 by StatsSA and compiled by the World Bank. Per the report, unemployment by skills level and duration was approximately 4 million in 2008. The figure surged to about 6 million in 2017.

The database from the OECD's Education at Glance (EAG), 2018 enumerated that the education in South Africa was characterized by some challenges. Per the report, tertiary education achievement in South Africa is yet low since as narrow as 6% young adults achieved the feat in 2017. This was the lowest share among OECD and partnering countries. In addition, between children at the ages of 5-14 years, 16% have not ever been enrolled in education but the enrolment is almost universal for children in this age bracket in most OECD and partnering countries. Similar to the NEET data shown above relating to 2011, South Africa had the highest rate of young people between the ages of 20-24 who fall in the NEET group compared to other OECD and partnering countries. South Africa's educational attainment statistical bulletin for people who are 25 years and above from 1996 to 2016 is provided in Appendix A2.

In the 2015 Trends in International Mathematics and Science Study (TIMSS) according to reports of Mullis, Martin, Foy, & Hooper, 2015, South Africa took the last to bottom position in Mathematics though marks improved in comparison to 2011.

"The National Advisory Council on Innovation" presented a similar data but also showing the fact that South Africa took the last to bottom positions in both Mathematics on both the 4th grade and 8th grade levels. The report sparked another form of controversy, as SA seems to have a continual grapple with poor performance in mathematics and science.

In order to obtain wholesome interpretation of the reports, it is worthwhile to stress that 39 countries participated in 2015 for grade 8 and 48 countries participated at grade 4. TIMSS normally uses five key 'international benchmarks' to scale the scores. These benchmarks are named and scaled in the following order: Advanced (above 625 points), High (550 to 625 points), Intermediate (475 to 550 points), Low (400 to 475) and Not Achieved (less than 400).

In the case of SA, the Human Sciences Research Council (HSRC) introduced one more benchmark that is 'Potentials' to account for the scores between 325 to 400 points in a bid to identify and target learners with the potentials for shifting upward to a higher benchmark. As a result, the Not Achieved benchmark is for less than 325 points as opposed to 400 in an ordinary context.

At the 9th grade level, SA achieved a national average score of 372 points for mathematics (representing the 38th position out of 39 countries) and 358 points for science (representing the last position). Concerning the 5th grade mathematics (Numeracy of TIMSS), SA attained 376 points (which makes up for the 47th out of 48 countries.

The deficiency in the South African education system has been tagged the sole substantial impediment to South Africa's economic viability and advancement by many pundits. The education system seems not to have resuscitated from the consequences of the Bantu education system. It has failed to equip students with basic skills and the distinguished core competencies needed for organizational work. In an article titled 'EDUCATION' and written by USAID, underperformance of teachers was cited as one of the main challenges of the education system in South Africa. Majority of the 420,608 teaching staff in South Africa as at 2018 had low content knowledge and lacked the necessary pedagogical skills required for delivering lessons thus, contributing to the current state of the low-quality education in the country. The article also revealed that though South Africa has made remarkable strides in the provision of access to schooling, with 98.8% of children between the ages of seven years to fourteen years enrolled in schools, the country has yet failed in providing quality education in its 25,851 schools.

The flaws in the education system sparks crime, contravenes poverty alleviation and thereby threatens the stability of the country. In the article, Analysis: South Africa's deficient education system, Michael Morris (2018) points out the following three points as the key problematic issues with the education system of South Africa.

- Poor mathematics education throughout the country with the figures being worse in the poorest quintile of schools.
- The under enrollment of tertiary education among the black people who serve as the majority of the total population. Concerning this, Cronje said, "it is futile to think that significant middle-class expansion, let alone demographic transformation, will take place as long as the higher education participation rate remains at around 15% for Black people".
- The high schools dropout rate among students in South Africa.

It is nearly above half of the students who usually complete high schools and the ones who dropout mostly do not enroll in any training institution (a feat that has contributed to the increase in the number of people in the category of NEET over the years). This is not in any way encouraging for a country whose growth has remained barely flat since 2007 (0.3% growth in 2016 and 0.8% growth in 2018) and is trying to evolve by focusing on the tertiary industry that demands high skilled labour force.

Improvement in the education system is an essential prerequisite for South Africa's transformation from the Bantu education system, producing the needed skilled labour force and curbing poverty to the barest minimum if not outright alleviation.

III. 1.2. Developmental Discourse in South Africa's Education System

The problems in the education system have not gone unnoticed by the government of SA. Ongoing attempts are been made to help rectify the deficiencies in the education system and the challenges that have bedeviled the country's education for several years. The government has prioritize education as the biggest problem the country is facing. This has been accompanied by an increase in the government's budget allocation for education. Between 2001 and 2018, education alone took on an average, 18% to 20% of total government expenditures. This figure amounts to 5% to 6% of GDP, making the lion's share of total government spending. In 2001 alone, the government invested about 20.5% of the country's total spending in education- a figure that in relative terms is one of the highest figures internationally. Secondary school and post-secondary education enrollment have both increased in recent periods with post-secondary enrollment rising from 8.9% to 15.2% between 2001 and 2015.

Table 1. 1 Headcount Enrolment in Public Higher Education by Race, 2008-2013

	2008	2009	2010	2011	2012	2013
African	515,085	547,686	595,963	640,442	662,123	689,503
Coloured	51,647	55,101	58,312	59,312	58,692	61,034
Indian	52,401	53,629	54,537	54,698	52,296	53,787
White	178,140	179,232	178,346	177,365	172,654	171,927
Total	799,490	837,779	892,943	938,200	953,373	983,692

Source: Council on Higher Education (World Education News and Review-WENR)

The education system in South Africa is divided into elementary, secondary and tertiary. Hitherto to 2009, all the three systems were under the responsibility and guidance of the National Department of Education. This partially accounted for the deficiencies and inefficiencies in the education system due to poor management and regulations.

Since 2009, different bodies have been deployed to oversee the management of the various subdivisions in the education sector in a bid to enable the government focus on the various sections of the country's education. The Department of Basic Education (DBE) manages the elementary and the secondary education systems, while the Department for Higher Education and Training (DHET) manages the post-secondary education systems, which incorporates post-secondary technical and vocational training and academic institutions.

Since the split of the management of the various education sectors, DBE has carved a clear educational path by setting goals and objectives that include improving the quality of teaching, undertaking regular assessments, improving early childhood development and ensuring a system of goal-achievement accountability.

1.2.1. Technical Education

Aftermath the split, tertiary enrollment and enrolment in Technical /Vocational Education and Training (TVET) has appreciably increased. From 2010 to 2014 alone, university-level institutions had a 13% increase in enrollment, which is from 983,703 to roughly 1.1 million students. The TVET institutions had nearly a double in enrollment from 2010 to 2014, from 405,275 to 781,378.

Respective to the high rate of unemployment in the country, TVET has become of huge strategic importance to the South African government. Enrollments have increased considerably in recent times. Out of the 781,378 of the students enrolled in TVET, 362890 of them were enrolled in the vocational education.
The government of South Africa has targeted expanding the TVET sector in an attempt to address the problem of lack of skilled labour force. In 2015, DHET took over the management and administration of 50 public TVET institutions to assist cater for the economic needs of for skilled labour.

1.2.2. Teacher Training Education

Aftermath South Africa's dire need of teachers cannot be taken for granted. A recent study conducted by Centre for Development and Education showed that the country would need as many as 30,000 teachers in addition to the current teacher corps by 2025. The government's investment in teacher training education has been massive, leading to an increase in the number of teacher trainee graduates from 5939 to 13708 between 2008 and 2012. The DHET expects public universities to produce about 30,000 teachers in 2019 alone.

The conventional prerequisite for teachers in South Africa is a Bachelor of Education Certificate, which is usually earned after a four-year study of a university program that includes a year internship in teaching. Alternatively, holders of a non-teaching education certificate can read a year post-secondary Advanced Diploma in Education. After the attainment of the necessary certification, qualified people must register with South African Council for Educators (SACE).

According to the database of World Bank, trained teachers in preprimary and primary education constituted 77.9% of the total population of teachers in South Africa in 2002, an increase of 10.3% from the figure in 2001 that was 67.6%. The reflection was also clear in the people-teacher ratio for preprimary bettering from 32.029 in 2013 to 29.644 in 2014 and that of primary bettering from 32.768 in 2014 to 30.332 in 2015. The people-teacher ratio for secondary education saw a slight improvement from 27.782 in 2015 to 26.848 in 2016 (World Bank Data). The indication is that, in the course of South Africa's progress in education, more attention has been paid to the primary education as against the lower and upper secondary and the tertiary. The lecturer to student ratio in the public TVET became worse from 1:47 in 2011 to 1:64 in 2013 (Centre for Development and Enterprise, 2016).

According to (Centre for Development and Enterprise, 2016), South Africa has two options in filling the skills gap. The first is to ensure that its citizens are equipped with formidable knowledge and skills needed by industries and for economic growth. The second is for South Africa to fall on skilled labour from abroad.
With the current statistics and state of the South African education, which lacks potential teacher corps who have the pedagogical skills to impart knowledge, the second option proves more feasible and can substantially contribute to the realization of the first option and improvement in the economic growth of the country, which would also ease the surging unemployment levels.

II. RELATED LITERATURE REVIEW

A broad-gauge analysis of the empirical framework of how education and technology contributes to the economic growth of several countries was drawn through inferences from the available literature.

IV. 2.1. Empirical Evidences of Education's Contribution to Economic Growth

(Amir, Khan, & Bilal, 2014), employed the Cobb Douglas production function and time series data to assess the role of educated labour force in economic growth of Pakistan and concluded that there is a long run positive relationship existing between human capital and the economic growth of Pakistan. They took sides with Abbas (2000; 2001) who propounded that human capital was paramount in the usage of physical capital since a rise in a country's human capital stock will propel investments in physical capital to cause a surge in output.

In his paper, "Level and Growth Effects of Human Capital: A Cross-Country Study of the Convergence Hypothesis", Kyriacou (1991) asserted that innovative human capital was on ascendancy and influenced the total factor productivity of a nation. He drew a conclusion that the economic growth and income levels of a country are influenced by human capital both qualitatively and quantitatively.

Benhabib and Spiegel (1994), when estimating human capital as a determinant for technology adoption used the Ordinary Least Square regression (OLS) and average years of school as suggested by Kyriacou (1991) as the human capital proxy. The results achieved was that changes in the years of schooling were not positively correlated with economic growth, however, there was a proof that human capital affects innovation and the diffusion of technology.

(Fuente and Doménech 2006) conducted a study about the relationship between production and human capital, both in level and in first-order differences and concluded that there exists a positive and significant statistical correlation as also opined by (Temple & Atkinson, 1999) in their paper, The New Growth Evidence.
McGivney and Winthrop (2016), divulged in a series of OECD data for the period of 2013, that an estimated 30% of the aggregate productivity differences that is seen between countries can be linked to the level of skills

utilized by workers in performing their tasks. Contrariwise, the system of education is not yielding graduates with skills required by firms. Skills are rapidly being used in the measurement of the success of education systems instead of only school attainment or progression or both.

Meanwhile, the imbalances in skills that cut across various countries has revealed the low quality level of education seen in most countries. To address the laxity of education systems in promoting the requisite skills needed by firms, it is significant for education and the human capital market to agree on the types of skills vital for stimulating productivity (McGivney and Winthrop, 2016).

To highlight the correlation between human capital and economic growth in Romania, Pelinescu (2014) adopted the approach of Hanushek (2013), and Fuente and Doménech (2000). He applied a panel model and arrived at the conclusion that there is a positive correlation that is statistically significant between the innovative capacity of human capital and the GDP per capita (indicated by the number of patents) and proficiency of employees (secondary education) as surmised in accordance to economic theory.

(Jesus Crespo, 2005) analyzed the emergence of educational attainment distribution by OECD countries. He analyzed three sets of data from (Barro-Lee, Cohen-Soto and De la Fuente-Doménech). His results showed contradictions in the conclusions of the emergence and existence of the convergence of educational achievement and countries that are industrialized.

(Doraisami, 2015) postulated that the short supply of skilled labour which drives knowledge-based economy should be urgently addressed. She attributed the inability of Malaysia to attain the 'developed country' status is partly because about 80% of the Malaysian workforce had obtained only secondary school certification.

Hanushek and Woessmann (2009) asserted in their article that the dingy level of cognitive skills attained by Latin American countries has a hand in their dismal growth achievement from 1960. They further contended that for Latin America and impliedly Sub-Saharan Africa to ameliorate their growth rate, they require a "Millennium Learning Goal" as suggested by Filmer, Hasan, and Pritchett (2006) instead of setting just quantitative earmarks for educational achievement. They concluded that economic growth is not achieved through merely going to school but through actual learning.

(Čadil, Petkovová, & Blatná, 2014), in their study of human capital, economic structure and growth, concluded that generally, human capital cannot be considered and classified as a positive factor for growth in the European Union region. Ramos et al. (2009) drew similar conclusion that higher endowment of human capital is not a warranty for growth or development and low unemployment but even the contrary could be true.

(Chakraborty & Krishnankutty, 2012), in their paper, "Education and Economic Growth in India" that was conducted on four different states arrived at the findings that there exist a positive effect of the state's expenditure on education and economic growth. Further, their studies revealed that there was a negative relationship between expenditure on education as a percentage of total government expenditure and economic growth.

(Muktdair-Al-Mukit, 2012) conducted a study to determine the existing functional correlation between government expenditure on education and economic growth in Bangladesh from 1995 to 2009. The study after being subjected to unit root test to ascertain its stationarity supported the null hypothesis that there existed a positive relationship between government expenditure on education and economic growth.

In the paper the link between educational levels and economic growth, a study that estimated the impacts of three levels of education on economic growth in Greece from 1960 to 2009, (Pegkas, 2014) arrived at a finding that there was a positive relationship between secondary and higher education and economic growth.

(Ozturk, 2001) pointed out that education is in every regard an indispensable factor of the development of a country. A country's achievement of economic growth moves hand in hand with its investment in human capital. Education increases the output per labour, produces creativity and entrepreneurship in an individual and promotes the technological advancement of a country.

(Loening, Bhaskara & Singh, 2010) concluded in their study "Effects of schooling levels on economic growth: time-series evidence from Guatemala" that there is a high positive impact between human capital and the economic growth of Guatemala.

V. 2.2. Empirical Evidence on Technology's Contribution to Economic Growth

(Nelson and Philip (1966) are known to be the first to initiate and stress the role of human capital or labour in the adoption of technology and its resultant effect on economic growth.

Technology is both imperative for economic growth of a country and its sustainability. For example, Gordon (2002) postulated that the acceleration in technology particularly in the area of Information and Communication Technology (ICT) played a prominent role in the output growth in the US in the 1995s.

Edquist and Henrekson, (2017) made an estimation of the extent to which ICT and research and development (R&D) have benefitted the Swedish business sector. They used data of 47 diverse industries for the periods of 1993- 2012 to estimate the output elasticities. Their studies revealed that for most specifications there was a significant association between ICT and R&D capital and value added. Adopting the Weighted Least

Square estimation tool, they came out with the conclusion that ICT's contribution to value added growth increased from 0.9 percent to 1.5 percent.
In their paper, "Information technology and the Japanese economy", Jorgenson, Kazuyuki, and Motohashi (2005) drew an analysis of the aggregate economic statistics for US and Japan to ascertain whether the increasing rate of increasing economic growth emanating from the rising ICT investment in the USA could also be seen in Japan. Their results showed that the enlargement of investments in ICT software and equipment in USA during the final half of the 1990's, followed by surging growth of TFP in the IT-producing industry has an accurate equidistant in Japan.

(Erumban & Das, 2016) made concluding remarks in their paper "information and communication technology and the economic growth in India" that faster productivity contribution from service sectors that use ICT is the driving force for economic growth in India.

Talking about how technology has substantially contributed to the rapid economic growth of China since 1978, (Borensztein & Ostry, 1996; Hu & Khan, 1997; Jefferson, Rawski, & Zheng, 1992; Yusuf, 1994) revealed that TFP contributes 40% to GDP growth, roughly the same as that contributed by fixed assets investment in China.

(Takahito Kanamori and Kazuyuki Motohashi, 2009) used the framework and model of (Jorgenson and Motohashi, 2005) to make a rigorous comparison of the role of IT on the economic growth of Japan and Korea. They indicated that IT has had a massive contribution on the economic growth of Japan and Korea recounting from the 1990s.

(Arora and Bhundia, 2003) while analyzing the growth in productivity in the aftermath of the apartheid regime in South Africa realized that Research and Development played a minimal role in the TFP growth of South Africa after the 1994.

Ritchie (2005) claimed that the inability of Malaysia to reach the 'developed country' status was also as a result of the lack of technological upgrading needed to achieve the same magnitude of development of the East Asian Newly Industrialized Countries (NICs). He further noted that technological improvement is significant for the sustainability of development in a progressively broad based global economy.

In the paper, "The strategic role of technology in a good society" (Brey, 2018) maintained that in order to draw an assessment of how technology mainly shaped the quality of the society, there is the need for an all-inclusive and coherent framework. The framework would address three issues including how diverse designs of technologies foster the beneficial societal impacts. Further on under the subtopic of 'How technology shapes the society', he asserted that technology indeed helps in the configuration of the society and went on to define technology as products that are of engineering makeup and practically utilized in a society.

To him, technological outcome would most likely necessitate some other peripheral conditions in order for them to function effectively. For instance, an establishment of a subway station in South Africa would require a recharging machine and luggage-checking machine for it operate well. The peripheral and other background conditionality that must be met for the technology to function effectively would need human capital thus contributing to employment.

(Vu, 2013), concluded in the paper, "Information and Communication Technology (ICT) and Singapore's economic growth" that Singapore achieved economic growth through ICT and intensive efforts. In the econometric examination, the study found that there exist a positive link between intensive ICT usage and value added in the various sectors and that ICT played a significant role in the growth of Singapore.

"ICT and economic growth – Comparing developing, emerging and developed countries" was a paper that was written by (Niebel, 2018) to analyze the impact of ICT on economic growth in developed, emerging and developing economies over 1995 to 2010. The conclusion was that there is a positive linkage between ICT and economic growth since the findings revealed excess returns and spillover effects of ICT from ICT factor investments.

(Wang, 2011) drew a conclusion in his paper "Science & Technology Input and Economic Growth: An Empirical Analysis Based on the Three Major Coastal Economic Regions of China", that technical and scientific work force, expenditures on technological and scientific activities expenditures on research and development are closely related to economic growth. However, among the three factors, technical and scientific work force had the closest relation to economic growth.

(Şener & Saridoğan, 2011) concluded in their paper "The effects of science-technology-innovation on competitiveness and economic growth" that countries that have economic strategies and policies based on science, technology and innovation tend to have sustainable competitive advantage and great superiority in terms of global competitiveness and economic growth. In effect, scientific, technological and innovative advancement are the core driving factors of global economic growth, development and competitiveness.

III. METHODOLOGY

Methodology is an integral part of every research process. It spells out the methods used in the study. The model used in this research study is the Cobb Douglas Production Function Model. The model conceptualizes a combination of an amount of two or more production inputs and their resultant effect on production. The Cobb Douglas Production function is popular in the sphere of economics and has been used in diverse studies both at the international and national levels to gain a screenshot of the effects of the various factors of production on economic growth. Such studies include, Spigel and Benhabib (1994), Kyriacou (1991), Caballe and Santos (1993), Quadri and Waheed (2011), Barro (2001), Roberts (2002), Black and Lynch (1996), Glomm and Ravikumar (1992), and Hina et al. (2014).

The Cobb Douglas production function adopted in this study was developed by considering factor inputs such as labour, capital and technology. The available literature explored either the role of labour on the economic growth or the role of technology on the economic growth of a country. Regardless of the contributions of previous researches, our model considered technology as a factor input in addition to labour and capital to explore their related resultant impact on the economic growth of South Africa.

To ascertain the resultant effect of labour on economic growth of South Africa, we used Secondary School Education and Vocational Education as proxies. We then employed Total Factor Productivity to ascertain the contribution of technology on the economic growth of South Africa. We further established an interaction between secondary education and total factor productivity growth and an interaction between vocational education and total factor productivity to ascertain whether investments in the two variables conjointly would yield a positive effect on the GDP of South Africa.

We also agree that technology and computerized machineries have advanced, and necessitated economic growth in most countries-a particularly recent case of China and India- and such can be replicated in South Africa to contribute to economic growth.

Therefore, technology would raise the demand for creative, problem solving, and flexible workers in South Africa. Hence, our model suggests that increase in technology to supplant routine and manual tasks would carve a clear threshold for South Africa's education system to focus on training the human resources with the skills needed to complement automation to achieve economic growth.

3.1. Model Specification

We used the Cobb Douglas Production Model: taking into consideration labour, capital and technology as the factors of production. The linear regression analysis was adopted to estimate the relationship that exists between RGDP and the explanatory variables of South Africa as shown equation 3.2.

$$Y = \beta_0 + \beta_1 TFP + \beta_2 \log K + \beta_3 \log L + \mu \qquad 3.2$$

Y = Dependent Variable (RGDP)
β_0 = Constant Variable
TFP = Total Factor Productivity
K = Capital
L = Labour
μ = All Other Unexplained Variables

We anticipated realizing a commendatory correlation between the independent variables and the RGDP of South Africa. Linear regression analysis is a predictive type of analysis that seeks to study and explain the relationship between two quantitative variables.

3.1.1. Interaction Term

Interaction term is used to assess the combined impact of some explanatory variables on the dependent variable. An interaction between secondary school education and TFP was determined to deduce the representation of their combined effects on the RGDP of SA. Further, we determined an interaction between VPS and TFP to extrapolate their combined effects on the RGDP of SA. The introduction of the interaction term resulted in the equation shown in 3.3.

$$Y = \beta_0 + \beta_1 TFP + \beta_2 \log K + \beta_3 \log L + \beta_4 \log SEP * TFP + \beta_5 TFP * \log VPS + \mu \qquad 3.3$$

3.1.2. Data

Our Cobb Douglas Production Model used dataset from the World Bank Indicators and covered 30 years from 1988 to 2017. The study considered explanatory variables including Total Factor Productivity (TFP), vocational education, labour force, capital, secondary school education, interaction between TFP and SEP and an interaction between TFP and VPS. The TFP of SA from 1998 to 2017 can be found below in Appendix B2. Statistical figures of general and vocational education pupils of SA from 1998 to 2016 is shown in Appendix A3.

The choice of periods and selected sample inclusion were largely based on availability of dataset on the South African economy and the extent to which we desire to obtain accuracy in our analysis. Data on TFP was drawn from the Penn World database. A few of the variables had incomplete data.

Table 3. 1: Descriptive Statistics of Data

Variables	Description	Mean	Standard Deviation	Min	Max
loggdp	Real Gross Domestic Product (US$)	26.42	0.25	26.10	26.78
loglabour	Labour force	16.57	0.33	15.54	16.91
logcapital	Capital	20.21	0.36	19.42	20.99
TFP	Total Factor Productivity	0.99	0.04	0.92	1.07
TFPlogSEP	Interaction of Total Factor Productivity and Secondary Education Pupils	14.82	0.97	12.02	16.02
TFPlogVPS	Interaction of Total Factor Productivity and Vocational Pupils, Secondary	11.19	1.64	8.12	13.05

Note: ***p<0.01, **p<0.05, *p<0.1, Critical value at 1%: -3.723; critical value at 5%: -2.989; critical value at 10 %: -2.625

The summary statistics give a representation of the univariate data used in the empirical analysis of this paper. The mean values show the average and unbiased estimate for the variables used in our research for the periods under study (1988-2017). The values shown in the standard deviation depict how the values of each variable is spread out from the mean.

For instance, the RGDP had a mean of 26.42 (300 billion dollars). This implies that on the average SA recorded 300billion in GDP from 1988 to 2017. The mean of the labour force of SA for the period understudy was approximately 16.57 (17.1 million) implying that the average value for labour force of SA between 1988 and 2017 was 17.1 million. The mean of 20.21 (636.1 million) for capital expounds that the average capital for SA from 1988 to 2017 was 636.1 million.

IV. ANALYSIS OF RESULTS AND DISCUSSIONS

The study empirically tested the complementary role of quality education and technology on the economic growth of South Africa by making use of time series data variables over the periods 1988-2017.

Using time series requires that data variables be previously tested to ensure their stationarity. As a result, all data variables used in the research were tested using the Augmented Dickey Fuller unit root test to examine their levels of stationarity. Three variables out of the six variables studied remained stationary after first differentiation while the remaining three were nonstationary, as shown in Table 4.1 below. All data variables used in the study were converted into their logarithm forms to avoid heteroscedasticity problems usually associated with different units of measurement for data variables over a range of values.

Table 4. 1: Stationarity Test Estimation Results

Variables	First difference	Integration order (I)
loggdp	0.471	I(1)
loglabour	-3.906***	I(1)
logcapital	-2.201	I(1)
TFP	-1.184	I(1)
TFPlogSEP	-1.990**	I(1)
TFPlogVPS	-2.502***	I(1)

***p<0.01, **p<0.05, *p<0.1, Critical value at 1%: -3.723; critical value at 5%: -2.989; critical value at 10 %: -2.625

The stationarity estimates show that log labor and the interaction terms, i.e., TFPlogSEP and TFPlogVPS were all stationary after first difference and significant at the 1% and 5% levels while loggdp, TFP, and logcapital showed no stationarity after first differencing.

Time series is associated with seasonal fluctuations, and independent variables are susceptible to high levels of multicollinearity among each other. After taking the logarithms of each variable, we conducted a further test to ensure the reliability of the dataset and the estimation results. Multicollinearity and tolerance tests were carried out to ensure the robustness of the data variables and the estimation results. The problem of multicollinearity arises when one explanatory variable in a multiple regression model highly correlates with one or more than one of the other explanatory variables. It is a problem because it underestimates the statistical significance of an explanatory variable (Allen, 1997). High correlation independent variables will result in a large standard error. This will make the corresponding regression coefficients unstable and statistically less significant.

The correlation matrix results, as reported in Table 4.2 above, revealed moderate and low multicollinearity among the explanatory variables. The highest score is 0.76, which reveals a high correlation between the interaction of TFP and SEP and the interaction with TFP and VPS. The correlation results also showed a high correlation between RGDP and labour (0.75), capital and TFP (0.61), TFP and the interaction with TFP and SEP (0.68).

The multicollinearity matrix indicated that RGDP and capital, RGDP and TFP, RGDP and interaction of TFP and SEP, labour and the interaction of TFP and SEP, capital and the interaction of TFP and SEP and capital and the interaction of TFP and VPS showed very low multicollinearity.

The general rule of econometrics states that these high levels of multicollinearity are likely to bias the estimate results in order to ascertain further the degree of correlation among the variables. The variance inflation factor (VIF) of the independent variables was computed to ascertain their degree of correlation. A VIF of 10 indicates the presence of high multicollinearity. A VIF below 10 is considered moderate multicollinearity, and a VIF below 5 shows a low correlation among the independent variables (Hamilton, 2009). As shown in Table 4.3, labor, capital, TFP all showed low multicollinearity while TFPlogVPS and TFPlogSEP showed moderate degrees of correlation.

Table 4. 2: Correlation Matrix of the Variables Used in the Analysis

	Loggdp (1)	Loglabour (2)	Logcapital (3)	TFP (4)	TFPlogSEP (5)	TFPlogVPS (6)
1	1.0000					
2	0.75	1.0000				
3	-0.16	-0.56	1.0000			
4	-0.27	-0.53	0.61	1.0000		
5	-0.04	-0.18	0.29	0.68	1.0000	
6	0.44	0.33	-0.13	0.31	0.76	1.0000

Table 4. 1: Variance Inflation Factors

VARIABLES	VIF
TFP log VPS	5.68
TFP	3.33
TFP log SEP	6.03
Log capital	2.08
Log labor	2.65
MEAN VIF	3.95

Table 4. 2: Estimation results of the complementary role of quality education and technology on the economic growth of South Africa

VARIABLES	LINEAR REGRESSION
LogLabor	0.450*** (3.96)
logcapital	0.377*** (4.13)
TFP	-0.639 (-0.56)
TFPlogVPS	0.131*** (3.97)
TFPlogSEP	-0.178*** (-3.08)
Constant	13.138*** (4.60)
R-Squared	0.7946
Adjusted R-Squared	0.7519
Number of Observations	30

Note: Significance level: *** p<0.01, ** p<0.05, * p<0.1. In parenthesis are the t-statistics for the coefficients

Table 4.4 reports the OLS linear regression results for the research study. The model had the expected goodness of fit with Prob> F=0.0000, R-squared of 0.7946, and Adjusted R-squared of 0.7519. The Prob > F value of 0.0000 means the explanatory variables reliably predict the dependent variable. The independent variables used in the study had the explanatory powers to explain the proportion of variations in the dependent variable, as reported by the R-squared and Adjusted R-squared. All the variables except TFP (which was not significant), were significant at the 1% level but vary in their coefficient signs.

The study predicted a positive and significant relationship between real gross domestic product and the independent variables. However, the estimation reported mixed results contrary to the theories of Cobb Production in the case of SA.

This coefficient of labor was 0.450 and significantly positive at the 1% level. This implies that there exists a positive relationship between labor and RGDP. In effect, if the labor force of SA increases by a percentage point, the resultant effect on RGDP will be 0.450%. This result supports the literature of (Amir, Khan & Bilal, 2014; Fuente and Doménech 2006; Chakraborty & Krishnankutty, 2012; Pegkas, 2014).

The empirical results show that capital is significant at 1% significance level with a relative coefficient of 0.377, which suggests that capital positively influences RGDP in SA. A 1% point increase in capital would contribute to an increase in RGDP by an estimated 0.377%. Real capital injection into an economy stimulates investment and economic activities. This, in turn, increases real gross domestic product. The result is consistent with the literature (Abbas, 2000; 2001).

The total factor productivity was statistically significant at the 1% but reported a negative coefficient of -0.639. The coefficient shows a negative correlation between TFP and RGDP of SA. The result supports the disclosure made by the Global Competitiveness Index of SA concerning technological readiness and innovation pillars provided in Appendix C below. It is consistent with the literature (Arora and Bhundia, 2003; Labour Market Review, 2005; Kem, 2007; IMD World Competitiveness Center Report, 2015). In addition, the value of SA high technology manufacturing exports has seen a decreasing and inconsistent trend over the years. This is shown in the High Technology Exports data shown in Appendix B1 below. The TFP statistics provided in Appendix B2 also show decreases in the TFP values of SA in recent years.

The coefficient for the interaction term between TFP and VPS was 0.131 and statistically significant at the 1% level. This result shows that a conjoint investment in TFP and VPS would yield a robust maximum impact on the RGDP. The results also support the claims of (Benhabib & Spiegel, 1994; Kyriacou, 1991) that educated human capital affects innovation and the diffusion of technology.

The interaction between TFP and SEP was significant at 1% significant level. The coefficient for the interaction between TFP and SEP was however -0.178. This divulges an inverse correlation between the interaction of TFP and SEP and the RGDP of SA. A conjoint investment of TFP and SEP would not produce the needed resultant positive effect on the RGDP of SA.

This may be due to the current state of SA's economy; the country's economy is driven mainly by the industrial and service sectors. Industry (including manufacturing) contributed about 38% of added value as a percentage of GDP in 2017 while the service sector contributed about 62% of added value as a percentage of

GDP (World Bank, 2019). Any investment made in SEP will have little impact on the country's overall GDP unless investment in SEP is aligned to areas that will contribute to total factor productivity.

V. CONCLUSION

The research methods and estimation utilized in this study was the OLS linear regression to estimate the relationship between RGDP and the independent variables. The empirical results supported the literature review and was consistent with our claims and expectations. The results disclosure that about 79% of the variances in the RGDP could be explained by the explanatory variables fulfills the purpose of this research.

In sum, the variables supporting the economy of SA are labour and capital. These variables showed a positive relationship with the RGDP. Variables such as TFP and the interaction between TFP and SEP showed inverse relationship with RGDP, contradicting a long-standing assertion that technology and education contribute to economic growth. Notwithstanding, it also supports claims by (Kem, 2007) and the article of 'the Economist' posted in 2017 that South Africa's education system is worst among other countries. It also agrees with the work of (Arora and Bhundia, 2003) that TFP growth of South Africa after the 1994 played a minimal role in productivity, in the aftermath of the apartheid regime in South Africa. Nevertheless, the results showed a positive relationship between RGDP and the interaction between TFP and VPS.

We conclude by the results of our research that there exist a positive relationship between the interaction of total factor productivity and vocational education on the economic growth of South Africa. Relating to the results, vocational education and technology would play a complementary role on the economic growth of South Africa. The interaction between TFP and VPS was significant at 1% significance level and had a coefficient of 0.131 offering an explanatory power consistent with economic theories.

A conjoint strategic investment in vocational education and technology would yield a massive positive effect on the economic growth of South Africa. This conjoint investment in technology and vocational education must be accompanied by an investment in formal education. The long run causative effect would be labour force possessing the skills needed by industries, increased innovation and technological readiness for attracting businesses. The widening skills gap would be reduced, unemployment rate (refer to Appendix D) would be reduced to the barest minimum if not totally eradicated and poverty would be alleviated.

The interaction between TFP and SEP was significant at 1% significant level. The coefficient for the interaction between TFP and SEP was however -0.178. This divulges an inverse correlation between the interaction of TFP and SEP and the RGDP of SA. A conjoint investment of TFP and SEP would not produce the needed resultant positive effect on the RGDP of SA.

Any investment made in SEP will have little impact on the country's overall GDP unless investment in SEP is aligned to areas that will contribute to total factor productivity.

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