



Handelshögskolan
Karlstad Business School

JAKIN ELIKEM FUI YAW AHLIJAH

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Abstract

Ever since Ghana gained independence, its policy makers have identified education as a tool to foster economic growth and development. In recognition of the vast potential for national development that education presents Ghana, various governments have invested considerably in the sector. These investments have been in the form of educational sector reforms, as well as yearly reoccurring expenditure. Despite these massive investments however, very little work has been done to empirically investigate the impact of such expenditure on the nation's economy.

This paper uses data from Ghana to empirically assess the nature of the relationship between education expenditure (a proxy for human capital development) and GDP growth (a proxy for economic growth). The Granger Causality Test is applied to education expenditure and GDP growth data, from 2003 to 2018. Using data from this same time frame, separate Granger Causality tests are also implemented to test the relationship between Gross Enrollment Rates/ Total Completion Rates, at some levels of education, and GDP growth.

Interestingly enough, the analysis shows no Granger causal relationship between our main variables of interest (Total Education Expenditure and GDP growth). Results also show that none of the education variables Granger cause GDP growth, if the test uses 1 lag and also if the test uses 3 lags. Additionally, results show that whether the test uses 1 lag or 2 lags, GDP growth Granger causes the percentage of total government expenditure that is dedicated to education. Results for tests that use 2 lags also shows that the only education variable that Granger causes GDP growth is enrolment rate at the primary level, with GDP growth also not Granger causing any education variable apart from the percentage of government expenditure dedicated to education. In the case of the test using 3 lags, results show that GDP growth Granger causes only one education variable which is expenditure on the Senior High School level.

Keywords: Ghana, Education expenditure, Economic growth, Granger causality test

Sammanfattning

Ända sedan Ghana blev självständigt har dess beslutsfattare identifierat utbildning som ett verktyg för att främja ekonomisk tillväxt och utveckling. Som ett erkännande av den enorma potential för nationell utveckling som utbildning erbjuder Ghana, har olika regeringar investerat avsevärt i sektorn. Dessa investeringar har varit i form av reformer av utbildningssektorn, såväl som årliga återkommande utgifter. Trots dessa massiva investeringar har dock mycket lite arbete gjorts för att empiriskt undersöka effekterna av sådana utgifter på landets ekonomi.

Denna artikel använder data från Ghana för att empiriskt bedöma karaktären av sambandet mellan utbildningsutgifter (en proxy för utveckling av mänskligt kapital) och BNP-tillväxt (en proxy för ekonomisk tillväxt). Granger Causality Test tillämpas på utbildningsutgifter och BNP-tillväxtdata, från 2003 till 2018. Med hjälp av data från samma tidsram implementeras även separata Granger Causality-tester för att testa sambandet mellan bruttoinskrivningsfrekvenser/Totala slutförandefrekvenser, på vissa nivåer utbildning och BNP-tillväxt.

Intressant nog visar analysen inget Granger-kausalt samband mellan våra huvudsakliga intressevariabler (Total Education Expenditure och BNP-tillväxt). Resultat visar också att ingen av utbildningsvariablerna Granger orsakar BNP-tillväxt, om testet använder 1 tidsfödröjning och även om testet använder 3 tidsfödröjningar. Dessutom visar resultaten att oavsett om testet använder 1 tidsfödröjning eller 2 tidsfödröjningar, Granger orsakar BNP-tillväxt andelen av de totala offentliga utgifterna som är dedikerade till utbildning. Resultat för tester som använder 2 tidsfödröjningar visar också att den enda utbildningsvariabeln som Granger orsakar BNP-tillväxt är inskrivningsgraden på primärnivå, där BNP-tillväxten inte heller Granger orsakar någon utbildningsvariabel förutom procentandelen av de statliga utgifterna som är avsatta till utbildning. I fallet med testet med 3 tidsfödröjningar visar resultaten att BNP-tillväxt Granger orsakar endast en utbildningsvariabel, vilken är utgifter på gymnasienivå.

Nyckelord: Ghana, Utbildningsutgifter, Ekonomisk tillväxt, Granger kausalitetstest

Abbreviations

ADF	Augmented Dickey-Fuller
CPI	Consumer Price Index
DF	Dickey-Fuller
ESPR	Education Sector Performance Report
GDP	Gross Domestic Product
GER	Gross Enrolment Rate
GH¢	Ghana Cedis
ILO	International Labor Organization
JHS	Junior High School
LCU	Local Currency Units
MoE	Ministry of Education
NEA	National Education Assessment
NFED	Non-Formal Education Division
SHS	Senior High School
SPED	Special Education Division
TVET	Technical and Vocational Education and Training

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1 Introduction

Education is high on the agenda list of almost all governments and international organizations across the world. It enjoys this priority position because it is widely seen as a means to fight poverty and inequality, and consequently drive economic development. Ghana, like most other countries in the world places a high emphasis on the education sector. In fact, different governments in the years since the country's independence have invested heavily in improving the quality and accessibility of the education sector.

In spite of the substantial theoretical backing that the strategy of education driven development has gathered, empirical results are mixed. Various researchers studying different sets of countries over different time periods, have found different results: some like Narayan & Smyth (2004), and Rostow (1960) have found a relationship between education and economic growth, while others like Levine & Renelt (1992), and Bils & Klenow (2000) have found no evidence of such a relationship. In the case of Ghana specifically, very little empirical research has been done regarding this link between education and economic growth.

This paper therefore seeks to closely examine the relationship between Ghana's public education expenditure and its economic growth, using gross domestic product (GDP) growth rate as a proxy for economic growth. I conduct a bivariate Granger causality test between several pairs of variables: GDP growth and one of the other variables. In all, I study 14 variables, each measured over the 16 year period from 2003 to 2018.

1.1 Purpose of the study and study question

This study seeks to investigate if human capital (proxied by public education expenditure and other education quality indicators) causes economic growth (proxied by GDP growth) in Ghana. Essentially, I am seeking to answer the question "Is there empirical evidence to show that education causes economic growth in Ghana?"

1.2 Study Limitations

This study analyzes education expenditure, enrolment rates, completion rates, and GDP growth rate for Ghana within the period 2003 to 2018. This study only tests for the causal relationship

between the education and the economic growth proxy GDP growth, using already existing data and real expenditure values that I compute based on existing data.

1.3 Statement of hypothesis

Based on some previous research, my starting hypothesis is that education expenditure should result in GDP growth. In other words, human capital development should lead to economic growth.

1.4 Method

Using the Granger causality test, I investigate the relationship between public education spending (both total education expenditure and expenditure for various sub-sectors) and GDP growth, between enrollment rates at various educational levels and GDP growth, and between total completion rates at selected levels and GDP growth. In all, I analyze 13 pairs of variables, conducting separate analysis for 1, 2, and 3 lags.

1.5 Disposition

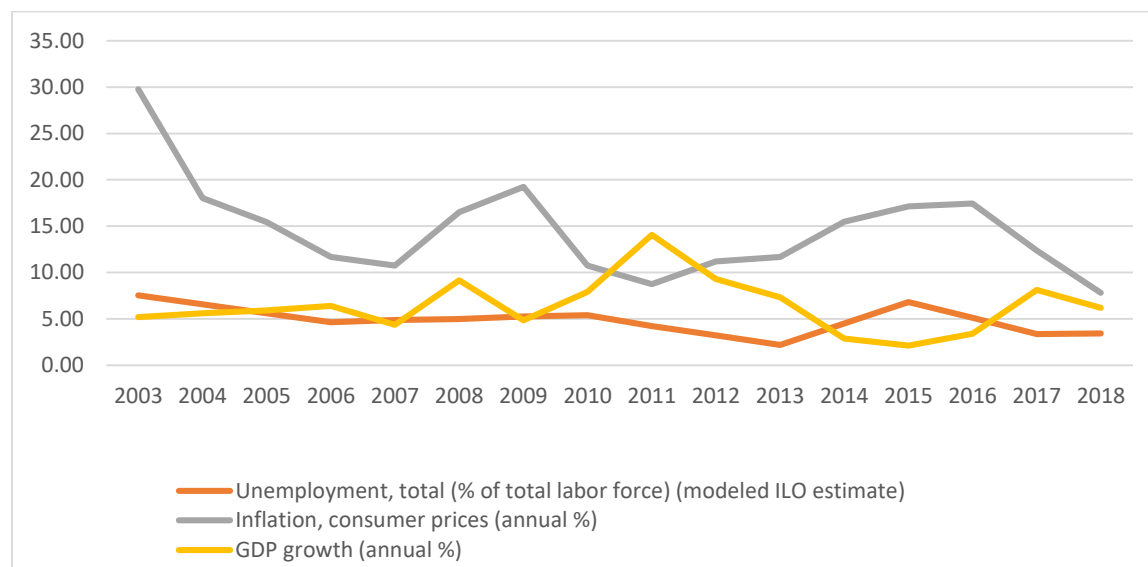
In the following sections of this paper, I first present a background about the Ghanaian Education Sector, highlighting some important information the sector. This is followed by a section that provides an overview of some related past research papers and concepts. Section 4 describes the data and methodology I used for my analysis. Section 5, gives an overview of the data used, and this is followed by Section 6, which presents the results and a discussion of the implications of the findings. Section 7 contains the conclusion, and the last part of this paper is dedicated to the reference list and an appendix, containing the raw data I use.

2 Background

2.1 Brief Overview of Ghana's Economic Performance from 2003 to 2018

According to the World Bank (2023), Ghana's real GDP, measured in constant local currency units (LCU), more than doubled from 2003 to 2018, growing from about GH¢ 60.7 billion to about GH¢155.2 billion. Within this same period, unemployment and inflation (based on consumer price index (CPI) changes) largely fell, even though both exhibit several peaks and troughs. GDP growth rate on the other hand generally increases, although it also exhibits some upward and downward motions. Starting at around 5.2%, GDP growth increases and falls a number of times before hitting a peak of about 14.05% in 2011. This is followed by successive decreases in growth rate, until 2015. Figure 1 shows the movement of these economic indicators from the year 2003 to 2018.

Figure 1: Trend Movements of Economic Indicators between 2003 and 2018



Source: Author's work using data from the World Bank (2023)

Within the period also, inflation falls from about 29.8% to about 10.7% in 2007, before peaking and dipping repeatedly. It finally reached a low of 6.2% in 2018. Unemployment (modeled International Labor Organization (ILO) estimate) also gradually fell from about 7.5% in 2003 to about 4.6% in 2006, before starting on an upward trend and peaking at about 5.4% in 2010. From then it follows a downward trend, before eventually hitting a low of about 2.2% in 2013.

Interestingly, the World Bank (2023) shows that unemployment levels among the educated are, in most cases, higher than the national unemployment estimates. For the all 5 years in this period that have data, the unemployment rates were higher among people with intermediate and those with advanced education. Table 1 below shows this data.

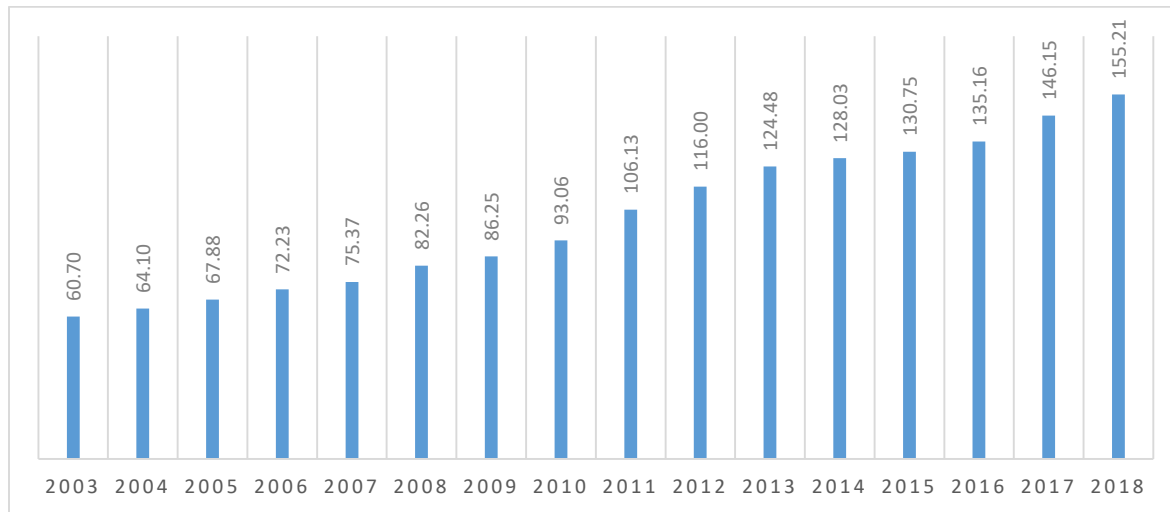
Table 1: Unemployment Rates among Classes of labor force

Year	Unemployment, total (% of total labor force) (national estimate)	Unemployment with basic education (% of total labor force with basic education)	Unemployment with intermediate education (% of total labor force with intermediate education)	Unemployment with advanced education (% of total labor force with advanced education)
2003	-	-	-	-
2004	-	-	-	-
2005	-	-	-	-
2006	4.9	5.54	13.29	5.07
2007	-	-	-	-
2008	-	-	-	-
2009	-	-	-	-
2010	5.38	5.44	10.44	7.8
2011	-	-	-	-
2012	-	-	-	-
2013	2.17	2.14	5.24	4.17
2014	-	-	-	-
2015	6.81	6.11	14.22	7.09
2016	-	-	-	-
2017	3.37	2.8	6.8	4.47
2018	-	-	-	-

(Source: Author's work using data from the World Bank (2023))

Furthermore, data from the World Bank (2023) shows that real GDP of Ghana, measured in 2013 GH¢, grew at the slowest pace in the period during 2015, when it recorded growth of about 2.1%. Ghana also experienced its fastest growth rate in 2011, when its economy grew by about 14%. Figure 2 shows the progression of real GDP over the whole period.

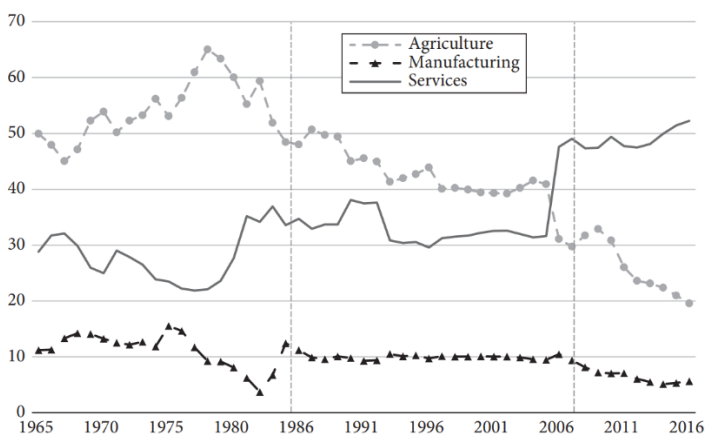
Figure 2: GDP (constant LCU) in billions of 2013 GH¢



Source: Author's work using data from the World Bank (2023)

Although Ghana attained lower middle income status by 2008, it has undergone little industrialization. Its services sector, on the other hand, has grown significantly. Between 2006 and 2016, its Agriculture sector shrank from around 31.1% to about 19.6% of GDP. Its Manufacturing sector also shrank from 10.5% to 5.6% within the same period. During this same time frame, both the Industry and Services sectors expanded, with the former increasing from 21.3% to 28.2% and the latter increasing from 47.6% to 52.2% (Diao et al. 2019). Figure 3 below shows the changes in the contributions of some sectors to Ghana's GDP over time.

Figure 3: Sector Shares of GDP



Source: Diao et al. (2019)

2.2 General Overview of the Ghanaian Education Sector

Since Ghana first gained independence, there has been a targeted drive to produce an educated workforce capable of propelling the country into middle income level. In the words of Kwame Nkrumah, the first president of Ghana, education for the newly independent Ghana was to achieve three goals: to be a tool for producing a scientifically literate population, for tackling mainly the environmental causes of low productivity, and for producing knowledge to harness Ghana's economic potential (Akyeampong 2010). The various governments that have led Ghana over these past 68 years have each placed emphasis on specific aspects of the education sector. With these different areas of focus have come several national educational reform policies, all ultimately geared towards improving the access and quality of education in Ghana.

The Ghanaian education sector, as it exists today, is predominantly shaped by the 1987 education reform. Under this reform, the government reduced the length of pre-university education to 12 years, to follow a 6-3-3 pattern. This means that Primary School education spans 6 years, while both Junior High School (JHS) education and Senior High School (SHS) education each last 3 years. This reform also led to the inclusion of practical courses into the array of formal academic courses offered in pre-university institutions (Kadingdi 2006).

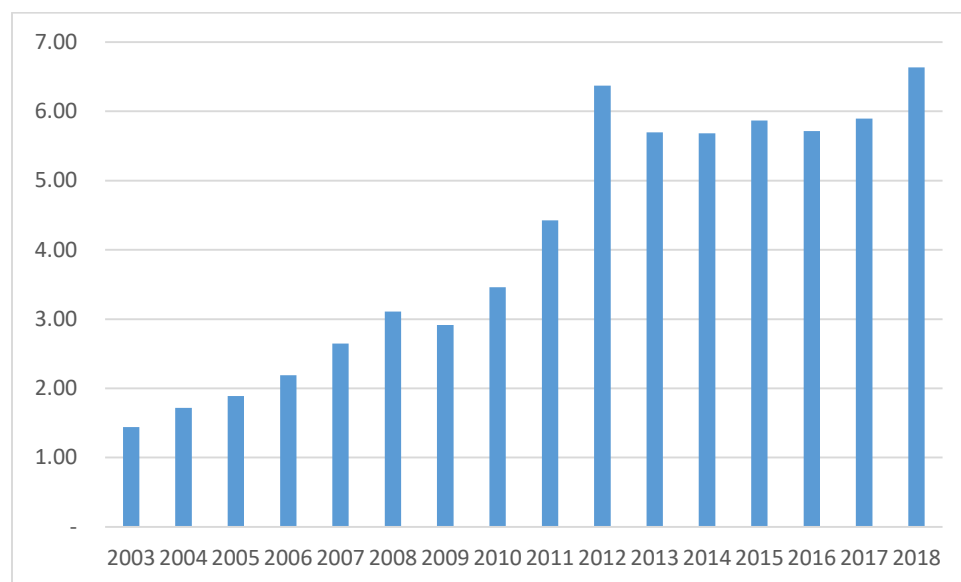
Currently, there are 3 main levels of formal education in Ghana: basic education, secondary education and tertiary education levels. The Free Compulsory Universal Basic Education Programme (FCUBE) of 1996, a constitutionally mandated charge of the 1992 Constitution, mandates every Ghanaian child to at least complete basic education (Kadingdi 2006). Typically, a child has to complete basic education by going through Kindergarten, Primary School and JHS. Successful graduates of the basic education level can then go on to pursue secondary education which is provided by either a SHS or a Technical and Vocational Education and Training (TVET) institute. Graduates of the secondary education level can then pursue tertiary education at any of the country's tertiary institutions.

2.3 Government Investment in the Ghana Education Sector

Data from MoE (2009, 2010, 2012, 2013, 2015, 2018, 2019) shows that the government of Ghana has generally increased its investment in the education sector over the years. From 2003,

real government spending on education increased from about GH¢1.44 billion to about GH¢6.64 billion. Expenditure increased in each year except for 2009, 2013, and 2016. Figure 4 summarizes education expenditure between 2003 and 2018.

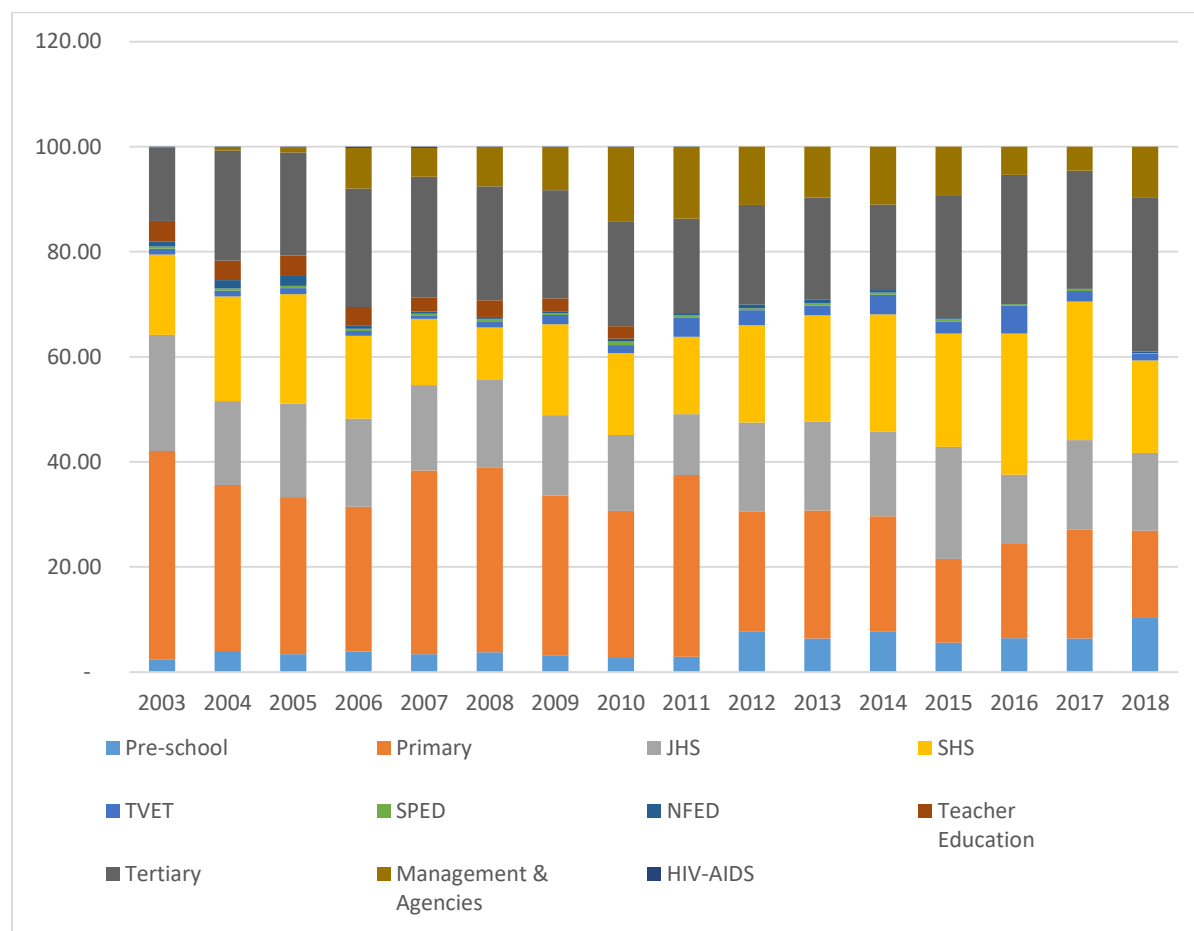
Figure 4: Real Educational Expenditure (in billions of 2013 GH¢)



Source: Author's work using data from MoE (2009, 2010, 2012, 2013, 2015, 2018, 2019) and the World Bank (2023)

According to the same documents, the government divides this expenditure between 11 subsectors of the education sector. The data shows that primary education consistently received a comparatively larger proportion of the expenditure from 2003 to 2013. Since then, SHS education and Tertiary education have enjoyed similar levels to that of primary education. For some reason, the government has not spent on the Teacher Education sector since 2011 and HIV/AIDS sector since 2012. Figure 5 below shows a detailed representation of the annual percentage distribution of real expenditure across these subsectors.

Figure 5: Distribution of Expenditure across the Subsectors of the Education Sector



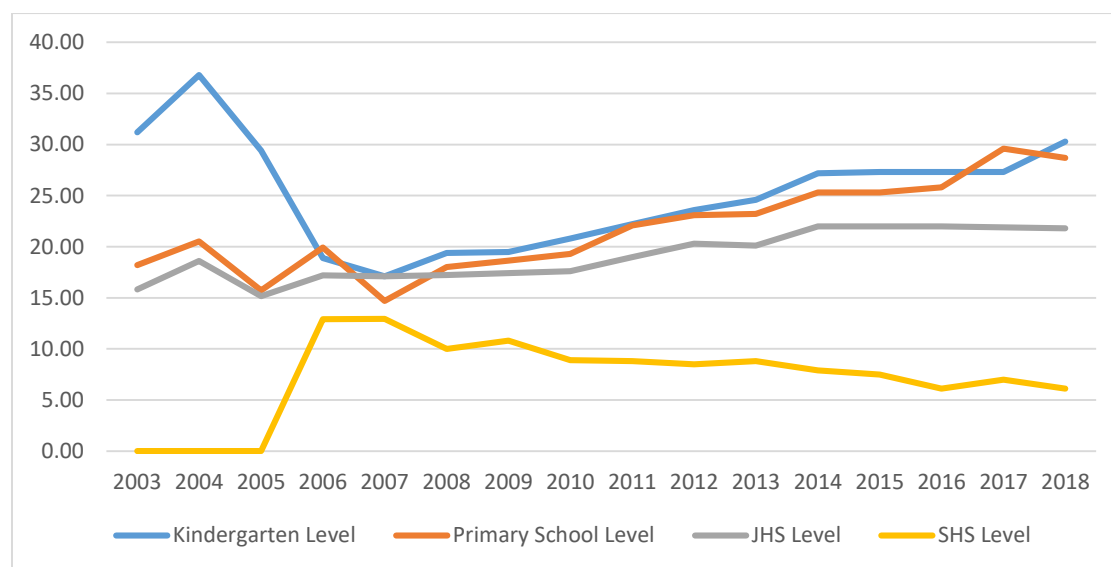
Source: Author's work using data from MoE (2009, 2010, 2012, 2013, 2015, 2018, 2019) and the World Bank (2023)

2.4 Private Participation in the Ghanaian Education Sector

Although Ghana's education sector is dominated by government institutions, there is still significant participation by private entities. Available data from MoE (2009, 2010, 2012, 2013, 2015, 2018, 2019) shows that private entities are especially significant players in the basic education sector. Measuring their contributions with the private enrollment as a percentage of total enrollment at each education level makes for a very interesting reading. Figure 6 below

shows the changes in this measure between 2003 and 2018. Note that the above mentioned sources do not provide information about SHS enrollment for 2003 to 2005.

Figure 6: Percentage of Private Enrollment

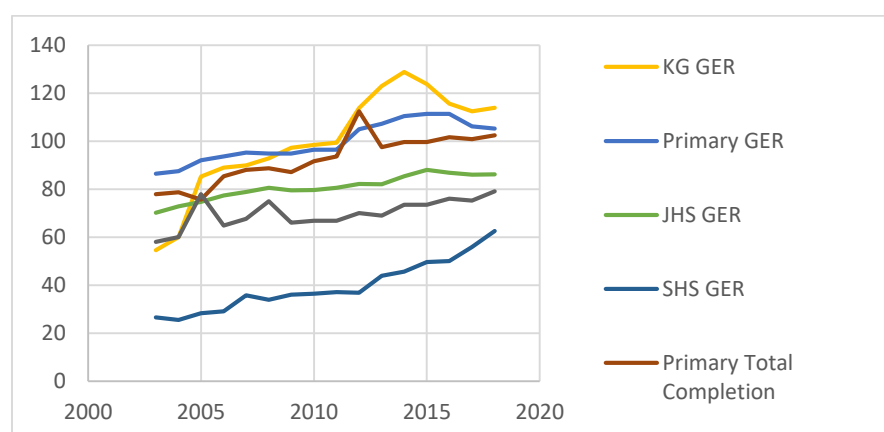


Source: Author's work using data from MoE (2009, 2010, 2012, 2013, 2015, 2018, 2019)

2.5 Quality of the Ghanaian Education Sector

Over time, access to education in Ghana has largely improved. According to data from MoE (2009, 2010, 2012, 2013, 2015, 2018, 2019), gross enrollment rates across the kindergarten, primary school, JHS and SHS levels have generally increased. Total completion rate at the primary school and JHS levels have also generally improved. Figure 7 below shows the changes in these measures within the period from 2003 to 2018.

Figure 7: Some Indicators of Quality in the Education Sector (in %)

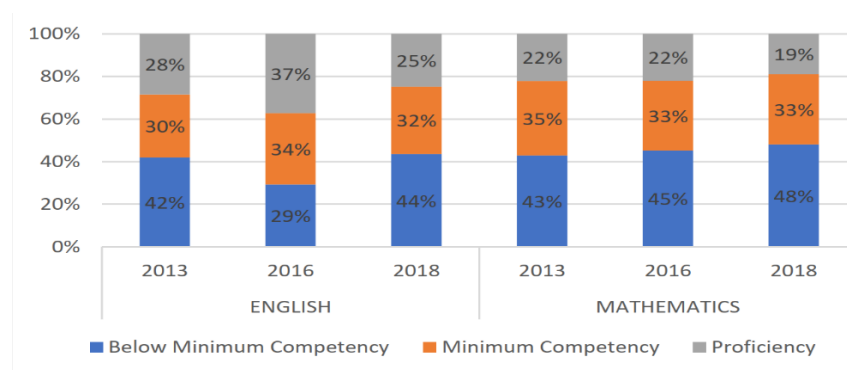


Source: Author's work using data from MoE (2009, 2010, 2012, 2013, 2015, 2018, 2019)

Beyond these measures however, the reports show that there is still a lack of quality aspects of the sector. MoE (2019) observes that Ghana placed a lowly 116th out of 157 countries in the World Bank's 2018 Human Capital Index. The report further highlights that the low position was due to the fact that children born at the time are expected to attend school for 11.6 years while only attaining 5.7 years' worth of knowledge. Equally alarmingly, it concludes that only 44% of children born then are estimated to become productive by the time they reach adulthood.

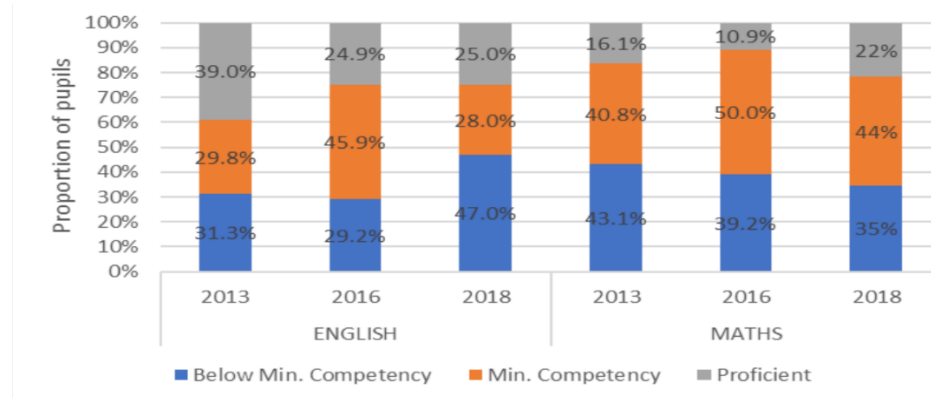
Furthermore, MoE (2019) shows some unflattering results for the National Education Assessment (NEA), a measure of the English and Math skill level of primary school students in Ghana. The results from the last 3 editions of the assessment highlight the low quality of Ghana's primary education sector, and lack of improvement in this quality. Figures 8 and 9 summarize the results.

Figure 8: NEA Results for Primary School Year 4 Students



Source: MoE (2019)

Figure 9: NEA Results for Primary School Year 6 Students



Source: MoE (2019)

This is further supported by findings from the Early Grade Reading Assessment (EGRA) and Early Grade Mathematics Assessment (EGMA). Conducted in 2015, they revealed that over 90% of primary year 2 pupils do not have foundational reading skills, and do not have mathematical skills beyond the most procedural level. According to this assessment, an estimated 350,000 to 400,000 pupils (65% of sixth-grade students) leave primary school without reaching proficiency in English or mathematics (MoE 2019).

3 Literature Review

3.1 General Link between Education and Economic Development

The World Bank (2019) defines human capital as being comprised of the knowledge, skills, and health that people accumulate throughout their lives, enabling them to realize their potential as productive members of society. According to the organization, the world can end extreme poverty and create more inclusive societies by developing human capital, with investments in various aspects of people's lives: nutrition, health care, quality education, jobs and skills.

Considering the aspects of human lives in question, it is little surprise that education is such a valuable tool of human capital development. An effective education system, one that provides both quality formal and informal training, has the potential to directly, and indirectly, affect the nutrition, health care, jobs and skills of people. Though human capital theory focuses on both the education and the health of the individual as an input to economic production, human capital development (proxied by expenditure on education or training) refers to the acquisition and an increase in the number of persons who have the skills; knowledge; and experience and are critical for the economic growth of a country (Adelakun 2011).

In this paper, I particularly focus on human capital development and its relation to economic growth and development. Arrow et al. (2004) define development as “meeting the needs of the present without compromising the ability of the future generation to meet their own needs”. Essentially, this means that in the pursuit of development, countries have to strive for a balance between catering for present needs and protecting the interests of future generations. One possible justification for this view is that a country's resources are not gifts to its children but are loans from them (Osiobe 2019). Another explanation could be that the each present generation is responsible for providing resources for its descendants, just as parents responsible for their children. Viewing these possibilities in relation to development reveals how important human capital could be for development. Human capital development, which predominantly occurs through education and training, could be a tool to reduce the quantity of natural resources (mainly non-renewable resources) that each generation exploits, while also ensuring that new and valuable resources are created (mainly improved human capital and technology).

In fact, there is an abundance of articles and scientific papers which provide substantial theoretical and empirical evidence of education being vital to economic growth. In one camp, Klenow & Rodriguez-Claire (1997), Hall & Jone (1997), and Easterly & Levine (2001), building on the ideas of earlier economists, theorize that growth primarily results from technological change and that the income disparity among countries is as a result of differences in the rate of technological change. Nelson & Phelps (1966), Romer (1989, 1990), and Abramovitz (1986) provide another link in the chain of reasoning for this school of thought. They argue that to attain technological change, a country must engage in either innovation or imitation activities, both of which are products of human capital.

In theory, there is very little argument against the existence of a link between human capital and economic growth, but results from empirical studies provides mixed evidence. Key evidence disputing this link include Levine & Renelt (1992), which shows that education, a proxy for human capital, has no significant statistical impact on economic growth. Temple (1999) and Bils & Klenow (2000) also report a weak correlation between the two, which would indicate the existence of other important deciding factors of economic growth. Dessus (1999), however, disputes Temple's (1999) findings, attributing the findings to a possible specification bias. Interestingly, Dessus (1999) finds that the standard of education decreases as the education enrollment level increases.

3.2 The Neo-classical Growth Model

Solow (1956) and Swan (1956) laid the foundations for the development of the neoclassical growth model. Working independently, and using different approaches, Robert Solow and Trevor Swan laid the groundwork for this exogenous model. This model, widely referred to as the "Solow" model, or "Solow-Swan" model in some cases, provides a simple, convenient, and powerful apparatus for finding the steady-state growth path of a one-commodity world (Dimand & Spencer 2009).

The Solow growth model asserts that long-run growth results from capital accumulation, skilled labor, population growth, and technological progress (Solow 1956). According to the model, long-term growth can be studied by considering 2 variables: capital (K) and labor (L). It explains that changes in labor and capital are explained by changes in the rate of population growth and

saving rates respectively. Output, in this model, results from the combination of capital, labor, investment, and technology. It is also worth noting that the model was underpinned by some critical assumptions: they are that labor force growth and technology are exogenous factors, which implies that labor force growth is constant; capital and labor have a constant return to scale; and the variable factor *GDP per capita* is subject to the law of diminishing returns (Osiobe 2019).

Ultimately, the neo-classical growth model assumes that the accumulation, as well as the utilization, of capital (savings) in an economy is key to economic growth. This model not only shows the relationship between capital and labor but also shows how capital and labor translate to output (Osiobe 2019). As useful as the model is however, it is not without flaws. For instance, the model does not provide any explanation of the divergence in growth rates of different national economies, as the idea of long-run equilibrium means all countries should progress at identical, exogenous rates of technical progress (Diebolt & Monteils 2000).

3.3 Theories of Endogenous Growth

In a bid to address the weakness of the previously mentioned Solow growth model, especially with regards to its assumption about technology, a number of new growth theories have emerged. According to Osiobe (2019), these theories are generally based on 3 fundamental assumptions about technology. The first is that technological change results from the “animal spirit” optimism and pessimism of the market, which determines long-run economic growth. The second assumption is that technological change causes labor to be more efficient, thereby improving output per capita, and the final assumption is that the cost of production of new inventions is incurred once as a fixed-sunk cost.

These theories are collectively referred to as the "new growth theories", and have been developed since the end of the 1980's. The “new growth theories” view the growth process to be endogenous and are based on the central principle that when other components such as human capital exist and can display endogenous accumulation, factor returns do not decrease. This endogenous quality of growth may also be seen if we accept the existence of positive externalities which emanate from activities like research and development, the dissemination of knowledge or the construction of public infrastructure. The presence of these externalities make

up for the decreasing marginal productivity of physical capital (Diebolt & Monteils, 2000). Diebolt & Monteils (2000) argues that endogenous growth theories aim to understand the long-term growth of per capita income and describe it as consequence of the economic system. Endogenous growth theories like Mankiw et al. (1992) and Lucas (1988) generally stress the importance of the role of human capital in development. One major recommendation of these theories is that countries who want to develop should invest in their educational systems. The argument is that in the long run, an investment in education would improve the knowledge and skills of citizens, thereby increasing the general quality of labor available to the country and increasing the country's capacity for innovation and imitation. Hanushek & Woessmann (2008) highlights 2 main mechanisms through which education affects economic growth. The first mechanism, based on Uzawa (1965) and Lucas (1988), proposes that human capital is an input in the production process, thereby implying a relationship between human capital and economic growth. In the second mechanism, it affects growth via the assumption that human capital is the primary source of productivity growth (Nelson and Phelps 1966).

Lucas (1988) specifically indicates that the accumulation of human capital directly leads to sustained economic growth and that education is the primary driving force through which human capital is improved. Romer (1989, 1990, 1994) also reason that human capital stimulates economic growth and can drive innovation. Through econometric analysis, Romer (1989) and Rostow (1960) show that education also provides spillover effects, improves the adaptation speed of entrepreneurs to disequilibrium, and boosts research productivity.

It is important to note that these theories each have unique approaches to explaining economic growth. They either approach it from the perspective of investment in physical capital, human capital, public capital, learning by doing, division of labor, research or technological innovation. Though these sources of growth are not new ideas, endogenous growth theories formalize them for the first time, making it possible to gain a better view of their effects (Diebolt & Monteils 2000).

3.4 Previous Empirical Studies

Over time, many researchers have set out to empirically investigate the link between human capital development and economic growth, and interestingly, these empirical exercises have

produced mixed results. The Granger causality test has proved to be particularly useful statistical tools for investigations like these. This test has helped researchers to evaluate the existence and direction of causality between these 2 variables: human capital and economic growth.

For instance, Omojimiye (2010) tests the idea that formal education accelerates economic growth using Nigerian data for the period 1980-2005. The authors apply the Granger Causality Test to assess the hypothesis of a growth strategy which is led by improvements in the education sector. They find that public expenditures on education Granger cause economic growth but find that economic growth does not Granger cause public expenditure on education. Further results from Omojimiye (2010) show bi-directional causality between public recurrent expenditures on education and economic growth. Their tests however yield no causal relationship between capital expenditure on education and growth, and primary school enrolment and economic growth. Based on their findings, the researchers conclude that the Nigerian education sector needed additional funding and also that the primary school curricula should be reviewed in order to make it more relevant to the needs of the Nigerian society.

Similarly, Asteriou & Agiomirgianakis (2001) examines the relationship between human capital and economic development in Greece, using data for the period 1960 to 1994. Based on the assumption that the main institutional mechanism for developing human skills is the formal education sector, the researchers investigate the relationship between educational variables and GDP. They also test for a causal direction between these variables. Their tests ultimately reveal that all the educational variables Granger cause economic growth, with the exception of higher education which does not Granger cause economic growth. Finally, they find that economic growth causes higher education.

Also using a similar approach, De Meulemeester & Rochat (1995), find mixed results after studying data for 6 countries: Sweden (1910-1986), United Kingdom (1919-1987), Japan (1885-1975), France (1899-1986), Italy (1885-1975), and Australia (1906-1986). The researchers find that higher education enrolment unidirectionally Granger causes economic growth in Sweden, United Kingdom, Japan and France. They however find no such Granger causal relationships in Italy and Australia. Based on this, they conclude that the relationship between higher education and economic development is not mechanistic. Narayan and Smyth (2004) however study data

from 1960 to 1999 and find unidirectional Granger causality running from human capital to economic growth in China.

Self & Grabowski (2003) rely on this approach to analyze data from the prewar (1888–1940) and the postwar (1947–1989) periods, in a bid to find the relationship between various levels of education and economic growth in Japan during these periods. The researchers find that primary schooling causes growth in both periods. They also find that secondary and tertiary education have a causal impact on growth in the postwar period. They however find that vocational education does not exert any causality effect on growth in either period. Ultimately, the authors find evidence of some causal feedback from economic growth to education at all levels as well as for vocational education in both the prewar and postwar periods.

Kyophilavong et al. (2018) observe that these mixed empirical results depend on the variables and country specifics. My paper therefore seeks to investigate this relationship in the context of Ghana.

4 Methodology

Inspired by the methodology of Omojimite (2010) and Asteriou & Agiomirgianakis (2001), I employ the Granger causality analysis. The Granger causality test, developed by Granger (1969), not only tests for a short run causal relationship between 2 variables, but also shows the direction of causality. Variable X is said to Granger cause variable Y if past and present values of X help to predict levels of Y. According to Gujarati & Porter (2008), the Granger causality test assumes that the information relevant to the prediction of the respective variables, X and Y, is contained solely in the time series data on these variables. Gujarati & Porter (2008) further states that Granger causality examines whether one can statistically detect the direction of causality when temporally there is a lead-lag relationship between two variables, say X and Y. It also explains that if variable X Granger causes Y, then one can use variable X to better predict variable Y than simply using the past values of variable Y.

4.1 Choice of variables

I choose my variables based on Asteriou & Agiomirgianakis (2001) and Omojimite (2010), but my choice of variables is ultimately limited by the available data in MoE (2009, 2010, 2012, 2013, 2015, 2018, 2019). I only obtain data for 3 of the 5 variables Omojimite (2010) uses: total public education expenditure, primary education enrolment and GDP growth rate. The reports and the World Bank (2023) however provide no data regarding recurrent expenditure on education and capital expenditure on education, the 2 other variables, so I use expenditure at the main subsectors of the education sector, since they are readily available. These are government expenditure at primary school, JHS, SHS, TVET, and tertiary levels, and also total government expenditure on the management and agencies subsector.

Inspired by Asteriou & Agiomirgianakis (2001), I also include, as variables, enrolment at the JHS level and the SHS level, and also education expenditure as a percentage of total government expenditure. I finally include total completion rates at primary school and JHS levels, since they are readily available.

In all, I use 14 variables: GDP growth rate as a proxy for economic development, while the 13 others serve as proxies for human capital development. These variables are listed below as follows:

- Total government expenditure at primary school level (PriExp)
- Total government expenditure at JHS level (JHSExp)
- Total government expenditure at SHS level (SHSExp)
- Total government expenditure at TVET level (TVETExp)
- Total government expenditure at tertiary level (TerExp)
- Total government expenditure on management and agencies (MgtExp)
- Total government expenditure on education (TotEduExp)
- Education expenditure as a percentage of total government expenditure (Edu%GovExp)
- GER at primary school level (PriGER)
- Total completion rate at primary school level (PriTCR)
- GER at JHS level (JHSGER)
- Total completion rate at JHS level (JHSTCR)
- GER at SHS level (SHSGER)
- Annual growth rate of GDP (GDPG)

4.2 Stationarity Tests

To avoid the occurrence of spurious regression, I run various Dickey-Fuller (DF) tests to ensure that I only use stationary variables in my Granger Analysis. I run these stationarity test at a 5% significance level and with a null hypothesis that the variable under consideration is nonstationary. Using the regression equation 1 for the DF test, I test whether or not the selected variables are stationary.

$$\Delta X_i_t = \delta X_{i,t-1} + u_t \quad (1)$$

In the equations above, the X_i term represents the various variables. Running a separate test for each variable, I find that none of the 14 variables are stationary. Because all the variables are nonstationary, I test the first difference of each, to determine if any of them are difference stationary. Using the equation 2, all 14 of the variables turn out to be stationary at first difference.

$$\Delta^2 Y_t = \delta \Delta Y_{t-1} + u_t \quad (2)$$

4.3 The Granger Causality Test

Based on the results of the stationarity test, it is appropriate to use the first differences of the variables in the Granger causality analysis. I perform a Granger Causality test for pairs of the first difference of GDPG ($\Delta GDPG$) and first difference of each of the other 13 variables. The general form of the Granger causality relationship I test is displayed in equations 3 and 4, where it is assumed that u_{1t} and u_{2t} are uncorrelated. Equation 3 is interpreted as first difference of variable X Granger causes the first difference of variable Y, and the interpretation of equation 4 follows a similar logic.

$$\Delta Y_t = \Phi + \sum_{i=1}^n \alpha_i \Delta X_{t-i} + \sum_{j=1}^n \beta_j \Delta Y_{t-j} + u_{1t} \quad (3)$$

$$\Delta X_t = \Psi + \sum_{i=1}^n \lambda_i \Delta X_{t-i} + \sum_{j=1}^n \delta_j \Delta Y_{t-j} + u_{2t} \quad (4)$$

The null hypotheses to be tested are:

$H_{0_1}: \alpha_i = 0, i = 1 \dots n$, which means that ΔX do not Granger cause ΔY ; and

$H_{0_2}: \delta_j = 0, j = 1 \dots n$, which means that ΔY do not Granger cause ΔX .

If none of the hypothesis is rejected, it means that there is no Granger causal relationship between the 2 variables, and this indicates that the two variables are independent of each other. If the first hypothesis is rejected, it shows that ΔX Granger cause ΔY . Likewise, if the second hypothesis is rejected, it shows that ΔY Granger cause ΔX . If both hypotheses are rejected, there is bi-directional causality between the variables.

To conduct the actual test, I follow the process suggested by Gujarati & Porter (2008). For instance, to test H_{0_1} , I use SPSS to compute the regression equations 5 and 6. With the restricted residual sum of squares (RSS_R) and unrestricted residual sum of squares (RSS_{UR}) from the SPSS output, I compute the F_{calc} value as shown by equation 7. I then compare the F_{calc} with the

critical value $F_{m,(n-k)}$ (obtained from an F-distribution table). In this test also, I opt to use only 1, 2, and 3 lags because I did not want to end up with very small degrees of freedom.

$$\Delta Y_t = \Omega + \sum_{j=1}^n \beta_j \Delta Y_{t-j} + u_{3t} \quad (5)$$

$$\Delta Y_t = \Phi + \sum_{i=1}^n \alpha_i \Delta X_{t-i} + \sum_{j=1}^n \beta_j \Delta Y_{t-j} + u_{1t} \quad (6)$$

$$F = \frac{(RSS_R - RSS_{UR})/m}{RSS_{UR}/(n - k)} \quad (7)$$

In all, I conduct a pairwise test between $\Delta GDPG$ and each of the 13 other variables, thereby conducting Granger causality test for 13 different pairs. Simply put, I tested the relationship between $\Delta LPriExp$ and $\Delta GDPG$; $\Delta LJHSExp$ and $\Delta GDPG$; $\Delta LSHSExp$ and $\Delta GDPG$; $\Delta LTVETExp$ and $\Delta GDPG$; $\Delta LTerExp$ and $\Delta GDPG$; $\Delta LMgtExp$ and $\Delta GDPG$; $\Delta LTotEduExp$ and $\Delta GDPG$; $\Delta Edu\%GovExp$ and $\Delta GDPG$; $\Delta PriGER$ and $\Delta GDPG$; $\Delta PriTCR$ and $\Delta GDPG$; $\Delta JHSGER$ and $\Delta GDPG$; $\Delta JHSTCR$ and $\Delta GDPG$; and between $\Delta SHSGER$ and $\Delta GDPG$.

5 Data

5.1 Source of variables

One of the major challenges of this paper is the unavailability of data regarding the variables of interest. The World Bank (2023) provides inadequate data regarding Ghana's education sector. I also reached out to the Ghana Statistical Service and the Ministry of Education but did not get adequate information. In the end, I had to put together my own dataset: one considerably smaller than I needed.

I extract the nominal expenditure, nominal GDP, GER and total completion rate data for my work from MoE (2009, 2010, 2012, 2013, 2015, 2018, 2019). I also use GDP growth rates from the World Bank (2023) in my analysis.

I use consumer price index (CPI) data obtained from the World Bank (2023) to convert the nominal expenditure values I extracted into real expenditure values. I also convert the nominal GDP values into real GDP values, using GDP deflator data I obtain from the World Bank (2023). Equations 8 and 9 show the conversion formulae for the real expenditure and real GDP respectively.

$$real\ exp = \frac{nominal\ exp}{CPI} * 100 \quad (8)$$

$$real\ GDP = \frac{nominal\ GDP}{GDP\ deflator} * 100 \quad (9)$$

Combining these obtained real values (real GDP and real expenditure, both in 2013 GH¢) and the additional data from the ESPR and the World Bank (2023), I develop an annual time series data set spanning 2003 to 2018 for 14 the variables. To facilitate the smooth analysis, I transform the expenditure values into their respective natural logarithms.

5.2 Descriptive Statistics

Table 2: Descriptive Statistics of Expenditure Variables

Variables	No. of Observations	Minimum (in millions GH¢)	Maximum (in millions GH¢)	Mean (in millions GH¢)	Std. Deviation (in millions GH¢)
PriExp	16	542.78	1,532.29	1,005.41	319.97
JHSExp	16	274.83	1,250.33	665.27	319.63
SHSExp	16	220.55	1,557.21	798.20	484.13
TVETExp	16	15.86	303.28	95.61	84.64
TerExp	16	200.37	1,944.94	879.42	475.00
MgtExp	16	1.44	704.70	347.40	246.13
TotEduExp	16	1,441.49	6,635.67	4,103.66	1,859.71

(Source: Author's work using data from the World Bank (2023) and MoE (2009, 2010, 2012, 2013, 2015, 2018, 2019))

Table 3: Descriptives Statistics of Remaining Variables

Variables	No. of Observations	Minimum (in %)	Maximum (in %)	Mean (in %)	Std. Deviation (in %)
Edu%GovExp	16	17.76	27.23	22.49	2.38
PriGER	16	86.50	111.40	99.66	8.37
PriTCR	16	75.60	112.40	92.54	10.25
JHSGER	16	70.20	88.00	80.68	5.18
JHSTCR	16	58.00	79.10	69.98	6.17
SHSGER	16	25.60	62.60	39.60	10.78
GDPG	16	2.12	14.05	6.42	2.94

(Source: Author's work using data from the World Bank (2023) and MoE (2009, 2010, 2012, 2013, 2015, 2018, 2019))

6 Analysis

6.1 Stationarity Tests

The tables below show results from the various stationarity tests. It is important to note that all tests are conducted at 5% significance level. Tables 4 shows the results of the Dickey-Fuller test for the variables at level, while table 5 shows results for these same test at first difference.

Table 4: Results for DF Test at Level (No constant and no trend Scenario)

Null Hypothesis	Statistical Value	Critical Value	Decision
LPriExp is not stationary	0.787	-1.95	Fail to reject null hypothesis
LJHSEExp is not stationary	0.997	-1.95	Fail to reject null hypothesis
LSHSEExp is not stationary	1.718	-1.95	Fail to reject null hypothesis
LTVETExp is not stationary	0.688	-1.95	Fail to reject null hypothesis
LTerExp is not stationary	2.527	-1.95	Fail to reject null hypothesis
LMgtExp is not stationary	1.714	-1.95	Fail to reject null hypothesis
LTotEduExp is not stationary	3.059	-1.95	Fail to reject null hypothesis
Edu%GovExp is not stationary	-0.185	-1.95	Fail to reject null hypothesis
PriGER is not stationary	1.501	-1.95	Fail to reject null hypothesis
PriTCR is not stationary	0.731	-1.95	Fail to reject null hypothesis
JHSGER is not stationary	2.587	-1.95	Fail to reject null hypothesis
JHSTCR is not stationary	0.588	-1.95	Fail to reject null hypothesis
SHSGER is not stationary	3.485	-1.95	Fail to reject null hypothesis
GDPG is not stationary	-0.847	-1.95	Fail to reject null hypothesis

(Source: Author's work using data from the World Bank (2023) and MoE (2009, 2010, 2012, 2013, 2015, 2018, 2019))

Table 5: Results for DF Test at 1st Difference

Null Hypothesis	Statistical Value	Critical Value	Decision
$\Delta L PriExp$ is not stationary	-3.196	-1.95	Reject null hypothesis
$\Delta L JHSExp$ is not stationary	-5.221	-1.95	Reject null hypothesis
$\Delta L SHSExp$ is not stationary	-3.279	-1.95	Reject null hypothesis
$\Delta L TVETExp$ is not stationary	-4.723	-1.95	Reject null hypothesis
$\Delta L TerExp$ is not stationary	-3.868	-1.95	Reject null hypothesis
$\Delta L MgtExp$ is not stationary	-3.107	-1.95	Reject null hypothesis
$\Delta L TotEduExp$ is not stationary	-2.311	-1.95	Reject null hypothesis
$\Delta Edu\%GovExp$ is not stationary	-4.172	-1.95	Reject null hypothesis
$\Delta PriGER$ is not stationary	-2.541	-1.95	Reject null hypothesis
$\Delta PriTCR$ is not stationary	-5.404	-1.95	Reject null hypothesis
$\Delta JHSGER$ is not stationary	-2.453	-1.95	Reject null hypothesis
$\Delta JHSTCR$ is not stationary	-5.765	-1.95	Reject null hypothesis
$\Delta SHSGER$ is not stationary	-2.355	-1.95	Reject null hypothesis
$\Delta GDPG$ is not stationary	-4.496	-1.95	Reject null hypothesis

(Source: Author's work using data from WDI and MoE (2009, 2010, 2012, 2013, 2015, 2018, 2019))

As evidenced by the tables 4 and 5 above, all 14 variables are difference stationary. Therefore, the Granger causality tests are subsequently conducted using the first differences of the variables so as to avoid running spurious regressions.

6.2 Granger Causality Tests

6.2.1 Summary of Results

The subsequent Granger causality tests show that, in the case of 1 lag, none of the education variables Granger causes GDP growth. There is however one Granger causal relationship in the opposite case (causality from GDP growth to the education variables), with causality running from GDP growth to the percentage of government expenditure dedicated to education. Table 6 below presents the results of the test conducted at 5% significance level.

Table 6: Results for Granger Causality Test using 1 Lag

Null Hypothesis	Statistical Value	Critical Value	Decision
ΔGDPG does not cause $\Delta\text{LPriExp}$	0.06133	4.75	Fail to reject null hypothesis
$\Delta\text{LPriExp}$ does not cause ΔGDPG	0.02096	4.75	Fail to reject null hypothesis
ΔGDPG does not cause $\Delta\text{LJHSExp}$	0.53299	4.75	Fail to reject null hypothesis
$\Delta\text{LJHSExp}$ does not cause ΔGDPG	1.15227	4.75	Fail to reject null hypothesis
ΔGDPG does not cause $\Delta\text{LSHSExp}$	3.29623	4.75	Fail to reject null hypothesis
$\Delta\text{LSHSExp}$ does not cause ΔGDPG	0.02459	4.75	Fail to reject null hypothesis
ΔGDPG does not cause $\Delta\text{LTVETExp}$	0.60491	4.75	Fail to reject null hypothesis
$\Delta\text{LTVETExp}$ does not cause ΔGDPG	0.00075	4.75	Fail to reject null hypothesis
ΔGDPG does not cause $\Delta\text{LTerExp}$	2.25522	4.75	Fail to reject null hypothesis
$\Delta\text{LTerExp}$ does not cause ΔGDPG	0.02194	4.75	Fail to reject null hypothesis
ΔGDPG does not cause $\Delta\text{LMgtExp}$	0.10478	4.75	Fail to reject null hypothesis
$\Delta\text{LMgtExp}$ does not cause ΔGDPG	0.15089	4.75	Fail to reject null hypothesis
ΔGDPG does not cause $\Delta\text{LTotEduExp}$	2.41341	4.75	Fail to reject null hypothesis
$\Delta\text{LTotEduExp}$ does not cause ΔGDPG	0.07414	4.75	Fail to reject null hypothesis
ΔGDPG does not cause $\Delta\text{Edu\%GovExp}$	10.1715	4.75	Reject null hypothesis

Null Hypothesis	Statistical Value	Critical Value	Decision
$\Delta \text{Edu\%GovExp}$ does not cause ΔGDPG	0.05322	4.75	Fail to reject null hypothesis
ΔGDPG does not cause ΔPriGER	1.07316	4.75	Fail to reject null hypothesis
ΔPriGER does not cause ΔGDPG	0.49944	4.75	Fail to reject null hypothesis
ΔGDPG does not cause ΔPriTCR	3.81443	4.75	Fail to reject null hypothesis
ΔPriTCR does not cause ΔGDPG	0.09971	4.75	Fail to reject null hypothesis
ΔGDPG does not cause ΔJHSGER	0.36907	4.75	Fail to reject null hypothesis
ΔJHSGER does not cause ΔGDPG	1.37495	4.75	Fail to reject null hypothesis
ΔGDPG does not cause ΔJHSTCR	0.02861	4.75	Fail to reject null hypothesis
ΔJHSTCR does not cause ΔGDPG	0.01801	4.75	Fail to reject null hypothesis
ΔGDPG does not cause ΔSHSGER	0.14910	4.75	Fail to reject null hypothesis
ΔSHSGER does not cause ΔGDPG	0.00520	4.75	Fail to reject null hypothesis

(Source: Author's work using data from WDI and MoE (2009, 2010, 2012, 2013, 2015, 2018, 2019))

In the case of 2 lags, results show that GDP growth again Granger causes percentage of government expenditure dedicated to education. Apart from this, GDP growth granger causes no other education variables. On the other hand, GER at primary school level Granger causes GDP growth, but no other education variable Granger causes GDP growth. Table 7 below presents the results of the test conducted at 5% significance level.

Table 7: Results for Granger Causality Test using 2 Lags

Null Hypothesis	Statistical Value	Critical Value	Decision
$\Delta GDPG$ does not cause $\Delta LPriExp$	0.19824	4.26	Fail to reject null hypothesis
$\Delta LPriExp$ does not cause $\Delta GDPG$	2.40551	4.26	Fail to reject null hypothesis
$\Delta GDPG$ does not cause $\Delta LJHSExp$	3.21154	4.26	Fail to reject null hypothesis
$\Delta LJHSExp$ does not cause $\Delta GDPG$	2.08416	4.26	Fail to reject null hypothesis
$\Delta GDPG$ does not cause $\Delta LSHSExp$	2.75874	4.26	Fail to reject null hypothesis
$\Delta LSHSExp$ does not cause $\Delta GDPG$	0.64910	4.26	Fail to reject null hypothesis
$\Delta GDPG$ does not cause $\Delta LTVETExp$	2.86161	4.26	Fail to reject null hypothesis
$\Delta LTVETExp$ does not cause $\Delta GDPG$	0.02792	4.26	Fail to reject null hypothesis
$\Delta GDPG$ does not cause $\Delta LTerExp$	1.73438	4.26	Fail to reject null hypothesis
$\Delta LTerExp$ does not cause $\Delta GDPG$	0.03041	4.26	Fail to reject null hypothesis
$\Delta GDPG$ does not cause $\Delta LMgtExp$	0.42160	4.26	Fail to reject null hypothesis
$\Delta LMgtExp$ does not cause $\Delta GDPG$	0.50625	4.26	Fail to reject null hypothesis
$\Delta GDPG$ does not cause $\Delta LTotEduExp$	1.39557	4.26	Fail to reject null hypothesis
$\Delta LTotEduExp$ does not cause $\Delta GDPG$	1.46843	4.26	Fail to reject null hypothesis
$\Delta GDPG$ does not cause $\Delta Edu\%GovExp$	6.41297	4.26	Reject null hypothesis

Null Hypothesis	Statistical Value	Critical Value	Decision
$\Delta \text{Edu\%GovExp}$ does not cause ΔGDPG	0.15394	4.26	Fail to reject null hypothesis
ΔGDPG does not cause ΔPriGER	2.91062	4.26	Fail to reject null hypothesis
ΔPriGER does not cause ΔGDPG	5.36431	4.26	Reject null hypothesis
ΔGDPG does not cause ΔPriTCR	3.09367	4.26	Fail to reject null hypothesis
ΔPriTCR does not cause ΔGDPG	0.24328	4.26	Fail to reject null hypothesis
ΔGDPG does not cause ΔJHSGER	0.54093	4.26	Fail to reject null hypothesis
ΔJHSGER does not cause ΔGDPG	0.89061	4.26	Fail to reject null hypothesis
ΔGDPG does not cause ΔJHSTCR	0.11078	4.26	Fail to reject null hypothesis
ΔJHSTCR does not cause ΔGDPG	1.92783	4.26	Fail to reject null hypothesis
ΔGDPG does not cause ΔSHSGER	0.77588	4.26	Fail to reject null hypothesis
ΔSHSGER does not cause ΔGDPG	0.17415	4.26	Fail to reject null hypothesis

(Source: Author's work using data from WDI and MoE (2009, 2010, 2012, 2013, 2015, 2018, 2019))

Finally, in the case of 3 lags, GDP growth only Granger causes expenditure on SHS and no other education variable. Results also show that none of the education variables Granger causes GDP growth. Table 8 below presents the results of the test conducted at 5% significance level.

Table 8: Results for Granger Causality Test using 3 Lags

Null Hypothesis	Statistical Value	Critical Value	Decision
ΔGDPG does not cause $\Delta\text{LPriExp}$	0.92013	4.76	Fail to reject null hypothesis
$\Delta\text{LPriExp}$ does not cause ΔGDPG	1.09370	4.76	Fail to reject null hypothesis
ΔGDPG does not cause $\Delta\text{LJHSExp}$	2.36512	4.76	Fail to reject null hypothesis
$\Delta\text{LJHSExp}$ does not cause ΔGDPG	3.24129	4.76	Fail to reject null hypothesis
ΔGDPG does not cause $\Delta\text{LSHSExp}$	4.93122	4.76	Reject null hypothesis
$\Delta\text{LSHSExp}$ does not cause ΔGDPG	0.67270	4.76	Fail to reject null hypothesis
ΔGDPG does not cause $\Delta\text{LTVETExp}$	2.01690	4.76	Fail to reject null hypothesis
$\Delta\text{LTVETExp}$ does not cause ΔGDPG	0.06787	4.76	Fail to reject null hypothesis
ΔGDPG does not cause $\Delta\text{LTerExp}$	2.13433	4.76	Fail to reject null hypothesis
$\Delta\text{LTerExp}$ does not cause ΔGDPG	0.51284	4.76	Fail to reject null hypothesis
ΔGDPG does not cause $\Delta\text{LMgtExp}$	0.77953	4.76	Fail to reject null hypothesis
$\Delta\text{LMgtExp}$ does not cause ΔGDPG	0.34651	4.76	Fail to reject null hypothesis
ΔGDPG does not cause $\Delta\text{LTotEduExp}$	0.56209	4.76	Fail to reject null hypothesis
$\Delta\text{LTotEduExp}$ does not cause ΔGDPG	1.43193	4.76	Fail to reject null hypothesis
ΔGDPG does not cause $\Delta\text{Edu\%GovExp}$	2.81432	4.76	Fail to reject null hypothesis

Null Hypothesis	Statistical Value	Critical Value	Decision
$\Delta \text{Edu\%GovExp}$ does not cause ΔGDPG	0.26721	4.76	Fail to reject null hypothesis
ΔGDPG does not cause ΔPriGER	0.93476	4.76	Fail to reject null hypothesis
ΔPriGER does not cause ΔGDPG	2.78160	4.76	Fail to reject null hypothesis
ΔGDPG does not cause ΔPriTCR	1.71197	4.76	Fail to reject null hypothesis
ΔPriTCR does not cause ΔGDPG	0.48453	4.76	Fail to reject null hypothesis
ΔGDPG does not cause ΔJHSGER	0.55911	4.76	Fail to reject null hypothesis
ΔJHSGER does not cause ΔGDPG	0.65702	4.76	Fail to reject null hypothesis
ΔGDPG does not cause ΔJHSTCR	0.05543	4.76	Fail to reject null hypothesis
ΔJHSTCR does not cause ΔGDPG	3.44604	4.76	Fail to reject null hypothesis
ΔGDPG does not cause ΔSHSGER	0.45526	4.76	Fail to reject null hypothesis
ΔSHSGER does not cause ΔGDPG	0.19728	4.76	Fail to reject null hypothesis

(Source: Author's work using data from WDI and MoE (2009, 2010, 2012, 2013, 2015, 2018, 2019))

6.2.2 Discussion of Granger Causality Test Results

My analysis reveals that most of the education variables do not Granger cause GDP growth and also that GDP growth does not Granger cause most of the education variables. The only exceptions are that GDP growth Granger causes the percentage of total government expenditure that is dedicated to education; GDP growth Granger causes expenditure at the SHS level; and GER at primary level Granger causes GDP growth. These findings contradict findings from most previous papers, particularly Omojinite (2010) which reports that total expenditure on education Granger causes economic growth and that primary school enrolment did not Granger cause GDP growth. My findings are also different from those of Asteriou & Agiomirgianakis (2001) who find that all the educational variables except for higher education variables Granger cause economic growth and also find that economic growth causes higher education.

The findings imply that given the current state of the Education sector, the government of Ghana can promote the economic growth of the country by increasing the enrolment at the primary school level. Furthermore, results indicate that as the economy of Ghana grows, the government will increase the share of its total expenditure that it dedicates to education expenditure. Results also indicate that government will invest more in SHS education increases as the Ghanaian economy grows at a faster rate.

These findings are alarming because they generally show that there is no direct causal link between human capital development and economic development in Ghana. This casts doubt on the education led development strategy that government advocates. Findings suggest that increased GDP growth causes the more investment in education as evidence by an increased share of total expenditure and increased spending on the SHS level. On the other hand, spending on these 2, the education sector and the SHS level do not cause the country to economy to grow any faster. This disconnect in the feedback loop means that the government's continued investments in the sector would not bear fruits of economic growth.

The fact that increasing enrolment rate at the primary level is the only way the government can boost growth compounds this issue because as pointed out by Dessus (1999), the quality of education declines as the enrollment increases. He further suggests that as a result, huge education investments fail to increase growth in developing countries.

In relation to the new endogenous theories, it is surprising that the Granger analysis reveals that Ghana's total education expenditure (as well as expenditure at most education levels) and its GDP growth are independent of each other. For instance based on Lucas (1988), one would expect an increase in the various education variables to lead to an increase in economic growth, since education is the main driving force for improvements in human capital. A similar outcome is expected according to Romer (1989, 1990, 1994) which argues that human capital stimulates economic growth and can drive innovation.

It is important to note that the quality of the education sector in Ghana could be a reason for this finding but there is sufficient evidence to suggest that it is still possible to determine a causal relationship even if the quality of education is relatively low. Omojinite (2010) for instance, finds that Nigeria's public expenditure on education Granger causes economic growth even though Nigeria has a relatively worse education sector compared to Ghana. This is according to the World Bank (2023). This means that the quality of the Ghanaian education sector alone cannot explain these results.

Another factor to consider is how the expenditure is distributed. Unlike in the case of Nigeria as reported by Omojinite (2010), the expenditure values I extracted presented no information about whether they were recurrent or capital expenditure. Investigating exactly what the education expenditure in Ghana is directed to will provide more insight into whether the findings of the analysis actually contradict the new endogenous growth models or if the Ghanaian government is not actually developing the country's human capital.

6.2.3 Discussion of Appropriateness

Given the data challenges regarding sample size, available variables and the time constraint, the simple Granger causality test is the best tool for the causal analysis. As highlighted by Gujarati & Porter (2008), the direction of causality may have been critically influenced by the number of lagged terms included. Considering the fact that basic education in Ghana lasts 12 years (6 years for Primary school, 3 years for JHS, and 3 years for SHS), it would have been ideal to perform the analysis with 6 or more lags. The data set however constrains me, as using many lags leads to an excessive loss of degrees of freedom for an already small sample size.

Also, given the current makeup of the education sector in Ghana, the proxy used for human capital development understates the actual value of the investments that are made in human capital development. Government education expenditure, which I use in this analysis is not a perfect representation of human capital development in Ghana, but like Asteriou & Agiomirgianakis (2001), I use it because it is readily available. Since the private sector plays a significant role in Ghana's education sector (as evidenced by the private enrolments rates at the various education levels), future studies should incorporate the associated investments. This is in line with the views of Asteriou & Agiomirgianakis (2001) who also did not include private spending on education either in Greece or abroad but remarked that this could be an issue to study in future research.

7 Conclusion

In this study, I analyse if there is a causal relationship between human capital development and economic growth, using education expenditure and other education variables (GER and total completion rates at some selected levels) as proxies for human capital development and GDP growth as a proxy for economic growth. The analysis shows no Granger causal relationship between our main variables of interest (Total Education Expenditure and GDP growth). Results also show that none of the education variables Granger cause GDP growth, if the test uses 1 lag and also if the test uses 3 lags. Also, results show that whether the test uses 1 lag or 2 lags, GDP growth Granger causes the percentage of total government expenditure that is dedicated to education. Results for tests that use 2 lags also shows that enrolment rate at the primary level is the only education variable that Granger causes GDP growth, with GDP growth also not Granger causing any education variable apart from the percentage of government expenditure dedicated to education. In the case of the test using 3 lags, results show that GDP growth Granger causes only one education variable which is expenditure on the Senior High School level.

These results indicate that the government of Ghana can only look to promote economic growth by increasing GER at the primary school level. Also the results show that increased GDP growth rate will cause the government to increase its expenditure on the SHS level and also increase the share of its total expenditure that it channels towards education.

Considering the limited data upon which this analysis is based however, it will be interesting to see how a repeat of this Granger causality analysis would turn out if the sample size (number of years that are studied) is increased because that will allow the test to be done with more lags. I therefore recommend further studies when more data becomes available. Future analysis using the cointegration approach should also be done to investigate if there is an underlying long-term relationship between Ghana's economic growth and its education variables.

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Appendices

Appendix 1: Raw Data

Raw Data for Real Expenditure on Selected Categories of the Education Sector

Year	PriExp	JHSExp	SHSExp	TVETExp	TerExp	MgtExp	TotEduExp
2003	572,271,415	318,569,421	220,547,926	15,856,506	200,367,205	1,441,405	1,441,490,125
2004	542,779,741	274,825,185	341,813,824	18,894,231	360,708,170	8,588,289	1,717,657,522
2005	565,267,403	336,513,706	393,229,502	22,686,316	370,543,180	18,905,264	1,890,526,432
2006	603,906,811	367,737,018	345,802,709	19,775,325	493,387,444	168,870,360	2,191,050,984
2007	926,015,790	429,832,760	333,890,683	17,104,650	608,294,973	146,065,736	2,644,603,723
2008	1,093,882,841	521,252,692	304,920,256	32,640,682	674,901,227	231,751,923	3,108,007,545
2009	889,356,637	444,961,927	504,313,023	52,377,460	599,718,119	240,426,574	2,914,593,591
2010	965,428,028	499,798,352	540,019,750	51,886,945	690,911,441	489,300,339	3,461,751,925
2011	1,532,286,049	511,092,772	654,073,917	157,658,199	793,653,432	605,652,789	4,427,099,003
2012	1,454,979,399	1,082,209,840	1,180,773,353	182,776,523	1,208,196,527	704,698,015	6,369,461,495
2013	1,388,792,576	965,117,148	1,152,064,995	103,039,432	1,106,283,329	549,865,010	5,696,678,317
2014	1,251,786,342	913,252,041	1,270,686,663	211,241,868	921,259,320	628,035,246	5,684,140,906

Year	PriExp	JHSExp	SHSExp	TVETExp	TerExp	MgtExp	TotEduExp
2015	938,991,848	1,250,334,899	1,266,511,276	135,961,503	1,366,319,981	550,442,769	5,866,683,040
2016	1,035,511,430	745,216,883	1,536,009,503	303,282,428	1,405,564,976	305,890,799	5,714,986,708
2017	1,224,999,921	1,001,243,542	1,557,207,600	118,168,340	1,325,736,708	268,458,098	5,894,102,257
2018	1,100,349,426	982,296,004	1,169,398,828	86,352,946	1,944,940,660	640,054,389	6,635,665,009

Raw Data for Other Important Variables

Year	Edu%GovExp	PriGER	PriTCR	JHSGER	JHSTCR	SHSGER	GDP growth (annual %)
2003	21.70	86.5	77.9	70.2	58	26.6	5.2
2004	22.80	87.5	78.7	72.8	60	25.6	5.6
2005	24.78	92.1	75.6	74.7	77.9	28.4	5.9
2006	23.77	93.7	85.4	77.4	64.9	29.1	6.39991
2007	22.64	95.2	88	78.8	67.7	35.8	4.34682
2008	21.77	94.9	88.7	80.6	75	33.9	9.1498
2009	23.64	94.9	87.1	79.5	66	36.1	4.84449
2010	22.24	96.4	91.6	79.6	66.9	36.5	7.89971
2011	26.65	96.5	93.7	80.6	66.8	37.1	14.0471
2012	27.23	105	112.4	82.2	70.1	36.8	9.29279
2013	20.89	107.3	97.5	82	69	43.9	7.31253
2014	20.54	110.4	99.6	85.4	73.5	45.6	2.85624
2015	21.25	111.3	99.6	88	73.5	49.6	2.12076
2016	17.76	111.4	101.6	86.8	76.1	50.1	3.37347
2017	20.25	106.2	100.8	86.1	75.2	55.9	8.12889
2018	21.95	105.3	102.4	86.2	79.1	62.6	6.20008

Appendix 2: SPSS Output for DF test at Level

Coefficients^{a,b}

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	LagLPriExp	.002	.003	.206	.787	.444

a. Dependent Variable: Δ LPriExp

b. Linear Regression through the Origin

Coefficients^{a,b}

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	LagLJHSExp	.004	.004	.257	.997	.336

a. Dependent Variable: Δ LJHSExp

b. Linear Regression through the Origin

Coefficients^{a,b}

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	LagLSHSExp	.005	.003	.417	1.718	.108

a. Dependent Variable: Δ LSHSExp

b. Linear Regression through the Origin

Coefficients^{a,b}

		Unstandardized Coefficients		Standardized Coefficients		
Model		B	Std. Error	Beta	t	Sig.
1	LagLTVETExp	.006	.008	.181	.688	.502

a. Dependent Variable: Δ LTVETExp

b. Linear Regression through the Origin

Coefficients^{a,b}

		Unstandardized Coefficients		Standardized Coefficients		
Model		B	Std. Error	Beta	t	Sig.
1	LagLTerExp	.007	.003	.560	2.527	.024

a. Dependent Variable: Δ LTerExp

b. Linear Regression through the Origin

Coefficients^{a,b}

		Unstandardized Coefficients		Standardized Coefficients		
Model		B	Std. Error	Beta	t	Sig.
1	LagLMgtExp	.018	.011	.416	1.714	.109

a. Dependent Variable: Δ LMgtExp

b. Linear Regression through the Origin

Coefficients^{a,b}

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
1	LagLTotEduExp.005	.001	.633	3.059	.008

a. Dependent Variable: Δ LTotEduExp

b. Linear Regression through the Origin

Coefficients^{a,b}

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
1	LagEdu%GovExp -.006	.030	-.049	-.185	.856

a. Dependent Variable: Δ Edu%GovExp

b. Linear Regression through the Origin

Coefficients^{a,b}

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
1	LagPriGER .012	.008	.372	1.501	.156

a. Dependent Variable: Δ PriGER

b. Linear Regression through the Origin

Coefficients^{a,b}

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	LagPriTCR	.014	.020	.192	.731	.477

a. Dependent Variable: Δ PriTCR

b. Linear Regression through the Origin

Coefficients^{a,b}

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	LagJHSGER	.013	.005	.569	2.587	.022

a. Dependent Variable: Δ JHSGER

b. Linear Regression through the Origin

Coefficients^{a,b}

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	LagJHSTCR	.015	.026	.155	.588	.566

a. Dependent Variable: Δ JHSTCR

b. Linear Regression through the Origin

Coefficients^{a,b}

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	LagSHSGER	.065	.019	.682	3.485	.004

a. Dependent Variable: Δ SHSGER

b. Linear Regression through the Origin

Coefficients^{a,b}

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	LagGDPG	-.105	.123	-.221	-.847	.411

a. Dependent Variable: Δ GDPG

b. Linear Regression through the Origin

Appendix 3: SPSS Output for DF at First Difference of Variables

Coefficients^{a,b}

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	Lag Δ LPriExp	-.887	.278	-.663	-3.196	.007

a. Dependent Variable: Dif Δ LPriExp

b. Linear Regression through the Origin

Coefficients^{a,b}

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	Lag Δ LJHSExp	-1.345	.258	-.823	-5.221	.000

a. Dependent Variable: Dif Δ LJHSExp

b. Linear Regression through the Origin

Coefficients^{a,b}

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	Lag Δ LSHSExp	-.842	.257	-.673	-3.279	.006

a. Dependent Variable: Dif Δ LSHSExp

b. Linear Regression through the Origin

Coefficients^{a,b}

		Unstandardized		Standardized	
		Coefficients		Coefficients	
Model		B	Std. Error	Beta	t
1	LagΔLTVETExp	-1.271	.269	-.795	-4.723
					.000

a. Dependent Variable: DifΔLTVETExp

b. Linear Regression through the Origin

Coefficients^{a,b}

		Unstandardized		Standardized		
		Coefficients		Coefficients		
Model		B	Std. Error	Beta	t	Sig.
1	LagΔLTerExp	-.947	.245	-.731	-3.868	.002

a. Dependent Variable: DifΔLTerExp

b. Linear Regression through the Origin

Coefficients^{a,b}

		Unstandardized		Standardized		
		Coefficients		Coefficients		
Model		B	Std. Error	Beta	t	Sig.
1	LagΔLMgtExp	-.703	.226	-.653	-3.107	.008

a. Dependent Variable: Dif Δ LMgtExp

b. Linear Regression through the Origin

Coefficients^{a,b}

Model		Unstandardized Coefficients		Standardized Coefficients	
		B	Std. Error	Beta	t
1	Lag Δ LTotEduExp	-.559	.242	-.540	-2.311
					Sig.
					.038

a. Dependent Variable: Dif Δ LTotEduExp

b. Linear Regression through the Origin

Coefficients^a

Model		Unstandardized Coefficients		Standardized Coefficients	
		B	Std. Error	Beta	t
1	(Constant)	.085	.046		1.864
					Sig.
					.087
	Lag Δ LTotEduExp	-.888	.283	-.671	-3.133
					Sig.
					.009

a. Dependent Variable: Dif Δ LTotEduExp

Coefficients^a

		Unstandardized Coefficients		Standardized Coefficients		
Model		B	Std. Error	Beta	t	Sig.
1	(Constant)	.187	.114		1.640	.129
	t	-.009	.010	-.227	-.973	.351
	LagΔLTotEduExp	-1.006	.309	-.760	-3.257	.008

a. Dependent Variable: DifΔLTotEduExp

Coefficients^a

		Unstandardized Coefficients		Standardized Coefficients		
Model		B	Std. Error	Beta	t	Sig.
1	(Constant)	.295	.150		1.972	.080
	t	-.016	.012	-.351	-1.380	.201
	LagΔLTotEduExp	-1.351	.452	-1.015	-2.989	.015
	LagDifΔLTotEduExp	.338	.318	.337	1.066	.314
	p					

a. Dependent Variable: DifΔLTotEduExp

Coefficients^a

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.430	.210		2.046	.080
	t	-.023	.015	-.450	-1.555	.164
	LagΔLTotEduExp	-1.872	.671	-1.412	-2.792	.027
	LagDifΔLTotEduExp	.727	.489	.722	1.488	.180
	Lag2DifΔLTotEduExp	.383	.354	.380	1.082	.315
	p					

a. Dependent Variable: DifΔLTotEduExp

Coefficients^{a,b}

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	LagΔEdu%GovExp	-1.154	.277	-.757	-4.172	.001

a. Dependent Variable: DifΔEdu%GovExp

b. Linear Regression through the Origin

Coefficients^{a,b}

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	LagΔPriGER	-.663	.261	-.576	-2.541	.025

a. Dependent Variable: DifΔPriGER

b. Linear Regression through the Origin

Coefficients^{a,b}

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	LagΔPriTCR	-1.385	.256	-.832	-5.404	.000

a. Dependent Variable: DifΔPriTCR

b. Linear Regression through the Origin

Coefficients^{a,b}

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	LagΔJHSGER	-.552	.225	-.562	-2.453	.029

a. Dependent Variable: DifΔJHSGER

b. Linear Regression through the Origin

Coefficients^{a,b}

Model		Unstandardized Coefficients		Standardized Coefficients		Sig.
		B	Std. Error	Beta	t	
1	LagΔJHSTCR	-1.446	.251	-.848	-5.765	.000

a. Dependent Variable: DifΔJHSTCR

b. Linear Regression through the Origin

Coefficients^{a,b}

Model		Unstandardized Coefficients		Standardized Coefficients		Sig.
		B	Std. Error	Beta	t	
1	LagΔSHSGER	-.709	.301	-.547	-2.355	.035

a. Dependent Variable: DifΔSHSGER

b. Linear Regression through the Origin

Coefficients^{a,b}

Model		Unstandardized Coefficients		Standardized Coefficients		Sig.
		B	Std. Error	Beta	t	
1	LagΔGDPG	-1.228	.273	-.780	-4.496	.001

a. Dependent Variable: DifΔGDPG

b. Linear Regression through the Origin

Appendix 4: Computations for Granger Causality Tests

Computations for Granger Causality Tests using 1 Lag

Null Hypothesis	RSS_R	RSS_{UR}	m	n	k	(n-k)	F_{calc}
$\Delta GDPG$ does not cause							
$\Delta LPriExp$	0.590	0.587	1	14	2	12	0.06133
$\Delta LPriExp$ does not cause							
$\Delta GDPG$	159.445	159.167	1	14	2	12	0.02096
$\Delta GDPG$ does not cause							
$\Delta LJHSExp$	0.823	0.788	1	14	2	12	0.53299
$\Delta LJHSExp$ does not cause							
$\Delta GDPG$	159.445	145.476	1	14	2	12	1.15227
$\Delta GDPG$ does not cause							
$\Delta LSHSExp$	0.710	0.557	1	14	2	12	3.29623
$\Delta LSHSExp$ does not cause							
$\Delta GDPG$	159.445	159.119	1	14	2	12	0.02459
$\Delta GDPG$ does not cause							
$\Delta LTVETExp$	3.980	3.789	1	14	2	12	0.60491
$\Delta LTVETExp$ does not cause							
$\Delta GDPG$	159.445	159.435	1	14	2	12	0.00075
$\Delta GDPG$ does not cause							
$\Delta LTerExp$	0.512	0.431	1	14	2	12	2.25522
$\Delta LTerExp$ does not cause							
$\Delta GDPG$	159.445	159.154	1	14	2	12	0.02194
$\Delta GDPG$ does not cause							
$\Delta LMgtExp$	5.892	5.841	1	14	2	12	0.10478

Null Hypothesis	RSS _R	RSS _{UR}	m	n	k	(n-k)	F _{calc}
<hr/>							
ΔLMgtExp does not cause							
ΔGDPG	159.445	157.465	1	14	2	12	0.15089
ΔGDPG does not cause							
ΔLTotEduExp	0.215	0.179	1	14	2	12	2.41341
ΔLTotEduExp does not cause							
ΔGDPG	159.445	158.466	1	14	2	12	0.07414
ΔGDPG does not cause							
ΔEdu%GovExp	92.191	49.897	1	14	2	12	10.17151
ΔEdu%GovExp does not							
cause ΔGDPG	159.445	158.741	1	14	2	12	0.05322
ΔGDPG does not cause							
ΔPriGER	116.739	107.156	1	14	2	12	1.07316
ΔPriGER does not cause							
ΔGDPG	159.445	153.074	1	14	2	12	0.49944
ΔGDPG does not cause							
ΔPriTCR	536.660	407.218	1	14	2	12	3.81443
ΔPriTCR does not cause							
ΔGDPG	159.445	158.131	1	14	2	12	0.09971
ΔGDPG does not cause							
ΔJHSGER	27.046	26.239	1	14	2	12	0.36907
ΔJHSGER does not cause							
ΔGDPG	159.445	143.054	1	14	2	12	1.37495
ΔGDPG does not cause							
ΔJHSTCR	500.233	499.043	1	14	2	12	0.02861

Null Hypothesis	RSS _R	RSS _{UR}	m	n	k	(n-k)	F _{calc}
<hr/>							
ΔJHSTCR does not cause							
ΔGDPG	159.445	159.206	1	14	2	12	0.01801
ΔGDPG does not cause							
ΔSHSGER	104.545	103.262	1	14	2	12	0.14910
ΔSHSGER does not cause							
ΔGDPG	159.445	159.376	1	14	2	12	0.00520

Computations for Granger Causality Tests using 2 Lags

Null Hypothesis	RSS _R	RSS _{UR}	m	n	k	(n-k)	F _{calc}
<hr/>							
ΔGDPG does not cause							
ΔLPriExp	0.474	0.454	2	13	4	9	0.19824
ΔLPriExp does not cause							
ΔGDPG	155.512	101.34	2	13	4	9	2.40551

Null Hypothesis	RSS _R	RSS _{UR}	m	n	k	(n-k)	F _{calc}
Δ GDPG does not cause							
Δ LJHSExp	0.802	0.468	2	13	4	9	3.21154
Δ LJHSExp does not cause							
Δ GDPG	155.512	106.286	2	13	4	9	2.08416
Δ GDPG does not cause							
Δ LSHSExp	0.692	0.429	2	13	4	9	2.75874
Δ LSHSExp does not cause							
Δ GDPG	155.512	135.908	2	13	4	9	0.64910
Δ GDPG does not cause							
Δ LTVETExp	3.954	2.417	2	13	4	9	2.86161
Δ LTVETExp does not cause							
Δ GDPG	155.512	154.553	2	13	4	9	0.02792
Δ GDPG does not cause							
Δ LTerExp	0.399	0.288	2	13	4	9	1.73438
Δ LTerExp does not cause							
Δ GDPG	155.512	154.468	2	13	4	9	0.03041
Δ GDPG does not cause							
Δ LMgtExp	4.506	4.12	2	13	4	9	0.42160
Δ LMgtExp does not cause							
Δ GDPG	155.512	139.786	2	13	4	9	0.50625
Δ GDPG does not cause							
Δ LTotEduExp	0.207	0.158	2	13	4	9	1.39557
Δ LTotEduExp does not cause							
Δ GDPG	155.512	117.251	2	13	4	9	1.46843

Null Hypothesis	RSS _R	RSS _{UR}	m	n	k	(n-k)	F _{calc}
Δ GDPG does not cause							
Δ Edu%GovExp	70.733	29.167	2	13	4	9	6.41297
Δ Edu%GovExp does not cause Δ GDPG	155.512	150.368	2	13	4	9	0.15394
Δ GDPG does not cause							
Δ PriGER	99.765	60.581	2	13	4	9	2.91062
Δ PriGER does not cause Δ GDPG	155.512	70.943	2	13	4	9	5.36431
Δ GDPG does not cause							
Δ PriTCR	490.372	290.594	2	13	4	9	3.09367
Δ PriTCR does not cause Δ GDPG	155.512	147.536	2	13	4	9	0.24328
Δ GDPG does not cause							
Δ JHSGER	25.767	23.002	2	13	4	9	0.54093
Δ JHSGER does not cause Δ GDPG	155.512	129.819	2	13	4	9	0.89061
Δ GDPG does not cause							
Δ JHSTCR	97.724	95.376	2	13	4	9	0.11078
Δ JHSTCR does not cause Δ GDPG	155.512	108.871	2	13	4	9	1.92783
Δ GDPG does not cause							
Δ SHSGER	100.23	85.49	2	13	4	9	0.77588
Δ SHSGER does not cause Δ GDPG	155.512	149.718	2	13	4	9	0.17415

Computations for Granger Causality Tests using 3 Lags

Null Hypothesis	RSS_R	RSS_{UR}	m	n	k	(n-k)	F_{calc}
$\Delta GDPG$ does not cause							
$\Delta LPriExp$	0.457	0.313	3	12	6	6	0.92013
$\Delta LPriExp$ does not cause							
$\Delta GDPG$	152.165	98.371	3	12	6	6	1.09370
$\Delta GDPG$ does not cause							
$\Delta LJHSExp$	0.801	0.367	3	12	6	6	2.36512

Null Hypothesis	RSS _R	RSS _{UR}	m	n	k	(n-k)	F _{calc}
<hr/>							
ΔLJHSExp does not cause							
ΔGDPG	152.165	58.064	3	12	6	6	3.24129
ΔGDPG does not cause							
ΔLSHSExp	0.655	0.189	3	12	6	6	4.93122
ΔLSHSExp does not cause							
ΔGDPG	152.165	113.866	3	12	6	6	0.67270
ΔGDPG does not cause							
ΔLTVETExp	3.802	1.893	3	12	6	6	2.01690
ΔLTVETExp does not cause							
ΔGDPG	152.165	147.171	3	12	6	6	0.06787
ΔGDPG does not cause							
ΔLTerExp	0.277	0.134	3	12	6	6	2.13433
ΔLTerExp does not cause							
ΔGDPG	152.165	121.11	3	12	6	6	0.51284
ΔGDPG does not cause							
ΔLMgtExp	1.765	1.27	3	12	6	6	0.77953
ΔLMgtExp does not cause							
ΔGDPG	152.165	129.695	3	12	6	6	0.34651
ΔGDPG does not cause							
ΔLTotEduExp	0.196	0.153	3	12	6	6	0.56209
ΔLTotEduExp does not cause							
ΔGDPG	152.165	88.676	3	12	6	6	1.43193
ΔGDPG does not cause							
ΔEdu%GovExp	68.231	28.345	3	12	6	6	2.81432

Null Hypothesis	RSS _R	RSS _{UR}	m	n	k	(n-k)	F _{calc}
$\Delta\text{Edu\%GovExp}$ does not cause ΔGDPG	152.165	134.231	3	12	6	6	0.26721
ΔGDPG does not cause ΔPriGER	86.756	59.123	3	12	6	6	0.93476
ΔPriGER does not cause ΔGDPG	152.165	63.646	3	12	6	6	2.78160
ΔGDPG does not cause ΔPriTCR	401.251	216.193	3	12	6	6	1.71197
ΔPriTCR does not cause ΔGDPG	152.165	122.49	3	12	6	6	0.48453
ΔGDPG does not cause ΔJHSGER	21.311	16.655	3	12	6	6	0.55911
ΔJHSGER does not cause ΔGDPG	152.165	114.538	3	12	6	6	0.65702
ΔGDPG does not cause ΔJHSTCR	91.846	89.369	3	12	6	6	0.05543
ΔJHSTCR does not cause ΔGDPG	152.165	55.881	3	12	6	6	3.44604
ΔGDPG does not cause ΔSHSGER	94.465	76.949	3	12	6	6	0.45526
ΔSHSGER does not cause ΔGDPG	152.165	138.503	3	12	6	6	0.19728