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The Impact of Infrastructure Development on Economic Growth in Sub-Saharan Africa with Special Focus on Ghana

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Abstract

Purpose- This research seeks to assess the impact of infrastructure development on Ghana's economic growth.

Design/methodology/approach- Using data obtained from the World Bank's World Development Indicators, the United States' (US) International Energy Statistics and the Central Intelligence Agency's (CIA) Factbooks from 1980 to 2016, an autoregressive distributed lag (ARDL) framework is used to determine the long and short run impact of the selected infrastructure stock and quality indices on Ghana's economic growth.

Findings- Findings indicate a statistically significant relationship between infrastructure development and economic growth. Additionally, electricity generating capacity is identified as the infrastructure stock index that has the greatest positive impact on Ghana's economic growth. The study reveals that electricity distribution loss has a significant negative effect over both long- and short-run periods.

Practical implications- The research provides pragmatic guidance to policy makers to focus efforts upon expanding electricity generating capacity while simultaneously taking steps to curb electricity transmission and distribution losses. These two related actions offer the greatest positive impact upon infrastructure development and as a consequence, Ghana's economic growth.

Originality/value- This paper represents the first attempt to empirically study the relationship between infrastructure development and Ghana's economic growth. A key contribution to the existing body of knowledge includes strong evidence of a positive effect of infrastructure development upon Ghana's economic growth. Results also reveal that the greatest positive impact upon economic growth is derived from electricity generation capacity. However, the study also uncovers a negative, but statistically significant, relationship between road and economic growth.

Research Limitations- Commercial petroleum export from Ghana since 2010 has been a key contributor to economic growth. Although its aggregate effect is included in the annual GDP figures adopted for the study, the authors would have wished to assess its impact on GDP as an independent standard growth determinant. However, because of a lack of available data over this study period, petroleum exports could not be adopted as an independent standard growth determinant. Additionally, an aggregated index of infrastructure stock and quality could not be derived due to the small size of data available. Hence, this study did not assess its impact upon Ghana's economic growth.

Keywords Infrastructure development, economic growth, autoregressive distributed lag (ARDL), electricity generating capacity, electricity distribution losses.

Paper type Research paper

1.0 Introduction

Infrastructure development is a key driver within countries for economic growth and poverty reduction (i.e. socio-economic development) (Union, 2010; Srinivasu and Rao, 2013; Bhattacharya et al., 2015). However, according to Torrisi (2009), there is no standard definition of infrastructure across economic studies. Dobbs et al. (2013) define infrastructure as the structure or underlying foundation upon which the continuous growth of a community depends; this definition delineates the critical role of infrastructure in socio-economic development.

More than half of sub-Saharan Africa's improved growth performance has been attributed to infrastructure development (Foster and Briceno-Garmendia 2009). This notwithstanding, infrastructure deficiency presents a major stumbling block that impedes Africa's socio-economic development (Calderon and Serven, 2008). Nearly 40% of depression of firms' productivity in Africa is attributed to the inability of developing countries to provide the needed infrastructure for businesses (World Bank, 2013). Current investments in infrastructure projects are insufficient to bridge the global infrastructure gap (Bhattacharya et al., 2015). According to recent estimates, US$ 4 trillion (representing 4% of global GDP), is required annually to meet global infrastructure requirements and within developing countries an estimated US$ 1.5 trillion annually is required up until the year 2030. A significant infrastructure financing gap is apparent with the current financing estimated to be between US$ 800 to US$ 900 billion per annum (OECD, 2013).

A plethora of studies conducted have sought to determine the impact of infrastructure development on economic growth (Calderon and Serven, 2004; Straub, 2007; Chakamera and Alagidede, 2017). Munnel (1992) credits Aschauer (1989) for drawing attention to the importance of public infrastructure in supporting economic growth. Calderon and Serven (2008) conclude that a positive long-run relationship exists between growth and increased infrastructure stock, and improved quality of service. Similarly, Calderon (2009) conclude that economic growth is positively affected by the stock and quality of infrastructure services. Loayza and Odawara (2010) also posit that infrastructure in general is an important determinant of economic growth in Egypt. Chakamera and Alagidede (2017) confirm that infrastructure has a positive and significant growth effect in sub-Saharan Africa.

Despite confirmation of its principal role in economic growth, there exists a distinct lack of specific evidence of infrastructure development in Ghana. Additionally, there is scant extant literature that presents pertinent empirical studies being carried out in Ghana. Faced with perennial challenges of high fiscal deficit and high debt to GDP ratio, it is imperative that Ghana identifies and prioritizes the specific infrastructure stock and quality indices that contribute the most to economic growth.

This research provides empirical evidence of the contribution of each infrastructure stock and quality index to Ghana's economic growth. This work will help with the prioritization of scarce resources into the expansion of infrastructure indices that have the greatest impact upon economic growth. Furthermore, the results provide guidance on both long- and short-run effects of the various infrastructure stock and quality indices. Cumulatively, this body of knowledge and information will be useful for policy formulation. A concomitant objective of this novel research is to stimulate further research investigation into the various aspects of infrastructure development and economic growth in the Ghanaian context. Furthermore, the findings of this research will also be useful to other countries within the sub-Saharan Africa region with similar infrastructure challenges and economic characteristics as Ghana.

1.1 State of Infrastructure in sub- Sahara Africa

Investments in infrastructure are currently insufficient to bridge the infrastructure gap that will guarantee the quality and quantity of growth demanded globally (Bhattacharya et al., 2015). Indeed, many developing countries who proactively seek to improve socio-economic development require additional infrastructure investments (Foster and Briceno-Garmendia, 2009; Calderon and Serven, 2010). Inderst (2013) argues that to date no attempt has been made at a proper quantification of the infrastructure financing gap. Most estimates are based on a small number of original studies that try to quantify infrastructure investment needs. The current estimate of global infrastructure need is circa 4% of global GDP or US$ 4 trillion per year (Estache et al., 2015). The World Economic Forum (WEF) (2012) estimates that the infrastructure gap is circa US$ 1 trillion per annum – this representing the difference between the annual need of US$ 3.55 trillion and actual spending of US$ 2.5 trillion. An estimate for developing countries is much higher at circa 15% of their GDP. Ultimately, developing countries require approximately US$ 1.5 trillion per year; taking into consideration the current investment of between US$ 800 and US$900 million per year (Solheim, 2013), a significant financing gap is apparent. An earlier projection by Dobbs et al. (2013) indicates that global infrastructure demand requires an investment of US$ 57 trillion by 2030 - equaling 3.5% of global GDP.

Crucial, and potentially transformational, infrastructure to propel socio-economic development is particularly lacking in sub-Saharan Africa (Gutman et al., 2015). The World Bank (2013) project that annually, the African continent requires US$ 37 billion for the maintenance of existing infrastructure and US$ 38 billion for new infrastructure to address the huge infrastructure deficit. Similarly, Gutman et al. (2015) note that in 2009 the World Bank, major donors and multilateral institutions estimated that Africa requires US$ 93 billion per annum to fill the infrastructure gap.

Sub-Saharan Africa suffers from acute lack of access to electricity (Bazilian et al., 2012) with approximately 580 million people unable to access this power source (IEA, 2010). Current access to electricity is little more that 20% (Banerjee et al., 2008) and indeed, Banerjee et al. (2008) further posit that fewer than 40% of African countries will have access by 2050. However, Calderon et al. (2018) estimate that people with access to electricity grew from 14% in 1990 to about 35% in 2014. Foster and Briceno-Garmenda (2009) and Estache and Garsous (2012) conclude that power or energy production presents the largest infrastructure gap for Africa, requiring nearly 40% to 60% of infrastructure investment. Eberhard et al. (2011) opine that 93% of Africa's economically viable hydropower potential remains unexploited. Africa has the potential to generate 937 terawatts-hours (TWh) per year, constituting one-tenth of the world's total. Additionally, Africa is endowed with abundant solar and wind renewable energy resources which could be harvested for growth.

According to Williams et al. (2011), Africa witnessed a significant growth in mobile telephone users between 1998 and 2008, by more than 247 million. The International Finance Corporation (IFC) (2016) argues that with a forecast increase from 500,000 subscribers in 1995 to over 750 million in 2015, mobile telephone has experienced phenomenal growth over the period. Yet, there remains substantial disparity in accessibility between rural and urban availability. In 2009, approximately 90% of Africa's urban population lived within reach of a mobile network, compared to 48% in the rural areas. Internet density, represented by number of users per 100 people, is also estimated to have increased from 1.3 people in 2005 to 16.7 people in 2015 (Calderon et al., 2018). Williams et al. (2011) estimate 32% of Africa's population (representing 263 million people) to be active subscribers of both mobile and fixed telephone networks. By December 2009, 234,000 kilometers of terrestrial fiber optic transmission network was estimated to be operational in sub-Saharan Africa with a further 41,000 kilometers under construction. Total investment in mobile telecommunications is estimated to have reached US$ 9 billion dollars in 2015 (IFC, 2016).

The distinct lack of an effective transportation system in sub-Saharan Africa is one of the greatest impediments to growth and poverty reduction (Beuran et al., 2015). Zietlow (2007) identifies road transport as being the most dominant mode of transport, carrying over 75% of passenger and freight in sub-Saharan Africa. UNECA (2009) notes that the total road network in Africa increased from 2.06 million kilometers in 2001 to about 2.42 million kilometers in 2005, resulting in an improvement in road density from 6.8km to 8.3km per 100 sq. km. Only 22.7% of the total road network was paved by 2005. Africa's international trade route is however dominated by marine transport accounting for between 92% and 95% of international trade. UNECA (2009) contends that Africa's 90 major ports account for over 95% of all international import and export trade. On the contrary, Africa's rail transport network has suffered a strong decline over the past decades (AfDB, 2015). Despite being the most cost effective means of transporting bulk cargo over long distances on land, the total railway network was estimated at 90,320km in 2005, representing only 3.1km per 1,000sq. km (UNECA, 2009). According to Perkins (2005), in most European countries railways developed in the 19th century by input of private capital. However, as rail grew to become the dominant mode of transport, by the end of the century governments had imposed regulations to limit monopoly power. Between 1990 and 2005, the total length of rail infrastructure in Europe experienced a slight decline (Nikolova, 2009). The low volume of demand and subsequent accumulated losses in some sections of certain countries resulted in the inability to properly maintain the rail tracks. The total rail network slightly reduced from 231,582km in 1990 to 215,439km in 2005. Smith and Zhou (2014) however observe that by the start of the 20th century, Great Britain and USA had 21,000miles and 182,000miles of rail tracks respectively. They further observe that by 2014, China alone had more than 100,000km of railway tracks representing 6% of the world's total and carrying about 20% of the world's traffic.

Sub-Saharan Africa has witnessed an increase in access to improved drinking water from 48% in 1990 to 68% in 2015 and a marginal increase in access to improved sanitation from 24% to 30% over the same period (UN, 2015). Despite these increases, the sub region is estimated to have very low water and basic sanitation coverage when compared to other developing regions (Bain et al., 2014). Sub-Saharan Africa fell short of meeting the 2015 Millennium Development Goal (MDG) target of providing access to drinking water and remains the region with the highest number of people without access (UN, 2015). According to JMP (2013), 344 million people in Africa did not have access to improved drinking water by the end of 2011, accounting for nearly half of the total worldwide estimate of 768 million people. AfDB (2015) opine that massive infrastructure investment is required to improve access to water as only 5% of Africa's unevenly distributed water resources have been developed.

1.2 Infrastructure Development and Economic Growth in sub-Saharan Africa

Given that infrastructure development is inextricably linked to economic growth (Foster and Briceno-Garmendia, 2009), any infrastructure deficiency within an economy will limit socio-economic development (Calderon and Serven, 2008). For example, insufficient power generation capacity has been identified as a huge limitation to economic growth prospects of Ghana (Estache and Vagliasindi, 2007). Diao and Yanoma (2003) also posit that poor transportation facilities, resulting in a high cost of bringing goods to market, has been a significant constraint on growth in the agriculture sector in sub-Saharan Africa.

Calderon and Serven (2008) find that similar to other regions in the world, sub-Saharan Africa exhibits a negative impact on income inequality and a positive long-run relationship between growth and increased infrastructure stock, and improved quality of service. Using a large pool of data on 100 countries, the study (*ibid*) concludes that the result is both statistically and economically significant.

Adopting telecommunication, electricity and roads as the key infrastructure sectors, Calderon (2009) established the relationship between infrastructure and economic growth in Africa. Calderon (*ibid*) concludes that economic growth is positively affected by the stock and quality of infrastructure services. The study additionally arrives at the following conclusions: i) larger infrastructure stock provides African countries with a greater probability of growth than quality enhancement in the existing stock; and ii) infrastructure stock contributes 99 basis points to per capita economic growth (89 basis points from infrastructure stock and 10 basis points from infrastructure quality). Chakamera and Alagidede (2017) derive similar conclusions in their study of the relationship between infrastructure stock and quality and economic growth in sub-Saharan Africa. They posit that infrastructure has a positive and significant growth effect in sub-Saharan Africa. Loayza and Odawara (2010) also conclude that infrastructure in general is an important determinant of economic growth in Egypt. When observed individually or combined, electricity index, transportation index and telecommunication index have the same positive and significant effect on the economic growth of Egypt.

1.3 Infrastructure Development in Ghana

Infrastructure development in Ghana has not been commensurate with demand. Despite renewed political focus on the importance of infrastructure in recent years, Ghana's infrastructure deficit has continued to inflate due to the inadequate financial commitment to expansion. According to Ploeg and Casey (2006), cited by Badu et al. (2012), the infrastructure financing challenges facing Ghana have brought about significant interest in the study of innovative financing of infrastructure. Aside others, Badu et al. (2012) identify three major challenges as being central to the success or failure of innovative financing of infrastructure delivery in Ghana, namely: investment capacity challenges; implementation challenges; and revenue mobilization challenges. The greatest impediment for infrastructure investment is the lack of stable, adequate and long-term financial resources (Badu et al., 2012). According to a Ghana News Agency report (2012) cited by Adjokacher (2014), Ghana requires an infrastructure investment of US$ 1.5 billion annually to meet the infrastructure financing deficit requirement.

The Government of Ghana has been, and continues to be, the singular most important financier of infrastructure in the country. In the midst of high fiscal deficit and growing debt to GDP ratio, budgetary allocations for infrastructure in recent years have witnessed an up and down trend. Successive Ghanaian governments have tried to minimize the huge infrastructure financing deficit through various policies and initiatives. According to Nyarko and Eghan (1998), cited by Badu et al. (2011), the District Assembly Common Fund (Act 455) mandates the Ghanaian Parliament to allocate not less than 5% of total government revenue to the District Assemblies for development.

Typically, infrastructure in Ghana will include power (mainly electricity), transportation (road and railway), telecommunications, housing and water and sanitation. These have been the focus of successive government's agendas in Ghana since 1957.

1.3.1 Power (Electricity)

Within Africa, Ghana is regarded as a country that has aggressively pursued electrification (Kumi, 2017). From a modest coverage of between 15% and 20% in 1989, 82.5% of Ghana's population had access to electricity at the end of 2016 (Ministry of Power, 2016), cited by Kumi (2017). Kumi (*ibid*) further identifies that the electricity supply during the Gold Coast era was mainly from diesel generators owned by industrial establishments and some institutions. The sector was however completely transformed with the completion of the

Akosombo Hydro Electric Power Station in 1972. In pursuing an agenda to rapidly extend electricity throughout the country, the National Electrification Scheme was established to oversee the implementation of a National Electrification Master Plan by 2020 (Ministry of Energy, 2010). To meet rising demand, the Kpong and Bui Hydro Electric Power Stations were also completed in 1982 and 2013 respectively (Kumi, 2017). Thermal generation sources, which depend mostly on natural gas, were also introduced.

The deficit in the electricity (power) sector presents the most pressing infrastructure challenge to Ghana's economic growth. A joint study by the US Department of State and Government of Ghana in 2011 concludes that an inadequate and unreliable supply of power is one of three major constraints impacting upon Ghana's future economic growth (Mathrani et al., 2013). The continuous use of outmoded transmission and distribution assets, rapid increases in demand and periodic hydrological shocks (leading to the reliance on higher cost oil based generation) are factors that accounted for infrastructure contributing just over 1% point to Ghana's per capita GDP growth during the 2000s (Foster and Pushak, 2011). Ghana therefore needs to invest US$ 4 billion in the next 10 years to close the deficit gap and upgrade the power sector infrastructure; generation, transmission and distribution (Power Africa, 2014). Mathrani et al., (2013) conclude that the power crises experienced in Ghana between 2006 and 2007 led to an estimated 1% loss in GDP growth.

1.3.2 Transportation

Ghana's total railway network length remained at 1300km between 2004 and 2008. The road sector, however, enjoyed an observed annual growth rate of 8% from 2000 to 2008 with the total portion of road being 67,291km at the end of 2008, excluding town roads which remain undocumented (MRH, 2009). In 2009, estimates indicate that the distance of paved and unpaved roads in Ghana were 12,442km and 533, 863km respectively and were sub-divided into urban roads (12,400km), feeder roads (42,209) and trunk roads (12,839km). Foster and Pushak (2011) claim that the road network quality was fairly reasonable with 75% of paved roads and 74% of unpaved roads in either good or fair condition. The Ministry of Roads and Highways medium-term expenditure framework estimates total national road coverage increased from 67,450km in 2010 to 71,063km in 2014. Additionally, the percentage of good roads increased from 40 to 45 % over the same period.

1.3.3 Telecommunication and ICT

According to Osiakwan (2008), reforms in the Ghanaian telecom industry were heralded by the promulgation of the National Redemption Council (NRC) Decree 311 in 1974 which resulted in the establishment of the Ghana Post and Telecommunication Corporation (GPTC). However, Tobbin (2010) contends that actual major reforms commenced in the 1990s when the Government of Ghana introduced a five year Accelerated Development Programme (ADP) for the telecommunications sector. The programme, which resulted in the privatization of Ghana Telecom, was to create the competition needed to improve access, reliability and quality of service (Frempong and Atubra, 2001). The reforms resulted in the liberalization and privatization of the sector, creation of a duopoly and the establishment of an independent regulatory body (Frempong, 2002). According to Frempong (*ibid*), Ghana had six mobile telephone operating companies by the end of 2009.

The telecommunication industry in Ghana has witnessed tremendous mobile telephone subscriber growth rate over the past decade (Nimako et. al., 2010). According to the National Communications Authority (2017), total mobile penetration rate is estimated at 137.92% as at January 2017. Total mobile voice subscriptions grew from 35,305,078 at December 2015 to 38,824,866 at end of January 2017. Today, the mobile phone is a major source of communication in Ghana (World Bank, 2007; Sey, 2008). Conversely, fixed telephony has not witnessed any major expansions with total subscription at 253,321 as at January 2017.

Mobile money transactions offered by mobile telecom companies have witnessed a tremendous increase over recent years. Abbey (2015) identifies that mobile money transactions by MTN, Tigo and Airtel rose from GHS 171 million to GHS 2.4 billion and then to GHS 11.6 billion in 2012, 2013 and 2014 respectively. The level of growth in mobile money transactions in recent years can only give credence to the impact of telecommunication and ICT on the Ghanaian economy.

1.3.4 Housing

In the post-colonial era, mass housing schemes through public housing development companies were undertaken by governments of Ghana (UN-HABITAT, 2011). State agencies such as State Housing Company Limited (SHCL), Tema Development Cooperation (TDC) and State Construction Company (SCC) were resourced by governments to provide housing. Such schemes characterized governments' housing strategy over the first three decades after independence. Past governments' interventions were also directed at giving loans to workers to build houses (MWRW&H, 2015). Yet despite these schemes, government interventions have been piecemeal and not yielded the desired results (UN-HABITAT, 2011). According to Badu et al. (2012), the Ministry of Works and Housing and National Trust Holding Company (NTHC) collaborated to raise US$ 200 million worth of domestic and foreign capital in 2004 with the aim of addressing the infrastructure financing deficit critical for Ghana's economic growth. Other interventions were also undertaken by governments of Ghana, such as: the establishment of the Ghana Educational Trust Fund (GETFUND) in 2000 for educational infrastructure development; the subsequent advocating of public-private partnership (Owusu-Manu et al., 2008); and the issuance of a US$ 750 million ten-year bond in 2007 (Stuart, 2008 cited by Badu et al., 2012). In addressing the shortfall, attempts have been made at drafting national policies but these have not had easy paths to implementation.

Despite concerted efforts by successive governments to provide affordable social or public housing, Ghana is still faced with serious housing deficit (Kwofie et al., 2011). The housing deficit was estimated at 1.2 million units in 2000 and out of the estimated annual demand of 133,000 units, only 25,000 units were provided leaving a deficit of 108,000 units (Boamah, 2010). Mahama and Antwi (2006) posit that the housing deficit in Ghana stood at 1,526,275 units in 2000, while the Ghana Statistical Service (GSS) (2012) estimates the deficit to be over 2 million units in 2010. Akuffo (2007) and Benjamin (2007) identify that major challenges facing the Ghanaian housing sector include: the absence of a clearly defined national housing policy; lack of access to sustainable capital or finance; and the lack of a control and regulatory framework for rent.

1.3.5 Water and Sanitation

Since the mid-1990s, successive governments of Ghana have implemented a series of reforms in the water sector with the aim of enhancing efficiency in the production and utilization of water. The provision of water and sanitation remains a prominent feature in Ghana's Growth and Poverty Reduction Strategies (GPRS I & II) (MWRW&H, 2007). According to the Ministry of Water Resources, Works and Housing (MWRW&H) (MWRW&H, 2014), the Water Sector Strategic Development Plan (WSSDP) 2012-2025 was developed with the aim of providing access to basic water and sanitation services to all Ghanaians by 2025. The WSSDP (which was developed through a national, regional and district consultative and participatory process) has the commitment to engage development partners and private sector to ensure financing for water and sanitation improvements (*ibid*).

Financial constraints and inadequate data on water and sanitation are key challenges to achieving the MDG on water and sanitation in Ghana (Awuah et al., 2009). According to the 2011 Country Status report, financial assistance from Ghana's developing partners has been consistently high for investment in water over the years. In 2003 for instance, development partners contributed about 90% of the total cost of rural water and sanitation facilities. In the 2006 quarterly report, development partners were estimated to have contributed 88% of investment funding (MWRW&H, 2007). The World Bank (2011) reports that the Community Water and Sanitation Agency (CWSA) and the Ghana Water Company Limited (GWSL) estimate rural and water coverage in 2008 at 57% and 58% respectively. Alternatively, the JMP (2010) report puts the use of improved water source at 82% of the population over the same period. The report further estimates that capital investments of US$ 237 million and US$ 406 million were required annually for investment in water and sanitation facilities respectively. The JMP (2015) report indicates that Ghana made limited or no progress in the use of sanitation facilities. There was a marginal improvement in the percentage of total population with access to improved sanitation facilities from 7% in 1990 to 15% in 2015. It is estimated that 19% of the total population still practice open defecation; an improvement from 22% in 1990. Ghana is however considered to have met the MDG 7 target C with an estimated 89% total population considered to have access to improved water sources.

The provision of water and sanitation in Ghana is currently under serious threat by illegal gold mining activities in rivers and other water bodies. The practice, commonly referred to as 'galamsey', has become the nation's most significant threat to the future supply of drinking water.

2.0 Infrastructure Quality and Economic Growth

Fourie (2008) defines infrastructure quality as a catch-all phrase that refers to all performance enhancing improvements of both physical infrastructure and of the services it provides. Consequently, infrastructure quality is the improvement in the performance of existing infrastructure stock. Caledron (2009) concurs with this view and defines infrastructure quality as the enhancement in the quality of infrastructure services.

A number of studies have examined the impact of infrastructure quality on growth, albeit Chakamera and Alagidede (2017) opine that the number of such studies is incredibly sparse. However, the focus has been on more infrastructure vis-a-vis better infrastructure (Fourie, 2008).

In their study of Latin American countries, Calderon and Serven (2004) conclude that infrastructure quality has a significant impact on growth. The study concludes that an increase of one standard deviation in the index of infrastructure quality would result in a 0.68 percentage point in growth per capita. Calderon and Serven (2010) also report upon the positive impact of infrastructure stock and improved quality of infrastructure services on long-term growth. According to Calderon (2009), infrastructure stock contributes 89 basis points to growth per capita as compared to 10 basis points by infrastructure quality. African countries are therefore more likely to gain from an increase in infrastructure stock than from enhancements in the quality of existing infrastructure. Chakamera and Alagidede (2017) contend that inadequate infrastructure, which negatively affects growth, is further exacerbated by the poor quality of existing infrastructure. This notwithstanding, the quality-growth effect of infrastructure quality is weak, contributing 10 basis points to growth per capita in sub-Saharan Africa compared to 47 basis points by infrastructure quantity.

3.0 Methodology and Data

The Autoregressive Distributed Lag (ARDL) cointegration technique was employed to establish the relationship between infrastructure development and economic growth. Cointegration and error correction modelling were employed to establish the short-run dynamics and the speed of adjustment to the long-run equilibrium. The methodology followed the use of the augmented Cobb-Douglas production function. This current study utilized some of the variables identified in Chakamera and Alagidede (2017) to undertake a cointegration in order to establish a relationship between infrastructure development and economic growth. Explanatory variables employed include: net electricity generation capacity (ElecGen); mobile subscribers (Mobile); roadways (Road); electricity distribution losses (ElecDL); paved roads (PavedRD); inflation (INF); trade (Trade); domestic credit to private sector (DomCredit); and annual population growth rate (Pop). Stationarity tests of the variables were undertaken using both the Augmented Dickey-Fuller and Phillips Perron procedures.

Testing for cointegration between two or more time series data using the ARDL approach began with the running of a stationarity test to determine whether the variables were stationary at level, at first difference or both. The model collapses when any of the variables are stationary at second difference (Nkoro and Uko, 2016). The cointegration test was then carried out on the variables to confirm the cointegration in the times series variables involved - one of the cardinal principles required for the adoption of the ARDL cointegration technique. In order to ascertain the goodness of fit of the adopted ARDL model, diagnostic and stability tests were conducted, which included: serial correlation; normality; and heteroskedasticity tests. Cumulative residuals (CUSUM) and the cumulative sum of squares of recursive residuals (CUSUMSQ) were conducted to determine the structural stability of the adopted model.

The study utilized annual times series data of Ghana for the period 1980-2016. Data on Ghana's infrastructure stock and quality over the period were obtained from various sources (refer to Table 1). Notably, data on roads and paved roads on one hand and that for mobile subscription were not available until 1989 and 1992 respectively. However, according to Elahi (2008), data collection in developing countries is faced with many challenges and Ghana is no exception. Nonetheless, this does not annul the findings of the study.

Data for the period between 1980 and 2016 was adopted because the total number of observations over the period (34) guaranteed the structural stability of the ARDL model adopted. Over the same period, the selected variables were stationary at either I(0), I(1) or both. Additionally, the CUSUM and CUSUM of squares were both within the acceptable 5% significance level. It was further observed that the adoption of any period of less than 30 observations rendered the ARDL model structurally unstable. The CUSUM of squares for the periods between 1990-2016 and 2000-2016 were out of the acceptable 5% significance level, rendering the model unstable. Not only was the ARDL model unstable for the period between 2000-2016, but two variables, Logmobile and LogPop, were not stationary at either I(0), I(1) or both - a condition necessary for the adoption of the ARDL model (Nkoro and Uko, 2016). As a result, the data for the periods between 1990-2016 and 2000-2016 were not adopted for the study.

Table 1: Definition and sources of variables

No	Variable	Definition	Year	Source
1	**ElecGen**	Net electricity generation capacity (Blns kWh)	1980-2016	US Energy Information: International Energy Statistics
2	**Mobile**	Mobile (subscription per 100 persons)	1992-2016	World Bank Group: WDI
3	**Road**	Roadways (km)	1989-2016	CIA Factbooks; Photius Coutsoukis

4	**ElecDl**	Electricity distribution losses (Blns kWh)	1980-2016	US Energy Information: International Energy Statistics
5	**PavedRd**	Paved roads (km)	1989-2016	CIA Factbooks; Photius Coutsoukis
6	**GDP**	GDP growth (annual %)	1980-2016	World Bank Group: WDI
7	**INF**	Inflation (Consumer prices: Annual %)	1980-2016	World Bank Group: WDI
8	**Trade**	Trade (% of GDP) = X + M share of GDP (proxy for trade openness)	1980-2016	World Bank Group: WDI
9	**DomCredit**	Domestic Credit to Private sector (% of GDP) (proxy for financial depth)	1980-2016	World Bank Group: WDI
10	**Pop**	Population (annual growth rate)	1980-2016	World Bank Group: WDI

3.1 Stationarity Tests (Unit Root Test)

The Augmented Dickey-Fuller (ADF) (1981) and Phillips Perron (PP) (1988) tests were adopted to test and confirm the stationarity of the variables. ARDL cointegration is applicable to variables that are stationary at purely I(0), purely I(1) or a combination of both. The model however collapses with the presence of integrated stochastic trends of I(2) (Nkoro and Uko, 2016). ADF is the most popular strategy for testing the stationarity property of a single times series (Nkoro and Uko, 2016), however the study uses both ADF and PP unit root tests to provide a good confirmatory test of the results.

Tables 3a and 3b present the results for stationarity properties based on the ADF and PP tests. The null hypothesis of unit root is not rejected either by ADF or by the PP test. The series are mostly non-stationary at I(0). The results of the first difference of the time series from both the ADF and PP unit root tests confirm that all the variables in the study are stationary at first difference, I(1).

Table 2: Log and first difference of variables

No	Variable	Log of Variable	First Difference of Log of Variable
1	ElecGen	LogElecGen	DLogElecGen
2	Mobile	LogMobile	DLogMobile
3	Road	LogRoad	DLogRoad
4	ElecDl	LogElecDl	DLogElecDl
5	PavedRd	LogPavedRd	DLogPavedRd
6	GDP	LogGDP	DLogGDP
7	INF	LogINF	DLogINF
8	Trade	LogTrade	DLogTrade
9	DomCredit	LogDomCredit	DLogDomCredit
10	Pop	LogPop	DLogPop

Table 3a: Unit root tests (tests based on MacKinnon critical values)

ADF test statistics

No constant No trend

Variables	Lag 0	Lag 1	Lag 2
Level			
LogElecGen	0.477	0.278	0.828
LogMobile	-0.993	0.439	-0.720
LogRoad	1.698 ***	1.985 **	2.448 **
LogElecDl	-0.779	-0.718	-0.939
LogPavedRd	0.405	0.404	0.597
LogGDP	-1.020	-0.693	-0.569
LogINF	-0.925	-1.154	-0.730
LogTrade	0.881	0.872	1.600
LogDomCredit	1.339	1.464	1.953 **
LogPop	-0.295	-2.595 **	-1.032
First Difference			
DLogElecGen	-4.766 *	-5.420 *	-5.256 *
DLogMobile	-3.305 *	-1.631 ***	-1.805 ***
DLogRoad	-4.347 *	-3.295 *	-1.925 ***
DLogElecDl	-5.819 *	-4.716 *	-3.231 *
DLogPavedRd	-4.974 *	-4.615 *	-3.315 *
DLogGDP	-8.631 *	-4.664 *	-3.315 *
DLogINF	-9.042 *	-6.486 *	-4.617 *
DLogTrade	-4.621 *	-5.342 *	-2.315 **

DLogDomCredit	-5.907 *	-4.769 *	-3.126 *
DLogPop	-5.500 *	-7.788 *	-4.766 *

*Note: The symbols *, **, and *** indicate significance at 1%, 5% and 10% statistical levels respectively.*

Table 3b: Unit root tests (tests based on Bartlett Kernel critical values)

Phillips-Perron test statistics

No constant No trend

Variables	Lag 0	Lag 1	Lag 2
Level			
LogElecGen	-3.170	-3.336 ***	-3.236 ***
LogMobile	-0.565	-0.598	-0.623
LogRoad	-2.208	-2.239	-2.162
LogElecDl	-2.783	-2.788	-2.749
LogPavedRd	-2.448	-2.580	-2.518
LogGDP	-3.697 **	-3.668 **	-3.742 **
LogINF	-5.207 *	-5.204 *	-5.175 *
LogTrade	-1.437	-1.657	-1.604
LogDomCredit	-2.578	-2.634	-2.546
LogPop	-3.383 ***	-3.432 ***	-3.561 **
First Difference			
DLogElecGen	-4.747 *	-4.788 *	-4.677 *
DLogMobile	-6.157 *	-5.771 *	-5.575 *
DLogRoad	-5.345 *	-5.351 *	-5.478 *
DLogElecDl	-5.879 *	-5.879 *	-5.908 *
DLogPavedRd	-4.823 *	-4.822 *	-4.824 *
DLogGDP	-8.357 *	-8.430 *	-8.480 *
DLogINF	-8.957 *	-9.044 *	-9.874 *
DLogTrade	-5.151 *	-5.187 *	-5.329 *
DLogDomCredit	-6.551 *	-6.589 *	-6.925 *
DLogPop	-5.348 *	-4.606 *	-4.413 *

*Note: The symbols *, **, and *** indicate significance at 1%, 5% and 10% statistical level respectively.*

3.2 Cointegration Test

Engle and Granger (1987), Johansen and Juselius (1990) and Gregory and Hansen (1996) discuss some conventional approaches available for testing of cointegration. This study however adopts the ARDL cointegration technique or bound cointegration testing technique (Nkoro and Uko, 2016). Pesaran and Shin (1995) and Pesaran et al. (1996b) postulate that the ARDL approach provides realistic and efficient long-run relationship estimates, providing that the underlying regressors are purely I(0), purely I(1) or a combination of both. Pesaran et al. (2001) subsequently posit the two sets of appropriate lower and upper critical values to be 3.65 and 4.66, 2.79 and 3.67, and 2.37 and 3.20 for 1%, 5% and 10% significance levels respectively. Narayan (2005) however opines that the critical values posited by Pesaran et al. (2001) could not be applicable to small samples. The study subsequently posits the appropriate lower and upper bound values for small samples of between 30 to 80 observations to be 4.068 and 5.250, 2.962 and 3.910, and 2.496 and 3.346 for 1%, 5% and 10% significance levels respectively. Tzougas (2013) also posits that the ARDL cointegration test is most appropriate as it is more robust and performs better for small sample data. Results of the bound test procedure for cointegration analysis between LogGDP and the independent variables are provided in Table 4 below.

Table 4: Bound test for cointegration analysis

F-Bound test **Null hypothesis: no levels relationship**

Test Statistics	**Significance Level**	**Restricted Constant No Trend**		**Unrestricted Constant No Trend**	
F-statistics		I(0)	I(1)	I(0)	I(1)
27.97076 (Rest	10.00 %	1.80	2.80	1.88	2.99
const., no trend)	5.00 %	2.04	2.08	2.14	3.30
30.40964 (unrest	2.50 %	2.24	3.35	2.37	3.60
const, no trend)	1.00 %	2.50	3.68	2.65	3.97

The results indicate the existence of a long-run relationship between LogGDP and the independent variables. The F-statistic for the bound test is 27.97076 and exceeds the 1% critical value for the upper bound. The null hypothesis of no levels or long-run relationship is therefore rejected. Afzal et al. (2013) conclude that the coefficient of error correction model, ECM (-1), also known as the adjustment parameter, points out the swiftness of variables as they progress towards equilibrium. A negative and statistically significant ECM (-1) therefore establishes a long-run causal effect, confirms the existence of cointegration and validates the model's stability. The significant negative coefficient of ECM (-1) from Table 6 further supports the existence of a long-run relationship.

4.0 Discussion of Results

The study's findings are discussed under the respective objectives below.

4.1 Relationship between infrastructure development and Ghana's economic growth using both indices of infrastructure stock and quality.

Overall, the study uncovered the existence of both long- and short-run relationships between indices of infrastructure stock and quality and economic growth of Ghana. Estimates for both long- and short-run coefficients underscore the statistically significant relationship between the selected indices of infrastructure stock, quality and GDP. Electricity generation (LogElecGen) has a positive and significant relationship with LogGDP. Results from Tables 5 and 6 suggest that a 2.97% and 1.51% increase in GDP in the long- and short-run periods respectively occur as a result of a 1% increase in electricity generation.

TABLE 5: Result of estimated long run coefficients using the ARDL approach

Dependent variable: LogGDP

Variable	Coefficient	Std. Error	t-Statistic
C	17.59433	2.808572	6.264512 *
LogGDP(-1)	-2.823487	0.182429	-15.47715 *
LogElecGen(-1)	2.974332	0.318302	9.344371 *
LogMobile(-1)	0.995864	0.071330	13.96141 *
LogRoad(-1)	-3.030346	0.257528	-11.76707 *
LogElecDl(-1)	-1.294860	0.144132	-8.983835 *
LogPavedRd	0.465471	0.126601	3.676665 **
LogINF(-1)	-0.610571	0.113216	-5.392964 *
LogTrade	3.021710	0.323271	9.347290 *
LogDomCredit(-1)	-3.365671	0.304760	-11.04369 *
LogPop	5.263320	1.075483	4.893911 *
R-squared	0.990772	F-statistic	-37.89502 *

Adjusted R-squared	0.964627	Durbin-Watson stat	2.747032

*Note: The symbols *, **, and *** indicate significance at 1%, 5% and 10% statistical level respectively.*

TABLE 6: Results of estimated short run coefficients using the ARDL approach

Dependent variable: D(LogGDP)

Variable	**Coefficient**	**Std. Error**	**t-Statistic**
C	17.59433	0.640359	27.47572 *
D(LogGDP(-1))	0.407791	0.038308	10.64514 *
D(LogElecGen)	1.506817	0.076677	19.65154 *
D(LogMobile)	0.537912	0.032293	16.65701 *
D(LogRoad)	-1.497448	0.068947	-21.71890 *
D(LogElecDl)	-0.834301	0.030431	-27.41576 *
D(LogINF)	-0.110322	0.021037	-5.24412 *
D(LogDomCredit)	-2.805179	0.112679	-24.89524 *
CointEq(-1)*	-2.823487	0.102402	-27.57247 *
R-squared	0.989951	F-statistic	184.71300 *
Adjusted R-squared	0.984592	Durbin-Watson stat	2.747032

*Note: The symbols *, **, and *** indicate significance at 1%, 5% and 10% statistical level respectively.*

The extended access to mobile communications has a positive and significant relationship with GDP. An increase in mobile communication by 1% will lead to about a similar level (1%) and 0.54% growth in GDP over the long- and short-run periods respectively.

The empirical long- and short-run relationship between Road and GDP is rather negative and statistically significant. Over the long-run, the negative coefficient of -3.0 seems to suggest that a 1% increase in the provision of roads will result in a circa 3.0% decline in GDP. Similarly, over the short-run, the negative coefficient of -1.49 suggests that a 1% increase in the provision of roads will result in a circa 1.5% decline in GDP - this is contrary to pertinent economic theory and literature. In view of this, this study adopts the interpretation that a 1% reduction in roads will lead to about 3.0% and 1.5% decline in GDP over the long- and short-run respectively, consistent with extant economic theory and literature.

The empirical results show a negative and significant long- and short-run relationship between electricity distribution losses (LogElecDl) and GDP. An increase in electricity distribution losses by 1% is likely to lead to about 1.3% and 0.8% reduction in GDP over the long- and short-runs respectively.

An increase of 1% of paved road (LogPavedRd) will yield a 0.47% increase in GDP over the long-run. The results therefore indicate a positive and significant relationship between paved roads and GDP. Interestingly though, paved roads do not seem to have a significant short-run impact on GDP as the variable was dropped under the Error Correction Model (ECM) for the short-run relationship between infrastructure and GDP.

These findings corroborate the work of Srinivasu and Rao (2013) who established a positive relationship between infrastructure development and economic growth in their study of Indian cities. In the study to determine the relationship between Africa's growth and infrastructure development, Calderon (2009) establishes a positive and statistically significant relationship. Calderon and Serven (2010) also identify a positive relationship between infrastructure stock and quality and growth in Latin America. The study posits that between 2001 and 2005, infrastructure contributed 2.43% points to growth in Latin American countries thus confirming a positive and significant relationship between infrastructure stock and quality and growth. More recently, Chakamera and Alagidede (2017) confirm the positive and significant growth effect of infrastructure on economic growth. The study (*ibid*) further concludes that infrastructure development is a key factor underpinning economic growth in sub-Saharan Africa.

4.2 The contribution of infrastructure quality on Ghana's economic growth.

The two indices of infrastructure quality used in this study exhibit a strong and significant impact on Ghana's economic growth. The empirical results in Tables 5 and 6 show a negative and significant long-run relationship between electricity distribution losses (LogElecDL) and GDP. With negative coefficients of 1.3 and 0.83, an increase in electricity distribution losses will lead to about 1.3% and 0.83% reduction in GDP over the long- and short-run respectively.

The results also indicate a positive and significant relationship between paved roads and GDP. In the long-run, an increase of 1% of paved road (LogPavedRD) will result in about 0.47% increase in GDP. Interestingly though, paved roads do not seem to have a significant short-run impact on GDP.

Calderon (2009) identifies that infrastructure quality contributed 10 basis points to growth in Africa compared to the 89 basis point by infrastructure stock. In a study of 36 Africa countries between 1960 and 2005, the Congo's growth declined by -0.4% mostly due to higher losses in electricity transmission and distribution. Calderon and Serven (2010) proffer that low infrastructure quality service contributed to a decline of 0.19 percentage points on average in Latin America between 1986 and 1990. However, enhanced infrastructure quality services accounted for 0.61 percentage points growth per annum in East Asia over the same period. Both Calderon (2009) and Chakamera and Alagidede (2017) conclude that the deterioration in electricity services served as a key hindrance to the economic progress in sub-Saharan Africa.

4.3 Infrastructure stock index with the greatest impact on Ghana's economic growth.

Tables 5 and 6 infer that electricity generation (LogElecGen) is the infrastructure index that has the greatest impact on Ghana's economic growth. For both the long- and short-run, electricity generation has the largest positive and statistically significant coefficient indicating its impact on economic growth relative to the other infrastructure indices. Over the long-run, a 1% increase in electricity generation is likely to result in a more than 2.97% increase in growth. Similarly, a 1% increase in electricity generation will result in about a 1.5% increase in GDP in the short-run.

Extant literature confirms the importance of electricity generation to economic growth, but only a few have proceeded to rank the impact of infrastructure stock and quality. According to Calderon (2009), higher electricity generation capacity had a positive impact on growth in North and East Africa between 1960 and 2005. Conversely, a deterioration in electricity generation capacity over the same period had a negative effect on growth in West, Central and Southern Africa. Similar conclusions on the impact of electricity generation capacity on economic growth are drawn by Calderon and Serven (2004; 2008).

5.0 Implication of Results

The positive effect of infrastructure stock and quality indices on the economic growth of Ghana provides justification for continuous investment in public infrastructure.

The results show that electricity generation (LogElecGen) provides the greatest impact on Ghana's economic growth over both the short- and long-run periods. According to Adom (2016), estimates by the Institute of Statistical, Social and Economic Research (ISSER) puts the economic cost of power crises between US$320 million to US$920 million per annum.

Consequently, the continuous expansion and diversification of electricity generation sources is essential to the acceleration of Ghana's economic growth. To achieve this requires the development of innovative and more sustainable ways to finance infrastructure expenditure.

The deterioration in the quality of infrastructure over time requires persistent maintenance and upgrading to support economic growth. The negative coefficient of electricity distribution losses (LogElecDl) suggests that loss of electricity is counter-productive to Ghana's economic growth. Electricity distribution losses have a negative impact upon businesses and other infrastructure indices such as telecommunication. Renewed focus must therefore be placed on resolving the challenges with power outages (cuts). Additionally, due to the potential negative impact on economic activities, electricity saving strategies (such as load shedding) must also be undertaken with caution. It is therefore important that Ghana strengthens the diversification of existing electricity supply channels and reduces the over reliance upon hydro.

Although the results show a rather negative but statistically significant relationship between road (LogRoad) and economic growth, the positive and significant long-run relationship between paved road (LogPavedRd) and economic growth must be emphasized. Road infrastructure is known to be instrumental in the production and distribution of food and is estimated to contribute up to 70% of food prices in the urban centers of Ghana (Amoatey, 2007). The maintenance of existing road infrastructure and expansion of the provision of good roads is therefore important to economic growth.

This study's findings are also relevant to the ordinary Ghanaians as the end users of infrastructure. For example, effective consumption of electricity by the public can aid economic growth in various ways. By avoiding the malicious destruction of infrastructure such as copper thefts and deliberate fibre cuts, the public can reap more benefits from infrastructure quality. As an exemplar, preserving the quality and integrity of electricity and telephone cables will reduce the cost of maintenance, therefore allowing more investment to fund upgrading existing infrastructure. Furthermore, by the careful use of assets, the public can prolong the duration of existing infrastructure stock. The results are therefore not only vital to policy makers but also ordinary Ghanaians.

6.0 Conclusion and Recommendations

Electricity generation has been identified as the infrastructure stock index with the greatest contribution to economic growth. Higher rates of economic growth could be achieved with an increase in electricity generating capacity. This paper recommends the need to intensify capital investments into electricity generation and diversify generation sources.

Electricity transmission and distribution losses have been identified as a huge drain on Ghana's economic growth. Extant literature confirms that Ghana continues to suffer from massive electricity transmission and distribution losses including pilfering (Adom, 2016). The huge losses to Volta River Authority (VRA), GRIDCO and Electricity Company of Ghana (ECG) resulted in their inability to generate enough revenue to re-invest in modern transmission and distribution equipment (Mathrani et al., 2013). The overreliance on old transmission and distribution systems results in the loss of electricity that is required for domestic, commercial and industrial usage (Foster and Pushak, 2011). It is recommended that public education on the cost of transmission and distribution losses to the economy be intensified. Furthermore, reliable and sustainable sources of finance must be sought for continuous investment into the replacement of old transmission and distribution systems.

Without an elaborate and comprehensive plan for the maintenance and repair of existing road infrastructure, Ghana's economic growth will continue to be negatively affected by the deterioration of its existing road network. The perennial challenge faced by food crop farmers (e.g. cocoa and vegetable) is an inability to transport produce to market due to un-motorable roads during raining seasons – such has a significant negative effect on Ghana's growth because produce cannot be sold and invariably rots as a consequence.

Mobile telecommunication is expanding fast and has been proven to contribute to the economic growth of the country. Telecommunications companies, largely foreign owned, typically expand the network service to locations that guarantee the fastest return on investment. This strategy excludes rural communities from obtaining basic telecommunication infrastructure. The impact of telecommunication on business development and expansion (as well as the enhancement of financial inclusion for the largely unbanked population in Ghana) cannot be over emphasized. With this level of impact and contribution to economic growth, the expansion of the telecommunication network should not be left to private telecommunication operators alone.

Based on the findings of this study, we can conclude that infrastructure development remains a key determinant of economic growth in Ghana. Ghana, as well as countries with similar infrastructure challenges and economic characteristics, should pay particular attention to the prioritization of their scarce resources into development of the appropriate infrastructure that is needed for rapid economic growth.

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The Journal of Financial Management of Property and Construction Author(s') Response to Reviewers Form

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Dear Editor,

Response to reviewers' comments

The authors would like to thank the editors and reviewers for their time and great effort in reviewing our manuscript. Please the manuscript has been revised in accordance with the reviewers' comments, suggestions, and questions. All changes in line with the reviewers' comments, suggestions, and questions have been highlighted in the revised manuscript and responses to each comment or suggestion or question are listed in the table below.

We hope the changes listed have made the manuscript suitable for publication and we look forward to your response.

Sincerely yours,
The authors.

Referee 1	
Reviewer #1's Comments	**Authors' Responses**
1. Originality: Does the paper contain new and significant information adequate to justify publication?: Yes.	We thank the reviewer for the careful review and these comments/observations.
2. Relationship to Literature: (a) Does the paper demonstrate an adequate understanding of the relevant literature in the field and cite an appropriate range of literature sources? (b) Is any significant work ignored?: Yes, the revised version demonstrates an adequate understanding of the relevant literature in the field and cite an appropriate range of literature sources	We thank the reviewer for the careful review and these comments/observations.
3. Methodology: (a) Is the paper's argument built on an appropriate base of theory, concepts, or other ideas? (b) Has the research or equivalent intellectual work on which the paper is based been well designed? (c) Are the methods employed appropriate? Yes, the employed methodology is built on n appropriate base of theory, concepts, or other ideas. The author has explained the choice of variables in a good way.	We thank the reviewer for the careful review and these comments/observations.
4. Results: (a) Are results presented clearly and analysed appropriately? (b) Do the conclusions adequately tie together the other elements of the paper?: Yes, the results are now presented clearly and analysed in the right manner in the revised version.	We thank the reviewer for the careful review and these comments/observations.

5. Implications for research, practice and/or society: (a) Does the paper identify clearly any implications for research, practice and/or society? (b) If applicable, does the paper bridge the gap between theory and practice? (c) If applicable, does the paper demonstrate how the research may be used in practice (economic or commercial impact); in teaching; to influence public policy; in future research? (d) What is the impact upon society (influencing public attitudes, affecting quality of life)? (e) Are any stated implications consistent with the findings and conclusions of the paper? Yes, post the revision, now the paper identifies the practical implications of the study, particularly from the Ghanaian point of view. It makes sense now.	We thank the reviewer for the careful review and these comments/observations.
6. Quality of Communication: (a) Does the paper clearly express its case, measured against the technical language of the field and the expected knowledge of the journal's readership? (b) Has attention been paid to the clarity of expression and readability, such as sentence structure, jargon use, acronyms, etc.: The quality of communication has improved post one more round of proof read.	We thank the reviewer for the careful review and these comments/observations. The work has been reviewed by a professional proof reader as recommended.

Thank you again for your time and effort, and for helping us improve the manuscript.