Environmental Quality, Economic Growth, and Health Expenditure: Empirical Evidence from a Panel of African Countries

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Abstract

This study investigates the relationship among environmental quality, economic growth and health expenditure in 47 African countries using both static (pooled OLS and fixed/random effect) and dynamic (system GMM) estimation methods. Data covering the period 2000 to 2018 are employed and three proxies (carbon dioxide, nitrous oxide and methane emission) are used to capture the effect of environmental quality. The findings of the study indicate evidence of a positive and significant effect of economic growth on health expenditure, while also revealing a positively significant relationship between poor environmental quality and health expenditure. The empirical findings of this study suggest that of the three proxies of environmental quality carbon dioxide emission had the highest effect on healthcare expenditure while economic growth significantly increased health expenditure across the five African regions (North Africa, East Africa, Central Africa, West Africa and Southern Africa). The study concludes that health is a necessity good and a deterioration of the environmental quality increases health expenditure. Hence, there is a need to uphold the SDG clean energy policies that target the reduction of environmental pollution while striving for an inclusive and sustainable economic growth.

Keywords: Environmental quality; Economic Growth; Health expenditure; Africa; Panel Analysis.

JEL Classification: Q5, I10

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1. Introduction

Environmental pollution is of major concern in Africa given the regions rapid rate of urbanization (above 4%)[1], industrialization, motorization, and increased productive activities. Higher energy consumption and a heavy reliance on biomass sources of energy for lighting, cooking and heating also contribute to environmental pollution (United Nations Environment Programme (UNEP), 2016). This deterioration of environmental quality which is majorly precedented by an increase in pollutants poses a serious threat to sustainable development and it affects human capital adversely. The cost is, however, undebatable because it poses a major risk to health by increasing the burden of diseases, reducing labour productivity, increasing morbidity, and mortality especially in developing countries whose regulations are not strict. Consequently, recent environmental policies are made in consideration of the health impact, while health interventions account for environmental factors among other determinants (Badulescu et al., 2019).

Health has been increasingly recognized globally as a key component of sustainable growth and development given the submission of Pritchett and Summers (1996) that 'wealthier nations are healthier nations'. That is, higher income is associated with improved education and other socio-economic factors which augments health. With a low but sustained growth rate of 3.4%[2] and an increase in Africa's industrial output, environmental contamination is expected. Given fewer resources to mitigate the effect (Zaidi and Saidi, 2018), emission of greenhouse gases (such as carbon dioxide, nitrous oxide, methane and ozone) amongst other pollutants contribute to climate change and a developmental challenge of the region, while putting a strain on healthcare demand and supply. Available statistics show that among the African countries, only Sierra Leone spent over 15% of its GDP on healthcare in 2016, even though countries like Lesotho, Sierra Leone, Malawi, Namibia, South Africa, Zimbabwe and Liberia spent over 8% of their GDP, while countries like Angola, Algeria, Benin, Democratic Republic of Congo, Equatorial Guinea, Mali, Eritrea, Nigeria, and Seychelles spent less than 4% of their GDP. This suggests that despite the increasing trend of Africa's health expenditure since 2000, there are variations across countries and regions (WDI, 2019).

Empirical discussion on the nexus among environmental pollution/quality, economic growth and health expenditure has been topical for about a decade and the discussions around it can be broadly classified into three. The first aspect relates to the relationship between the environment and economic growth, with most studies (Liu et al., 2007; AkbostancI et al., 2009; Orubu and Omotor, 2011; Shahpouri et al., 2016; and Blázquez-Fernández et al., 2019) focusing on validating or invalidating a U-shaped relationship. The second aspect focuses on the relationship between economic growth and health expenditure (Devlin and Hansen, 2001; Baltagi and Moscone, 2010; Piabuo and Tieguhong, 2017; and Ye and Zhang, 2018) while focusing on their elasticities, the direction of causality and testing if health is a luxury good or a necessity. Another group of scholars focused on the relationship between environmental quality and health expenditure (Narayan and Narayan, 2008; Assadzadeh et al., 2014; Hao et al., 2018; Raeissi et al., 2018) in different countries and economic regions of the world. However, findings have been mixed and conflicting in some cases. Besides the inconclusive nature of empirical evidence provided, these studies confirm that

[1] The annual compound growth rate of urbanization in Africa has been above 4% since 1950 (OECD/Sahel and West Africa Club, 2020)

[2] In 2019, Africa's growth rate was recorded at 3.4% (African Development Bank, 2020)

the emission of greenhouse gases leads to environmental pollution which depletes the quality of the environment.

Based on the foregoing, it is imperative to revisit the empirical relationship among environmental quality, economic growth, and health expenditure in developing countries. Using a panel data set, this study differs from other studies (Yazdi and Khanalizadeh, 2017; Zaidi and Saidi, 2018; and Ssali et al., 2019) because it employs both static and dynamic models in the analysis; while also focusing on Africa as a whole and not just sub-Saharan Africa. This study also allows for comparison of findings across the continent because it focuses on five major sub-regions[3] of Africa and it relies on three greenhouse gas emissions (carbon dioxide emission, nitrous oxide and methane) as a robustness checks unlike other studies that concentrated sorely on one measure of environmental quality. The choice of these proxies for environmental quality over other sources of pollution such as water and land are because air pollutants have been identified as the main causes of environmental risk to health (WHO, 2018)**.**

The rest of the article is organised into five sections. The second section presents a review of empirical and theoretical literature, while the third section is devoted to the methodology and data presentation. The fourth section presents the results, while the conclusion/recommendation is made in the last section.

2. Literature Review

The relationship between environmental quality, economic growth and health expenditure has been discussed extensively in the literature with topics ranging from the relationship between environmental quality and economic growth to studies on economic growth and health expenditure. Proxies used for capturing environmental quality range from carbon dioxide (CO_2), sulphur dioxide (SO_2), nitrous dioxide (NO_2), atmospheric particle matter ($PM_{2.5}$), to carbon monoxide (CO) emissions amongst others and health expenditure in these kinds of literature were captured majorly by the public, private or total healthcare spending. Consequently, this review has been sub-sectioned into four and it summarises some existing studies on the relationship between environmental quality, economic growth and health expenditure.

2.1 Environmental Quality and Economic growth

The interaction between environmental quality and economic growth has been topical but controversial for decades. The debates around this discourse centres on the Environmental Kuznets Curve (EKC) which posits that there is a U-shaped relationship between economic development and environment. That is, at the initial phase of economic growth, there will be a deterioration of the environmental quality but when a country's per capita income approaches $8,000 there will be a turning point and an improvement in the environmental quality (Grossman and Krueger, 1995). On the contrary, Liu et al. (2007) emphasised that consumption-induced pollutants do not support the EKC but it is the production-induced pollutants that support it; while Shahpouri et al. (2016) added that the EKC does not form an inverted U shape for developed countries with low income.

Using time series analysis, AkbostancI et al. (2009) showed that there is a monotonically increasing nexus between income and CO_2 emissions, in the long run, hence the EKU hypothesis

[3] These include; North Africa, East Africa, Central Africa, West Africa and Southern Africa

is not supported in Turkey. However, a panel data analysis of 28 provinces using the GMM and ARDL approach on data covering the period from 1996 to 2012 support the environmental Kuznets Curve Hypothesis in China (Li et al., 2016). A more recent panel study (Kong and Khan, 2019) on 29 (15 developing and 14 developed) countries covering the period 1977 through 2014 confirm the existence of the EKC hypothesis using the generalized method of moments (GMM) approach. Besides, Andrée et al. (2019) employed the non-parametric model of environmental output and economic development on a panel of 95 countries and also confirmed the existence of the U-shaped hypothesis between economic growth and environmental quality (proxied by air pollution, deforestation and carbon intensities).

Focusing on Africa, an investigation of the relationship between environmental quality and economic growth was carried out by Orubu and Omotor (2011) using longitudinal data on 47 African countries. To investigate the EKC hypothesis, two different measures of environmental quality (organic water pollutants and suspended particulate matter) were employed and the findings from this study support the Kuznets hypothesis but the turning point was low for most African countries. In 17 Middle East and North African (MENA) countries, Abdouli and Hammami (2017) suggested the existence of a two-way causality running from CO_2 emission to economic growth. Meanwhile, findings from Zerbo (2017) which is similar to Akbostanci et al. (2009) indicated that there is no EKC hypothesis operational in Sub-Saharan Africa (SSA) using the Toda Yamamoto approach.

It can be summarised from the extant studies reviewed in this section that findings on the nexus between environmental quality and health expenditure differ across the scope of the study and the methodological approach employed. That is, while some studies supported the existence of the EKC hypothesis some others refuted the hypothesis.

2.2 Environmental Quality and Health Expenditure

A considerable amount of literature also exists on the relationship between environmental quality or air pollution and health expenditure. Some of these studies include Narayan and Narayan (2008) who employed the panel Ordinarily Least Square (OLS) and Dynamic OLS on 8 Organisation for Economic Co-operation and Development (OECD) countries. Using data from 1980 to 1999, and three measures of environmental quality, the authors discovered that there is a long-run positive inelastic relationship between carbon monoxide emissions and health expenditures and also from sulphur dioxide to health expenditure. However, the effect of nitrogen oxide emission is statistically insignificant. Similarly, Assadzadeh et al. (2014) employed a panel data analysis on 8 petroleum exporting countries from 2000 to 2010. Their result showed that CO_2 emissions and output has a significant and positive effect on health expenditure and that an improvement in life expectancy reduces health expenditure in these countries. A more recent study panel study (Blázquez-Fernández et al., 2019) on 29 OECD countries between 1995 and 2014 suggested that the sulphur oxide emissions and carbon monoxide emissions are the air pollutants that have the most effect on health expenditure (especially private health expenditure).

In China, Chen et al. (2017) found that between 2006 and 2012, air pollution increases the expenditure on health in 116 cities. Meanwhile, Yang and Zhang (2018) employed China's Urban Household Survey (UHS) Database and discovered that household health expenditures are increased by increases air pollution with elderly people more sensitive to the effects of air pollution (Pm2.5). Similarly, Hao et al. (2018) employed the first-order difference generalized method of moments (GMM) approach on a panel data of Chinese provinces for the period of 1998–2015.

Their study in agreement with Yang and Zhang (2018) confirmed that health expenditure per capita is significantly increased due to increases in environmental pollution (SO_2)

Centring on an upper-middle-income country, Abdullah et al. (2016) examined the nexus between health expenditure and environmental quality in Malaysia using carbon dioxide, sulphur dioxide and nitrogen dioxide as proxies for environmental quality. Findings from the Auto Regressive Distributed Lag (ARDL) approach indicated that there is cointegration between the three measures of environmental quality and health expenditure which suggests that environmental quality affects health expenditure in both the long and short-run. Also using the ARDL approach, Raeissi et al. (2018) found that in the long-run, air pollution in Iran positively and significantly affects health expenditure but the effect is greater in the long-run than the short-run.

Some other studies that have focused on developing countries include (Yahaya et al., 2016; and Alimi et al., 2019). Yahaya et al. (2016) investigated the relationship between per capita healthcare spending and environmental quality on 125 developing countries using four measures namely, carbon dioxide, sulphur dioxide, nitrous dioxide, and carbon monoxide emission. The findings from these panel data covering 1995 to 2012 suggest a long-run and short-run relationship between per capita healthcare spending and all measures of environmental quality. Whereas, Alimi et al. (2019) examined the link between environmental quality and healthcare expenditure in 15 Economic Community of West African States (ECOWAS) countries using the system GMM, fixed effects and pooled OLS on data spanning from 1995 till 2014. This study found no relationship between private healthcare expenditure and environmental pollution, but a positive effect of environmental pollution on both national and public healthcare spending, which is similar to Yahaya et al. (2016).

Summarily, while most studies suggest that environmental quality increases expenditure, some indicate that there is a statistically insignificant relationship between the two. As such, there are diversities in the findings of these studies which could stem from the use of different techniques of estimation or different proxies for the variables of interest.

2.3 Economic Growth and Health Expenditure

The nexus between growth and health expenditure has been a focus of some literature, and a number of them have established a positively strong and significant relationship between these two. Theoretically, the bidirectional causation is based on Grossman (1972) where health expenditure is considered an investment in health, and Knowles and Owen (1995) with the incorporation of health capital in the neoclassical growth model. Earlier studies like Hansen and King (1998); McCoskey and Selden (1998); Pritchett and Summers (1996) also established a relationship between economic growth and health expenditure and others like Devlin and Hansen (2001) emphasised that health expenditure is significantly affected by economic growth and vice versa.

Some studies have also emerged to confirm whether health is a necessity or a luxury good given its effect on income. For instance, in 20 Organization for Economic Co-operation and Development (OECD) countries, Baltagi and Moscone (2010) employed a panel data from 1971 to 2004 while controlling for unobserved heterogeneity and cross-section dependence through the fixed effects and common factor model respectively. Findings from this study suggest that healthcare is more of a necessity than a luxury in this region. A similar OECD study by French (2012) confirmed that improvement in income is preceded by an improvement in health and otherwise. More recently, Ye and Zhang (2018) used the linear and non-linear tests to examine causality between health expenditure and economic growth in 15 OECD countries and found a unidirectional linear and non-linear causality between these variables in Korea, Ireland, Portugal and India.

With a focus on developing countries, Balaji et al. (2011) investigated the dynamic relationship between economic growth and health expenditure in four southern Indian states and found evidence of no-long-run relationship among the variables despite a one-way causality running from economic growth to health expenditure in one of the states. Whereas, Elmi and Sadeghi (2012) employed panel co-integration and VECM framework for causality approach. Their findings on panel data spanning from 1990 to 2009 revealed that there is a short-run causality funning from GDP to health expenditure and a long-run relationship between health expenditure and economic growth. Hence, income is important and the study confirmed the health-led growth hypothesis which is in agreement with Atilgan et al. (2017). Also, Piabuo and Tieguhong (2017) employed the Fully Modified OLS (FMOLS) on five African countries and countries in the Economic and Monetary Community of Central Africa (CEMAC) sub-region. For both samples, the study found a positive significant effect of health expenditure on economic growth and a long-run relationship.

2.4 Environmental Quality, Economic Growth, and Health Expenditure

Bringing the three variables of interest together, we find that very few and relatively recent studies have considered this relationship globally. In 51 countries, Chaabouni and Saidi (2017) documented the causal nexus between health expenditure, CO_2 emissions, and GDP growth. The Generalised Method of Moments (GMM) approach was employed and the result confirms that there is a two-way causality between GDP per capita and carbon dioxide emissions and between health spending and economic growth in these countries. Applying the bootstrap autoregressive-distributed lad (ARDL) approach, in OECD countries, Wang et al. (2019) found a short-run relationship between these variables and a two-way causality between health expenditure and output growth for USA and Germany, between GDP growth and CO_2 emissions for USA Germany and Canada and between CO_2 emission and health expenditure for Norway and New Zealand. A similar study conducted by Usman et al. (2019) found that CO_2 emissions have a significantly positive effect on government health expenditures in emerging economies but negatively affect private health expenditures. They also observed that other factors such as the level of education, ageing population and foreign direct investment have causal links with health expenditure. Besides, Badulescu et al. (2019) found that there is cointegration between health expenditure, economic growth, non-communicable diseases (NCDs) and health expenditure in EU countries. They also observed that economic growth significantly affects health expenditure in both the long-run and short-run. However, CO_2 emissions negatively influence economic growth in the short-run but positively in the long-run.

In Africa, Yazdi and Khanalizadeh (2017) examined the role of economic growth and environmental quality in the determination of health expenditure using data from 1995 to 2014. The study focused on the Middle East and North Africa region (MENA) countries and the result of ARDL shows that there is cointegration between these variables and that output and environmental quality positively affect health expenditure. Zaidi and Saidi (2018) focused on health expenditure, environmental pollution and economic growth in sub-Saharan African countries. Annual data from 1990 to 2015 was employed and the result from the panel ARDL suggest that economic growth has a positive impact on health expenditure while environmental pollution harmed health expenditure in the long run. They also employed the granger causality test and they found that there is a unidirectional causality running from health expenditure to GDP and a bidirectional causality running from health expenditure to environmental pollution and from environmental pollution to output per capita. A similar study on SSA (Ssali et al., 2019) did not just focus on these three variables, but also considered energy use and foreign direct investment in 6 sub-Saharan African countries between 1980 and 2014. This study like Zaidi and Saidi (2018) found a long-run unidirectional causality running from CO_2 to GDP and a long-run unidirectional causality running from GDP to CO_2 emission.

Summarily, studies that have focused on Africa have concentrated on the sub-regions and did not consider the possibility of endogeneity because they employed the ARDL panel co-integration approach. This study, however, employs both static and dynamic panel data approach while focusing on 47 African countries and the sub-regions.

3. Methodology

3.1 Model Specification

This study adapts the empirical model specification of Narayan and Narayan (2008); Yahaya et al. (2016); Yazdi and Khanalizadeh (2017); and Zaidi and Saidi (2018) which was developed from Newhouse (1977) where health expenditure is a function of per capita income. This study incorporates environmental quality into the equation, using alternative measures such as carbon dioxide emissions, nitrous oxide emission, and methane emission. The effect of other socio-economic determinants of health expenditure such as urbanization, ageing population and mortality are also considered. The choice of urbanization as a control variable is based on the documented steady increase in urbanization across Africa, while there has also been an increase in Africa's ageing population. These alongside changes in health outcomes (mortality rate) has been documented to be of a substantial effect on health expenditure. Consequently, the linear association between the variables in the model has the following form:

$$HEX_{it} = \alpha_0 + \alpha_1 GDP_{it} + \alpha_2 ENQ_{it} + \alpha_3 ARG_{it} + \alpha_4 MRT_{it} + \alpha_5 URB_{it} + \varepsilon_{it} \quad (1)$$

Where HEX denotes health expenditure; GDP represents per capita GDP; ENQ is environmental quality; ARG denotes ageing population; MRT is the mortality rate; URB represents urbanization. Subscript $i = 1, 2, \ldots, N$ denotes the country and $t = 1, 2, \ldots, T$ represents the time period. The error term (ε_{it}) is assumed to be normally distributed, α_0 represents the constant, and α_{1-5} denotes the slope.

Disaggregating environmental quality (ENQ) into three, model (1) takes the following form:

$$HEX_{it} = \alpha_0 + \alpha_1 GDP_{it} + \alpha_2 CO2_{it} + \alpha_3 CH4_{it} + \alpha_4 N20_{it} + \alpha_5 ARG_{it} + \alpha_6 MRT_{it} + \alpha_7 URB_{it} + \varepsilon_{it} \quad (2)$$

Where CO_2 represents carbon dioxide emission, CH_4 implies methane emission and N_2O is nitrous oxide emission.

The a priori expectation is that an increase in economic growth will lead to an increase in the total health expenditure because countries with higher levels of income tend to spend more on healthcare while countries with lower levels of income spend less on healthcare as buttressed by Devlin and Hansen (2001); Baltagi and Moscone (2010); and (Piabuo and Tieguhong, 2017). Besides, greenhouse gases (such as CO_2, CH_4, and N_2O emissions) increase environmental pollution, have been linked with the deterioration of human health and leads to an increase in the demand for health care and thus an increase in health expenditure. Thus, depletion of environmental quality through an increase in the emission of greenhouse gases will increase health expenditure as empirically buttressed by Narayan and Narayan (2008); Assadzadeh et al. (2014); Yang and Zhang (2018); and Raeissi et al. (2018). This study further expects that an increase in the ageing population will increase health expenditure (Chaabouni and Saidi, 2017) while an increase in mortality (Pasali et al., 2019) and urbanization (Zaidi and Saidi, 2018) will reduce health expenditure as there will be a decline in the demand for healthcare.

3.2 Method of Estimation

To examine the relationship between environmental quality, economic growth, and health expenditure in Africa, this study adopts both dynamic and static models. These methods serve as a robustness check for one another particularly in testing the consistency of the effect of environmental quality and economic growth on health expenditure. The fixed effect/random effect (FE/RE) which allows for panel heterogeneities and pooled OLS (POLS) which does not recognise panel heterogeneities serves as the static models, while the generalised method of moments (GMM) serves as the dynamic model. The GMM approach is appropriate for this study given that 47 countries are covered across 18 years (N > T) and the regressors are not strictly exogenous. The system GMM approach of Arellano and Bond (1991) and, Blundell and Bond (1998) is preferred in this study unlike the difference GMM since it is more efficient and it resolves the issues of a weak instrument which renders it hypothesis test and point estimate unreliable.

The efficiency of this approach is validated by the Hausman test (for fixed effect over random effect), while the Arellano-Bond test for AR(1) supports the use of a dynamic panel model. AR (2) establishes that there is no second-order serial correlation and the Sargan/Hansen test for the system GMM approach is used to validate the instrument. To avoid collinearity between economic growth and carbon dioxide emissions, given their correlation index of over 0.8, both are not included together in the same model.

3.3 Data (sources, measurement and description)

This study employs data on 47 African countries[4] using data from 2000 to 2018. Annual data on all variables used are obtained from three main sources. The data on current health expenditure is obtained from WHO's Global Health Expenditure Database (GHED), real GDP per capita is obtained from the World Banks's, World Development Indicators (WDI, 2019), and the data on

[4] The 47 countries are: "Algeria, Angola, Benin, Botswana, Burkina Faso, Burundi, Cabo Verde, Cameroon, Central African Republic, Chad, Comoros, Congo Dem. Rep., Congo, Rep., Côte d'Ivoire, Egypt, Equatorial Guinea, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritania, Mauritius, Morocco, Mozambique, Namibia, Niger, Nigeria, Rwanda, Sao Tome and Principe, Senegal, Seychelles, Sierra Leone, South Africa, Sudan, Tanzania, Togo, Tunisia, Uganda, Zambia".

environmental quality are obtained from the Emissions Database for Global Atmospheric Research (EDGAR 5.0). Drawing from existing literature on health care spending, three main control variables are considered, specifically: urbanization, mortality (Under-five) and an ageing population all of which are sourced from WDI (2019)[5]. Besides, the sample is subdivided into five regions to indicate the sub-region effect of environmental quality and GDP per capita on health care spending in Africa. The data is transformed into natural logarithm form for easier interpretation and it was analysed using EVIEWS 11.0 and STATA 16.0 software.

The descriptive statistic and correlation matrix of health expenditure, per capita GDP, carbon emission, nitrous oxide, methane, ageing population, mortality and urbanization for the entire sample and the sub-regions are presented in Appendix 2 and 3. The average health expenditure per capita in the complete sample is 100USD with the highest average in Southern Africa (US$ 202) and the lowest average in West Africa (US$ 45). Per capita GDP ranges from US$ 195 to US$ 20,513 with the lowest average also in West Africa (US$ 1002.39). With regards to the environmental quality, Southern Africa has the highest average of CO_2 emissions, North Africa has the highest average methane emission, while the average emission of nitrous oxide is approximately 18 thousand metric tons of CO_2 equivalent. On average, 42% of the African population is urbanized and over 3% of the population are aged 65 years and above. Despite the global reduction in global child mortality, Africa mortality rate is still comparatively high on the average (91 under-five mortality per 1,000 live births) with West Africa experiencing the highest average (110 under-five mortality per 1,000 live births). Appendix 2 further shows that the data is consistent and all the variables are positively skewed.

The correlation matrix of the variable in Appendix 3 shows that health expenditure is positively and significantly correlated with all the variables of interest except mortality rate which is negative, while no significant association is found between nitrous oxide and health expenditure. Interestingly, a strong and positive correlation is observed between per capita GDP and CO_2 emission (⊔ 0.8). To buttress this Appendix 4 depicts the scattered plot of per capita health expenditure, carbon emission and GDP in among African countries and the sub-regions. By implication, there is a positive association between environmental quality (CO_2 emissions) and health expenditure per capita and a positive association between per capita GDP and health expenditure per capita at 5% level of significance.

4. Result and Discussion

4.1 Static Panel Result (POLS and FE/RE)

The result of this study using the entire sample is presented in Table 1. They are presented in two panels, the pooled ordinary least square approach (panel A) and the fixed/random effect approach (panel B). In panel A, the result of POLS shows that there is a significant and positive relationship between health expenditure and economic growth and between environmental quality (carbon

[5] The variables included in this study and their unit of measurement are presented in Appendix 1

emission and nitrous oxide) and economic growth in Africa. The output elasticities of economic growth, carbon emission and nitrous oxide are 0.8%, 0.5%, and 0.04% respectively. Panel B of Table 1 which reports the fixed effect estimate shows similar result given that both economic growth and environmental quality positively (carbon emission and nitrous oxide) and significantly influence economic growth at 1.2%, 0.1%, and 0.6% respectively. When the three measures of environmental quality are combined in the same model, the result suggests that carbon emissions have the largest explanatory power on health expenditure at 0.5% (POLS) and 0.1% (FE) relative to other indicators of environmental quality. This is consistent with a priori expectation and the findings of Yahaya et al. (2016). By implication, an increase in economic growth increases health expenditure per capita and an improvement in environmental quality reduces per capita health expenditure in Africa. This is in tandem with Chaabouni and Saidi (2017), Yazdi and Khanalizadeh (2017), and Usman et al. (2019).

For the control variables, the result in panel A suggests that an increase in urbanization increases health expenditure across board, an increase in under-five mortality rate reduces health expenditure per capita and an increase in the ageing population increases per capita health expenditure. This is similar to the findings in panel B, however, the effect of the ageing population on health expenditure is not consistent across the different models in panel A. Focusing on the fixed effect output, our findings suggest that an increase in urbanization and ageing population increase health expenditure. This is in agreement with the a priori expectation because health generally depreciates with age and this leads to a demand in health goods and services which ultimately increases healthcare spending. This finding is also consistent with Novignon et al. (2012), Chaabouni and Saidi (2017), and Usman et al. (2019), while Zaidi and Saidi (2018) confirm the effect of urbanization on health expenditure.

The coefficients of regional dummies in Panel A suggests that health expenditure in Central African region is approximately 12% lesser than the per capita health expenditure in Southern African region, and the East African region has approximately 16% lower per capita health expenditure relative to Southern Africa, while North Africa and West Africa also have a lower health expenditure per capita relative to Southern Africa by 8% and 6% respectively for the GDP regression. This is consistent with the result in the other models for carbon dioxide, methane, nitrous oxide emissions and combined environmental quality in Central Africa given that it is 10%, 16% and 18% and 11%[6] respectively lower than that of Southern Africa. Per capita, health expenditure is also lower in East Africa, North Africa and West Africa when compared with Southern Africa. Additionally, the F-statistics indicates that the regressors are jointly significant in explaining the dependent variables and the proportion of variation in the dependent variable explained by the regressors in Panel A ranges from 65% to 84%. The Hausman test in Panel B (Table 1) is significant across board, hence the use of fixed-effect over random effect. The F-statistics also indicate that the regressors are jointly significant in explaining the dependent

[6] Since the regions are expressed as dummy variables, the percentage is derived using $[e^{\hat{\alpha}}-1]\times 100$, where $\hat{\alpha}$ is the coefficient and e is the exponent of the natural logarithm.

variables and the proportion of variation in the dependent variable explained by the regressors in Panel B ranges from 59% to 67%.

Table 1: Estimations of the effect of Environmental Quality and Economic Growth on Health Expenditure

Variables	Dependent Variable: Health Expenditure									
	Panel A: OLS Pooled					Panel B: Fixed Effect				
	Model [1][a]	Model [2][a]	Model [3][a]	Model [4][a]	Model [5][a]	Model [1][b]	Model [2][b]	Model [3][b]	Model [4][b]	Model [5][b]
GDP per capita	0.789***	---	---	---	---	1.172***	---	---	---	---
	(0.024)					(0.085)				
CO_2 emissions	---	0.447***	---	---	0.450***	---	0.075*	---	---	0.140***
		(0.024)			(0.027)		(0.045)			(0.048)
CH_4 emissions	---	---	0.039***	---	-0.004	---	---	-0.049		-0.355***
			(0.014)		(0.030)			(0.085)		(0.095)
NO_2 emissions	---	---	---	-0.003	-0.011	---	---	---	0.600***	0.719***
				(0.014)	(0.029)				(0.095)	(0.100)
Urbanization	-0.105**	0.090	0.928***	0.933***	0.074	0.485**	1.161***	1.244***	1.103***	1.098***
	(0.050)	(0.067)	(0.056)	(0.058)	(0.069)	(0.198)	(0.214)	(0.213)	(0.207)	(0.209)
Mortality	-0.211***	-0.222***	-0.336***	-0.326***	-0.219***	-0.290***	-0.450***	-0.470***	-0.337***	-0.358***
	(0.016)	(0.020)	(0.023)	(0.023)	(0.022)	(0.029)	(0.030)	(0.033)	(0.034)	(0.035)
Ageing Pop.	-0.289***	-0.132	0.290***	0.198*	-0.167*	0.066	0.615***	0.665***	1.002***	0.983***
	(0.072)	(0.091)	(0.109)	(0.109)	(0.097)	(0.151)	(0.162)	(0.160)	(0.165)	(0.167)
Constant	0.597***	2.929***	1.670***	1.776***	2.982***	-1.443***	1.572***	1.594***	0.490	1.447***
	(0.125)	(0.164)	(0.180)	(0.183)	(0.171)	(0.461)	(0.457)	(0.506)	(0.468)	(0.522)
Central Africa	-0.113***	-0.096***	-0.150***	-0.165***	-0.102***					
	(0.023)	(0.029)	(0.035)	(0.035)	(0.030)					
East Africa	-0.147***	-0.127***	-0.170***	-0.192***	-0.136***					
	(0.022)	(0.028)	(0.034)	(0.034)	(0.029)					
North Africa	-0.078***	-0.205***	-0.282***	-0.250***	-0.191***					
	(0.025)	(0.030)	(0.037)	(0.038)	(0.032)					
West Africa	-0.059***	-0.153***	-0.276***	-0.295***	-0.157***					
	(0.021)	(0.027)	(0.030)	(0.030)	(0.027)					
Observation	893	893	893	893	893	893	893	893	893	893
R-square	0.839	0.744	0.651	0.648	0.745	0.668	0.595	0.593	0.612	0.619
F Statistic	578.33***	321.17***	205.84***	203.17***	256.95***	423.01***	308.83***	307.33***	331.79***	227.60***
Hausman						42.67***	17.89***	12.57**	35.82***	80.89***

Note: Standard errors are in parenthesis, *** *p<0.01*, ** *p<0.05*, * *p<0.1*. *GDP* represents economic growth, CO_2 implies carbon dioxide, methane is denoted by CH_4, nitrous oxide is denoted as NO_2. Model [1][a] through [5][a] are results of pooled OLS while model [1][b] through [5][b] are results of fixed effect. All the variables are presented in logarithm form. The fixed-effect model reports the within R-square.

4.2 Static Model Estimates for the Sub-Regions of Africa

The result of fixed/random effect which controls for panel heterogeneities is shown in Table 2 for the sub-regions. The findings show that in the African sub-regions economic growth positively and significantly explains health expenditure as obtained for the full sample. The effect of environmental quality (specifically carbon dioxide and nitrous oxide emissions) is consistent across the regions. For instance, carbon dioxide emission positively and significantly affects health expenditure in North Africa, West Africa and Southern Africa with elasticities ranging from 0.2% to 1.5%, while it had no statistically significant effect in the other regions. Methane emission, on the other hand, increases health expenditure only in Central Africa. As expected, an increase in nitrous oxide increases health expenditure in all the African regions with elasticities ranging from 0.5% in Central Africa to 1.7% in North Africa. The control variables, urbanization, mortality and ageing population also has a statistically significant effect on health expenditure in the sub-regions. Hence, the findings from Table 2 support the increasing effect of economic growth on Africa and its sub-regions, and it also supports the a priori expectation that an improvement in environmental quality leads to a reduction in health expenditure.

Table 2: Parameter Estimates for Fixed/Random Effects Models Estimated by Geographic Region.

Variables	Dependent Variable: Health Expenditure per capita									
	Central Africa		North Africa		East Africa		West Africa		Southern Africa	
GDP per capita	1.26***		3.26***		0.71***		0.65***		2.02***	
	(0.14)		(0.42)		(0.19)		(0.19)		(0.22)	
CO_2 emissions		-0.21		1.48***		-0.06		0.10		0.23**
		(0.18)		(0.29)		(0.08)		(0.07)		(0.10)
CH_4 emissions	-0.21	0.58**	-1.41***	-1.95***	-0.36**	-0.22	-0.33	-0.43**	-1.41***	-0.48*
	(0.15)	(0.24)	(0.48)	(0.58)	(0.15)	(0.17)	(0.21)	(0.20)	(0.23)	(0.26)
NO_2 emissions	0.25	0.54**	1.72***	0.39	0.94***	0.96***	0.67***	0.72***	0.67***	0.99***
	(0.22)	(0.27)	(0.39)	(0.42)	(0.19)	(0.20)	(0.24)	(0.21)	(0.15)	(0.19)
Urbanization	2.04***	5.64***	0.16	3.50***	-0.05	-0.14	1.12***	1.44***	-0.28	0.98*
	(0.72)	(0.76)	(0.52)	(0.83)	(0.35)	(0.36)	(0.41)	(0.27)	(0.40)	(0.52)
Mortality	0.10	0.34**	0.16	-0.60***	-0.09	-0.21***	-0.29***	-0.34***	-0.32***	-0.28***
	(0.13)	(0.15)	(0.16)	(0.12)	(0.06)	(0.05)	(0.07)	(0.05)	(0.07)	(0.09)
Ageing Pop.	-0.99***	0.02	-0.51	-1.54*	-2.41***	-2.22***	-0.18	0.11	0.46	2.02***
	(0.36)	(0.46)	(0.65)	(0.82)	(0.42)	(0.44)	(0.47)	(0.39)	(0.28)	(0.28)
Constant	-5.26***	-10.92***	-7.59***	4.51**	1.29	3.58***	-0.37	1.36	-0.18	0.92
	(1.73)	(2.15)	(2.49)	(2.12)	(0.90)	(0.68)	(1.01)	(0.70)	(1.10)	(1.54)
R-squared (within)	0.80	0.69	0.83	0.78	0.75	0.73	0.67	0.66	0.78	0.66
Hausman	25.84***	44.29***	67.11***	176.56***	35.42***	35.20***	28.19***	7.54[a]	84.31***	198.81***
F Statistic	92.83***	50.08***	82.69***	61.79***	85.25***	77.07***	91.12***	87.11***	83.16***	45.15***
Observations	152		114		190		285		152	
No. of Countries	8		6		10		15		8	

Note: Standard errors are in parentheses. *** p<0.01, ** p<0.05, * p<0.1 [a] implies that the Hausman test is not significant at 10% level and the random effect estimates have been reported.

4.3: System GMM Result

Having controlled for heteroscedasticity, endogeneity and omitted variables, the result of the dynamic approach, shown in Table 3 is consistent with the findings from the static approach. For instance, columns 1 and 3 which incorporates economic growth suggests that an increase in economic growth leads to a significant increase in health expenditure per capita at 0.15% and 0.12% respectively. Since the income coefficient is not greater than one, then health expenditure in Africa is a necessity good. This is in agreement with other studies on African regions such as Zaidi and Saidi (2018) who focused on sub-Saharan Africa, and Piabuo and Tieguhong (2017) whose study focused on Central African countries. Considering the effect of environmental quality, column 2 shows that carbon dioxide emission has a positive and significant effect on health expenditure at the 10% significance level, while column 4 buttresses the positive and significant effect of carbon emission on per capita health expenditure at 5% level. Columns 2, 4, 5 and 6, however, suggests that of the three proxies of environmental quality, carbon dioxide emission has the most significant effect on health expenditure. This is implied because findings in Table 4 suggest that there is no significant relationship between methane emission and per capita health expenditure as well as nitrous oxide and per capita expenditure.

The effect of urbanization on health expenditure remains constantly negative (in Table 3) has it drags down per capita health expenditure as expected. That is, an increase in urbanization reduces health expenditure by at least 0.1%. Meanwhile, mortality (under-five) is found to increase health expenditure significantly at 1% level with elasticities ranging from 0.09% to 0.11%. This shows some level of inconsistency in the direction of effect with the result from the static approach, even though it still has a significant effect. This could be due to the control of the unobserved heterogeneities in the data. In addition, an increase in an ageing population increases health expenditure per capita at 10% and 5% significance level.

Summarily, Models [1] and [2] of Table 3 suggest that an increase in per capita GDP and a deterioration of environmental quality through increases in carbon dioxide emissions increase health expenditure. Increase in under-five mortality rate and ageing population also increase health expenditure at 1% and 10% level of significance respectively. Meanwhile, a 10% increase in urban population reduces Africa's health expenditure by 11% and 15% respectively. Focusing on the model's goodness-of-fit, no evidence of a second-order serial correlation is observed given the *p*-values of the AR (2) statistic, and the Hansen statistics *p*-values validate the instruments at 5% significance level.

Table 3: Dynamic Model Estimates (System GMM) of the effect of Environmental Quality and Economic Growth on Health Expenditure

Variables	Dependent Variable: Health Expenditure per capita					
	[1]	[2]	[3]	[4]	[5]	[6]
Health Expenditure (-1)	0.983***	1.002***	0.979***	0.997***	1.093***	1.054***
	(0.040)	(0.039)	(0.039)	(0.038)	(0.085)	(0.047)
GDP per capita	0.149**		0.119**			
	(0.064)		(0.046)			
CO_2 emissions		0.100*		0.088**		
		(0.050)		(0.038)		
CH_4 emissions	-0.063	-0.048			-0.139	
	(0.034)	(0.031)			(0.139)	
NO_2 emissions	0.053	0.034				-0.088
	(0.032)	(0.027)				(0.072)
Urbanization	-0.105**	-0.148**	-0.124**	-0.161**	-0.064	-0.129
	(0.051)	(0.065)	(0.052)	(0.063)	(0.087)	(0.096)
Mortality	0.106***	0.096***	0.091***	0.089***	0.121***	0.094***
	(0.028)	(0.030)	(0.027)	(0.026)	(0.040)	(0.025)
Ageing Pop.	0.135*	0.090	0.175**	0.131**	0.067	0.153
	(0.076)	(0.067)	(0.066)	(0.061)	(0.247)	(0.138)
Constant	-0.652***	-0.073	-0.600***	-0.136	-0.247	-0.284
	(0.193)	(0.207)	(0.181)	(0.192)	(0.398)	(0.273)
Obs.	846	846	846	846	846	846
AR (2)	0.420	0.423	0.418	0.422	0.377	0.379
Hansen OIR	0.149	0.126	0.155	0.125	0.197	0.199
DHT for instruments						
(a)Instruments in levels	0.101	0.085	0.105	0.085	0.146	0.148
H excluding group						
Diff (null, H=exogenous)	0.993	0.949	1.000	0.919	0.837	0.832
(b) IV (years, eq (diff)						
H test excluding group	0.075	0.055	0.090	0.075	0.118	0.130
Diff (null, H=exogenous)	0.856	0.915	0.954	0.873	0.963	0.865
Fisher	1236.74***	1376.11***	2034.20***	2019.12***	490.86***	717.58***
Instruments	42	42	42	40	40	40
Countries	47	47	47	47	47	47
Observations	846	846	846	846	846	846

Note: Robust Standard errors are in parenthesis. *** $p<0.01$, ** $p<0.05$, * $p<0.1$. OIR: Over-identifying Restrictions Test. Diff: Difference. DHT: Difference in Hansen Test for Exogeneity of Instruments' Subsets.

5. Conclusion

This study investigates the relationship between environmental quality, economic growth and health expenditure in Africa. An exclusive panel data of 47 African countries covering the period 2000 to 2018 are employed. Three indicators (carbon dioxide emissions, methane emission and nitrous oxide emission) of environmental quality are modelled with economic growth using both static and dynamic modelling techniques. The general implication of this study is that air pollutants, more importantly, carbon dioxide emission reduces the quality of the environment and it increases health expenditure per capita. Furthermore, this study conforms with the theory that economic growth has a positive, inelastic and significant effect on per capita health expenditure. This is also the case in all the five sub-regions (Central Africa, North Africa, East Africa, West

Africa and Southern Africa). By implication, while increases in economic growth augment health expenditure per capita, air pollutions caused by greenhouse gases deteriorate environmental quality and also spur increases in health expenditure. This study, therefore, suggests that increases in economic growth should not be at the expense of the environment but the use of clean and renewable energy sources should be central to development as encompassed in SGD 13. Other studies can focus on approaches that consider country-specific effects and other measures of environmental quality can also be incorporated in future studies.

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Appendices

Appendix 1: Definition of Variables

Variables	Representation	Unit of Measurement	Source
Health Expenditure	HEX	Current Health Expenditure per capita (constant 2017 USD)	GHED
Economic Growth	GDP	GDP per capita (constant 2010 USD)	WDI
Environmental Quality	ENQ		
Carbon dioxide emissions	CO_2	CO_2 emissions (metric tons per capita)	EDGAR
Nitrous Oxide	N_2O	Nitrous oxide emission (thousand metric tons of CO_2 equivalent)	EDGAR
Methane Emission	CH_4	Methane emissions (kt of CO_2 equivalent)	EDGAR
Ageing Population	ARG	Population ages 65 and above (% of total population)	WDI
Mortality	MRT	Mortality rate, under-5 (per 1,000 live births)	WDI
Urbanization	URB	Urban population (% of total population)	WDI

GHED: WHO's Global Health Expenditure Database. WDI: World Bank's World Development Indicators. EDGAR: Emissions Database for Global Atmospheric Research.

Appendix 2: Summary Statistics (2000-2018)

Sample	Health Expenditure	GDP per capita	Carbon Dioxide	Methane	Nitrous Oxide	Urbanization	Ageing Population	Mortality
Aggregate								
Mean	100.35	2367.44	1.13	893.53	17.78	41.54	3.49	90.87
Median	46.6	1057.36	0.32	369.38	7.97	41	3.05	89.3
Maximum	842.82	20512.94	12.33	7758.1	132.76	89.37	11.47	234
Minimum	4.69	194.87	0.02	1.63	0.03	8.25	1.87	13.7
Std. Dev.	132.36	3162.94	1.97	1321.34	25.42	16.85	1.41	45.73
Skewness	2.4	2.52	2.99	2.79	2.19	0.23	2.1	0.29
Kurtosis	8.9	10.11	12.54	12.31	7.29	2.55	7.79	2.6
Jarque-Bera	2147.29	2825.71	4717.15	4381.52	1402.04	15.7	1507.59	18.99
North Africa								
Mean	130.15	2680.84	1.79	1564.41	33.96	52.06	5.03	56.57
Std. Dev.	83.11	1198.81	1.06	1192.34	31.7	12.8	1.55	42.28
East Africa								
Mean	90.32	1999.03	1.14	625.43	15.95	31.99	2.98	81.68
Std. Dev.	162.64	3210.86	2.75	650.72	17.64	15.95	1.5	38.05
Central Africa								
Mean	93.41	3872.47	1.29	915.32	19.19	49.89	3.09	109.58
Std. Dev.	95.79	5118.41	1.64	1074.93	31.97	21.69	0.6	42.81
West Africa								
Mean	44.75	1002.39	0.33	769.62	13.45	40.84	3.1	110.48
Std. Dev.	33.03	744.86	0.28	1744.13	22.55	11.25	0.6	43.78
Southern Africa								
Mean	201.71	3647.32	1.99	936.05	14.65	38.52	4.08	72.6
Std. Dev.	192.25	3191.47	2.73	1175.37	21.14	15.77	1.76	36.84

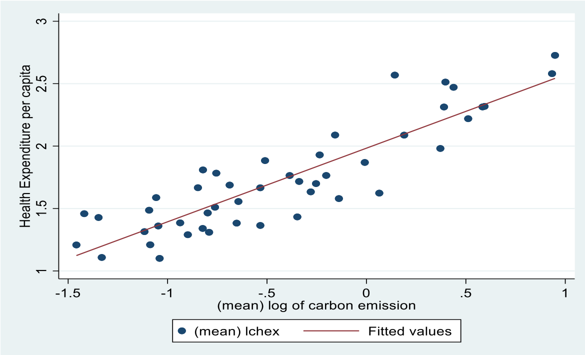
Note: Actual values are reported and not logged values. Std. Dev represents the Standard Deviation

Appendix 3: Correlation Matrix (uniform sample size: 893)

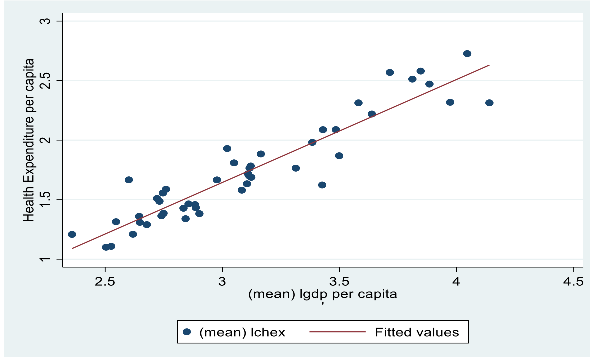
Variables	Health Expenditure	GDP per capita	Carbon Dioxide	Methane	Nitrous Oxide	Urbanization	Ageing Population	Mortality
Health Exp.	1.000	0.811*	0.809*	0.084*	-0.035	0.481*	0.624*	-0.534*
GDP per capita		1.000	0.799*	0.04	-0.107*	0.583*	0.511*	-0.389*
CO_2 emissions			1.000	0.142*	0.046	0.524*	0.611*	-0.446*
CH_4 emissions				1.000	0.821*	0.046	-0.008	0.007
N_2O emissions					1.000	-0.194*	-0.057	0.019
Urbanization						1.000	0.400*	-0.427*
Ageing Population							1.000	-0.536*
Mortality								1.000

Note: Variables are without natural logarithm * shows significance at the 0.05 level

Appendix 4: Member States Plot of Environmental Quality (CO_2 emission), GDP per capita and Health Expenditure in Africa.

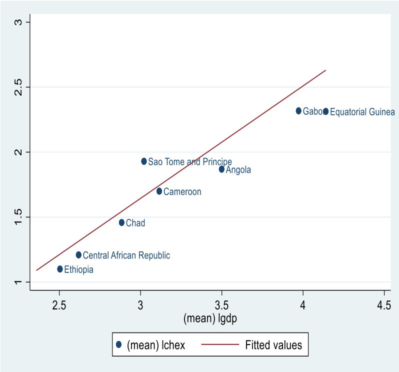


Appendix 4A: Environmental Quality (CO_2) and Health Expenditure

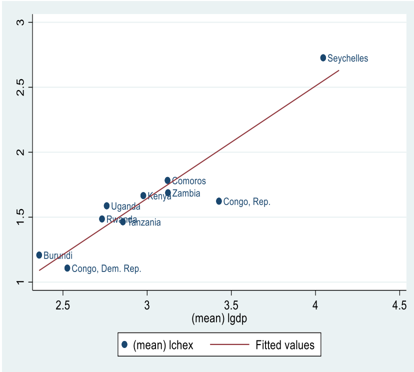


Appendix 4B: Economic Growth and Health Expenditure

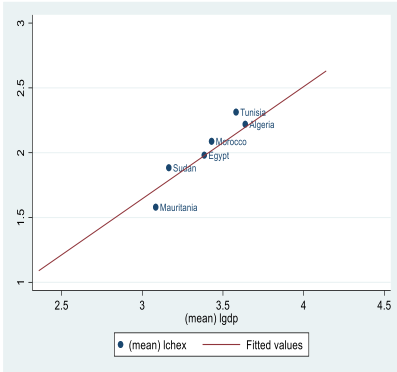
Appendix 4C: Regional plot of GDP per capita and health expenditure per capita



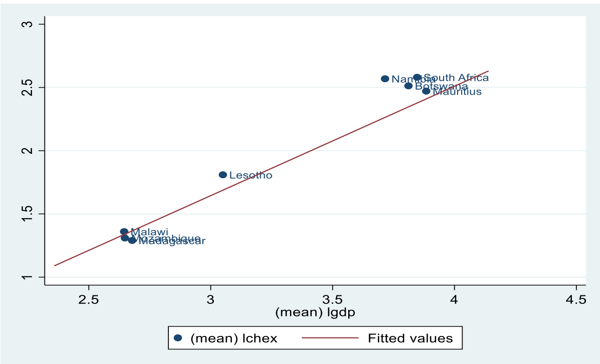
Appendix 4Ci: Central Africa



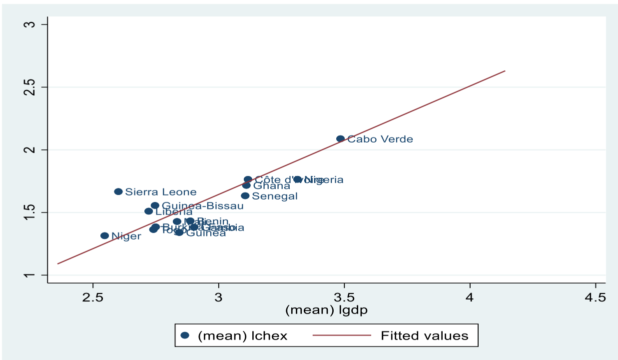
Appendix 4Cii: East Africa



Appendix 4Ciii: North Africa



Appendix 4Civ: Southern Africa



Appendix 4Cv: West Africa