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Determinants of Economic Benefit from Environmental Welfare in sub-Saharan Africa: Evidence from Energy Transition in Ghana

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Abstract
This study analysed the economic effect of energy transition on holistic environmental welfare in sub-Saharan Africa. It models the long run and short run determinants of environmental welfare using the Autoregressive Distributed Lag (ARDL) econometric methodology. The empirical analysis examined environmental welfare in Ghana, one of sub-Saharan Africa's leading countries in electricity access and a strong advocate of the continent's ideas on energy transition. The study found a positive and highly significant relationship between energy price and environmental welfare. Also, CO_2 emissions had a negative and statistically significant effect on environmental welfare, confirming the adverse effect of fossil fuel use on environmental welfare in sub-Saharan Africa. The study also found that environmental welfare in Ghana is explained by state borrowing. The results indicate that the value of future economic benefits, if sub-Saharan African countries transition to renewable energy now, far outweigh the benefit expected from retaining fossil fuel as the main energy source till 2070. Thus, sub-Saharan Africa's decision to hold unto fossil fuels as its main source of energy while a transition to cheaper and environmentally friendly renewable energy is ongoing, constitutes an economic setback for the continent. The analysis also indicate that Ghana's energy transition plan, which largely reflects the sub-Saharan African plan, does not conform to the current financial reality of the country and requires a second thought in favor of a speedy transition to renewable energy. Sub-Saharan Africa will be better off with a quick transition to renewable energy than otherwise.
Keywords: *Energy transition; Environmental welfare; Fossil fuels; Ghana; Renewable energy; Sub-Saharan Africa.*
JEL Classification Codes: *Q35, Q42, Q43, Q58*

1. Introduction

The transition to a global sustainable energy future has become one of Africa's recent dilemmas. Effective functioning of physical infrastructure to enhance human welfare depends to a large extent on the heating, lighting and mobility derived from energy. However, constraints on the capacity of energy sources to meet the needs of humanity sustainably have necessitated changes in the best ways to produce and use energy. To act correctly through policy, the relationship between energy and the life support system of the earth from which it is derived, must be understood, explained and sustainably managed.

Historically, civilization has followed a trend dictated by energy transitions. Starting from the primitive economy's dependence on biomass to the use of hydropower, the world was ushered into the use of coal in the nineteenth century with oil and gas coming on board in the twentieth century. Nuclear energy was then added to the stock in the 1950s. This sequence shows how each stage of economic development was driven by a transition from one main source of energy to the other.

It is therefore not surprising that the twenty first century is witnessing another energy transition, which is driven by challenges to sustainable living, due to energy pricing and supply issues, climate change and technological advancement (Timmons et al., 2014). The earth has so far witnessed a rise in carbon emissions of about 49% over preindustrial levels (WMO, 2022). So far, efforts to control carbon emissions have left too much to be desired, since the failure of the Kyoto Protocol in managing global emissions for optimal human welfare.

In addition, indications of significant scarcities of major non-renewable energy sources are showing in increasing extraction and opportunity costs, making the resources technically too challenging or expensive to extract. Thus threats to the stability of global energy systems have become very real from geological issues to refined end- product issues (BP, 2013). This calls for measures which must only be correctly guided by detailed scientific analysis of energy resource allocations that would guarantee optimal welfare for current and future generations.

Sustainable energy to a large extent secures the means of production for needed holistic human welfare improvement. Current trends in global energy dynamics as well as over reliance on fossil fuels has shown how energy insecure the world is. This insecurity has tended to be more costly to the developing world than to the developed world. Thus sub-Saharan Africa and its people have been exposed to the most severe energy insecurity in recent history, to the extent that millions of African households are no longer able to meet their basic human needs and have been pushed below the poverty line (IEA, 2022). This study therefore assesses the economic implication of the current global energy transition for Africa, to inform policy on Africa's sustainable energy development path. Specifically, it examines the welfare effect of sub-Saharan Africa's plan regarding the ongoing global energy transition.

Man's habitable natural environment is generally made up of three interdependent subsystems. These are the natural subsystem, the social subsystem and the economic subsystem. The natural subsystem is composed of all living and nonliving organisms called the biosphere. The social subsystem is made up of all the property rights, social norms, ethics, laws, customs, and traditions, religious and political institutions through which the various resources from the natural subsystem are allocated. The economic subsystem defines the production, distribution and consumption frameworks within which resources are allocated from extraction, for optimal welfare. The economic subsystem thus functions within the natural and social subsystems. Equations (1) to (7) show the composition of holistic societal welfare. Let

$$W_T = W(Q) \quad (1) \qquad Q = Q(K, \tau) \quad (2)$$

$$Q = \{Q_E, Q_S, Q_N\} \quad (3) \qquad W_E = W_E(Q_E) \quad (4)$$

$$W_S = W_S(Q_S) \quad (5) \qquad W_N = W_N(Q_N) \quad (6)$$

$$\text{Therefore } W_T = \{W_N, W_S, W_E\} \quad (7)$$

Where Q, Q_E, Q_S, Q_N are total, economic, social and environmental outputs respectively.

W_T, W_E, W_S, W_N are total, economic, social and environmental welfare respectively.

K and τ are the level of capital stock and technology available to the economy respectively.

Thus the holistic welfare for society is given by a combination of environmental welfare (4), social welfare (5) and economic welfare (6), which is synonymous with sustainable development or total system welfare (7).

Ghana, a country with the highest access to electricity in sub-Saharan Africa, has been at the forefront of the continent's approach to the global energy transition. Ghana's Ministry of Energy sees no urgency in transition to renewable energy. In its energy transition framework for 2022 to 2070, the country wishes to attain only 20% renewable energy capacity by 2070 (Ministry of Energy, 2022). The country intends to expand its natural gas capacity from 2022 to the 2050s, by which time it hopes to replace natural gas with nuclear energy as its main source of energy by 2070 (Ministry of Energy, 2022). Thus, from its official approach, Ghana has no plans for any substantial transition to renewable energy even by 2070, since neither natural gas nor nuclear energy which it hopes to depend on for most of its energy are both not renewable energy sources. Generally, Ghana's position reflects what most sub-Saharan African countries intend to do. To sub-Saharan Africa, the time has come for its fossil fuel boom and not an imposed energy transition (Tena, 2022; Lawrynuik, 2022). Such a position comes with environmental effects which have consequences for economic development and human welfare.

Holdren & Ehrlich (1974) developed the IPAT model for analyzing human activity effects on the natural environment. The model basically serves as a framework for identifying the determinants of environmental impacts (Harrison &

Pearce 2000). In its formulation, the IPAT model postulates that environmental influences or impact represented by (I) are a function of three other causal agents, namely, Affluence (A), Technology (T) and Population (P).
Over the years some critics of the model provided alternative models. Waggoner & Ausubel (2002) suggested the ImPACT Model while Schulze (2002) presented the IPBAT Model to explain the relationship between human activity and the natural environment.

Another way of presenting the IPAT Model and its variants was through the Stochastic Impacts by Regression on Population, Affluence, and Technology (STIRPAT) Model advanced by Dietz & Rosa (1997). To address the equality of impact among the factors in the IPAT equation, the STIRPAT Model used indices to model the varying weights of influence among the causal factors. Basically, the STIRPAT Model is presented as:

$$I_i = \propto P_i^b \, A_i^c \, T_i^d \, \varepsilon_i \qquad (8)$$

Extending the basic STIRPAT model by applying natural logs gives:

$$In\ I_{it} = In \propto + b\ In\ P_{it} + c\ In\ A_{it} + d\ In\ T_{it} + In\ \varepsilon_{it} \qquad (9)$$

where I, P, A and T are defined as in the IPAT equation. The parameter $\propto$ is a constant while $b, c, and\ d$ are the exponents of the variables $P, A, and\ T$ showing the impact elasticities of the causal factors. The error term is denoted by ε, time or year is denoted by t while i captures the variations in I, P, A, T as well as the error term, ε, across observational units.

The following section presents the methodology for the study. This is followed by empirical analysis of energy use and environmental welfare in Ghana. The results of the analysis are then discussed toward energy transition. The final section concludes the study with some implications for energy transition policy in sub-Saharan Africa.

2. Methodology

To model the link between environmental welfare and its determinants, this study uses a modified STIRPAT model. Environmental welfare (EW) based on energy sector performance is the dependent variable for the model. Considering all costs of energy sources, Bielecki et al. (2020) concluded that the sources of energy that have minimal negative effect on the natural environmental subsystem are the truly clean ones, namely; geothermal, solar and wind energy. Thus, the amount of renewable energy consumed is directly proportional to the level of environmental welfare. Hence the study uses the amount of renewable energy consumed in a given year as proxy for environmental welfare for that year.

The study modifies equation 9 to model the link between environmental welfare and its determinants, by substituting for T as in equation (10):

$$InEW_t = \beta_0 + \beta_1 InPOP_t + \beta_2 InGDP_t + \beta_3 InEP_t + \beta_4 InCO2_t + \beta_5 InIND_t + \beta_6 InU_t + \varepsilon_t \qquad (10)$$

Where EW_t is environmental welfare, POP_t represents population growth, GDP_t stands for gross domestic product, EP_t is energy price, CO_{2t} carbon dioxide emissions, IND_t is industrialization and U_t denotes urbanization. The β_s are the parameters that would be estimated in the environmental welfare model with t being time and an error term ε.

Time series data providing annual values from 1986 to 2018 was used to analyze the determinants of environmental welfare in Ghana. The choice of time period was based on availability of data. The World Development Indicators Database (WDI) and the US Energy Information Administration Database (EIA) (2019) were the main sources of data for the study. As depicted in equation (10), the independent variables for the study are fully defined and explained in Table 1.

Table 1: A description of independent variables and their expected signs

Variable	Description/ Definition	Expected Sign
Population (POP)	Population growth rate measured as an annual percentage growth of total population.	+
Gross Domestic Product (GDP) per capita	Income per head for the country, measured as annual GDP per person.	+
Energy Price (EP)	Price of crude oil measured by the Brent Oil Spot Prices	+
Carbon Dioxide Emission (CO_2)	Amount of carbon dioxide emission in the country in a year	+/-
Industrialization (IND)	Industrial value added expressed as a percentage of gross domestic product per annum	+/-
Urbanization (U)	Urban populations expressed as a percentage of total population	-

The Autoregressive Distributed Lag (ARDL) Model based on bounds test for co-integration was used as the framework for estimation. The test for stationarity was performed by means of the Augmented Dickey Fuller (ADF) test and Phillip-Perron (PP) test. The procedure also tested for reliability and goodness of fit of the model.

The ARDL procedure began with testing the F-Statistic, then estimating the long-run model, followed by the short-run model and then the error correcting model (ECM). The conditional ARDL model depicted by equation 10 is stated as:

$$\Delta lnEW_t = \beta_0 + \alpha lnEW_{t-1} + \beta_1 lnPOP_{t-1} + \beta_2 lnGDP_{t-1} + \beta_3 lnEP_{t-1} + \beta_4 lnCO2_{t-1} + \beta_5 lnIND_{t-1} + \beta_6 lnU_{t-1} + \sum_{i=1}^{\rho} \gamma \Delta lnEW_{t-i} + \sum_{i=1}^{\rho} \varphi_{1i} \Delta lnPOP_{t-i} + \sum_{i=1}^{\rho} \varphi_{2i} \Delta lnGDP_{t-i} + \sum_{i=1}^{\rho} \varphi_{3i} \Delta lnEP_{t-i} + \sum_{i=1}^{\rho} \varphi_{4i} \Delta lnCO2_{t-i} + \sum_{i=1}^{\rho} \varphi_{5i} \Delta lnIND_{t-i} + \sum_{i=1}^{\rho} \varphi_{6i} \Delta lnU_{t-i} + \varepsilon_t \quad (11)$$

Where α, β_i, γ and φ_{ji} are parameters with β_0 being the drift term while ε_t is the error term.

3. Analysis of Data

3.1 Descriptive Statistics

A summary of the statistics describing the data used for the study is provided in Table 2. Between the minimum and maximum environmental welfare, the standard deviation of 0.0102 shows a relatively stable level of environmental welfare with respect to the mean level of 0.0581. Energy prices (EP), per capita gross domestic product (GDP), urbanization (U) and industrialization (IND) have the most deviations. The mean population growth of 2.55 is quite high but characteristic of sub-Saharan Africa.

Table 2: Summary of statistics

Variable	Observations	Mean	Standard Deviation	Minimum	Maximum
EW	34	0.0581	0.0102	0.0372	0.0776
POP	34	2.5496	0.2329	2.1626	2.9385
GDP	34	1143.10	346.00	761.92	1884.29
EP	34	45.3521	32.1983	12.76	111.63
CO_2	34	0.3851	0.1201	0.2315	0.5943
IND	34	23.8898	5.4469	16.3190	34.8600
U	34	45.3982	7.0076	33.591	56.707

Figure 1 shows that the peak level of environmental welfare occurred in 2015, since then environmental welfare has been declining.

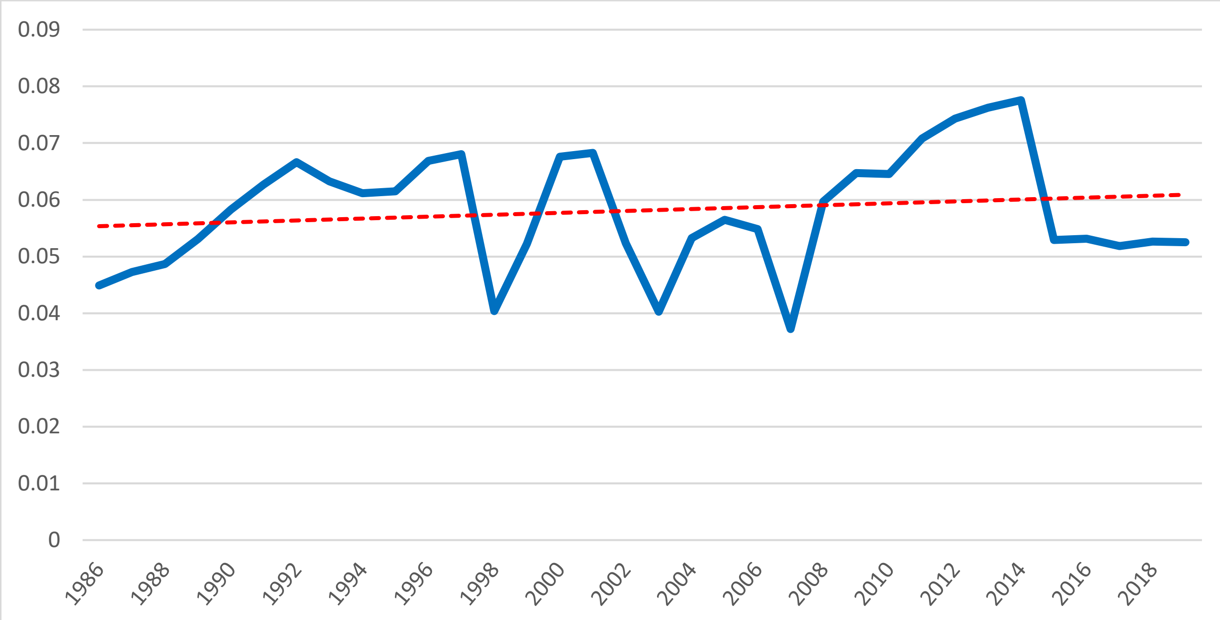

Figure 1: Trend of Environmental Welfare in Ghana

3.2 Unit Root and Co-integration Tests

Results of the Augmented Dickey Fuller (ADF) and Philips-Perron tests are shown in Tables 3 and 4 respectively. From Table 3, the rejection of the null hypothesis for unit root is done at levels for only environmental welfare (LnEW), population (LnPOP) and urbanization (LnU). However, at the first difference, the null hypothesis is rejected for the remaining variables.

Table 3: Augmented Dickey Fuller (ADF) Test

Level			First Difference		
Variable	Constant	Constant & Trend	Variable	Constant	Constant & Trend
LnEW	-3.6484***	-3.5378**	*D(LnEW)*	-5.2760***	-5.3419***
LnPOP	-1.1561	-3.9806**	*D(LnPOP)*	-2.3804	-2.3315
LnGDP	1.1675	-1.4169	*D(LnGDP)*	-3.2068**	-.3.6768**
LnEP	-1.2116	-1.8156	*D(LnEP)*	-5.1894***	-4.9365***
LnCO2	-0.6140	-2.5858	*D(LnCO2)*	-5.5778***	-5.5087***
LnIND	-1.3349	-1.8586	*D(LnIND)*	-4.7086***	-4.6301***
LnU	-2.5340*	-1.9406	*D(LnU)*	-0.6619	-1.3555

***, ** and * indicate significance at 1%, 5% and 10% levels of significance respectively.

From Table 4, only environmental welfare (LnEW) and urbanization (LnU) were stationary at the levels, however, at the first difference the remaining variables are stationary. The results from Tables 3 and 4 show the suitability of the data for the analysis.

Table 4: Phillips-Perron (PP) Test

Level			First Difference		
Variable	Constant	Constant & Trend	Variable	Constant	Constant & Trend
LnEW	-3.4398***	-3.2879*	*D(LnEW)*	-11.0583***	-11.3111***
LnPOP	-0.5860	-1.8599	*D(LnPOP)*	-2.0451	-2.1300
LnGDP	2.3448	-0.9333	*D(LnGDP)*	-3.2091**	-3.6508**
LnEP	-1.1898	-1.9451	*D(LnEP)*	-5.1941***	-5.0939***
LnCO2	0.1321	-2.4903	*D(LnCO2)*	-9.0553***	-9.8950***
LnIND	-1.4558	-1.8586	*D(LnIND)*	-4.6673***	-4.5496***
LnU	-18.6679***	-1.6105	*D(LnU)*	-0.6581	-1.5875

***, ** and * indicate significance at 1%, 5% and 10% levels of significance respectively.

The F-statistic shows the existence or otherwise of a relationship among the variables, based on a comparison with the lower and upper bound critical values for the cointegration results. Since from Table 5, the F-statistic computed from the bounds test exceeds the upper bound critical value (3.99) at the 1% level of significance. This implies a long run relationship exists between environmental welfare and the independent variables at 1% level of significance. Thus the independent variables are the predictors of environmental welfare in the long run.

Table 5: Bounds Test for Cointegration

Test Statistic	Value	Significance Level	$I(0)$	$I(1)$
F-statistic	7.0828***	10%	1.99	2.94
K	6	5%	2.27	3.28
		1%	2.88	3.99

*** indicates significance at 1% level of significance.

3.3 Analysis of Long Run Model

Table 6 shows the long run model results. Specifically, a 1% rise in the price of energy results in 0.03% improvement in environmental welfare.

Table 6: Long Run Results

ARDL (1, 0, 1, 0, 2, 0, 2) selected based on SBC			Dependent Variable: LnEW	
Variable	Coefficient	Standard Error	T-statistic	Probability
LnPOP	0.0142	0.0288	0.4921	0.6286
LnGDP	0.0552*	0.0304	1.8170	0.0859
LnEP	0.0257***	0.0068	3.7694	0.0014
LnCO2	-0.1061*	0.0586	-1.8095	0.0871
LnIND	0.0347**	0.0151	2.2954	0.0339
LnU	0.0220	0.1238	0.1776	0.8610
C	-0.7444	0.6149	-1.2106	0.2417

Note: ***, ** and * indicates 1%, 5% and 10% level of significance.

This is because as prices of conventional energy increase, households and other users would seek for alternative sources of energy like renewable energy, hence stimulating the consumption of renewable energy to enhance environmental welfare. This finding agrees with Sadorsky (2009) and Mudakkar et al. (2013) who found that energy prices influence renewable energy consumption.

The results for Industrialization (LnIND) show that at the 5% level of significance, 1% increase in industrialization will cause a 0.03% improvement in environmental welfare. The result supports the empirical works of Shi (2003), Poumanyvong & Kaneko (2010) and Dogan & Seker (2016) who found industrialization positively drives renewable energy use.

From the results, 1% increase in per capita GDP results in 0.06% improvement in environmental welfare. This positive effect and link between GDP per capita and environmental welfare agrees with the findings of Rafiq & Alam (2010) and Omri et al. (2015) who found per capita GDP to positively influence renewable energy use.

Carbon dioxide emission (LnCO_2) showed a negative and significant relationship with environmental welfare. The result is confirmed by Mehrara et al. (2015) and Bilgili, Kocak & Bulut (2016) who found carbon dioxide emission to have negative impact on environmental welfare.

Finally, the results revealed that population growth (LnPOP) and urbanization (LnU) were not statistically significant determinants of environmental welfare. Following from the results of the long run model, adjustment from a shock in the short run towards restoration of a long run equilibrium is presented as:

$$ECM = LnEW + 0.0142POP + 0.0552GDP + 0.0257EP - 0.1061CO2 + 0.0347IND + 0.0220U - 0.7444C$$

3.4 The Short Run Model

Results from the short run model show a 75% explanatory power of environmental welfare by the independent variables. Population (POP) is shown to have a negative and significant effect on environmental welfare at the 5% significance level.

Table 7: Short Run Model Results

ARDL (1, 0, 1, 0, 2, 0, 2) based on SBC			Dependent Variable: LnEW	
Variable	Coefficient	Standard Error	T-statistic	Probability
D(LnPOP)	-0.0720**	0.0313	-2.2986	0.0337
D(LnGDP)	0.0472*	0.0236	2.0017	0.0606
D(LnEP)	0.0220***	0.0048	4.5826	0.0002
D(LnCO2)	-0.0907**	0.0430	-2.1081	0.0493
D(LnIND)	0.0112	0.0092	1.2199	0.2383
D(LnU)	6.8728	5.0127	1.3711	0.1872
CointEq(-1)	-0.8551***	0.0964	-8.8712	0.0000

R-sqaured	0.7937	Mean dependent var	0.0001
Adj. R-squared	0.7524	S.D. dependent var	0.0106
S.E. of regression	0.0053	Akaike info criterion	-7.4830
Sum squared resid.	0.0007	Schwarz criterion	-7.2055
Log likelihood	121.99	Hannan-Quinn criterion	-7.3926
Durbin-Watson	2.1595		

***, ** and * show 1%, 5% and 10% significance levels respectively.

Energy price (LnEP) has a positive statistically significant relationship with environmental welfare at 1% significance level in the short run. This result is consistent with the long run result on energy price and confirms the finding of Mudakkar et al. (2013).

Carbon dioxide emission (LnCO_2) has a negative and statistically significant effect on environmental welfare at 5% significance level. This result is consistent with the findings of Bilgili et al. (2016) who found CO_2 emissions to be negatively related to environmental welfare.

The error correction term CointEq(-1) has a coefficient which shows that any deviation from equilibrium as a result of short run disturbances will converge back to the equilibrium by 85.5%. This shows a fast adjustment speed significant at 1% level of significance.

3.5 Diagnostics and Stability Tests
Table 8 presents the output of the post estimation tests for heteroscedasticity, serial correlation, functional form and normality. The table shows that each test recorded insignificant F-statistic, indicative of the fact that the model was free from autocorrelation, non-constant variance, model misspecification as well as uneven distribution of data series as evidenced by the Jarque-Bera.

Table 8: Environmental Welfare Model Diagnostics

Diagnostic	Test	F-statistic	Probability
Serial Correlaton	Breusch Godfrey	0.7319**	0.4964
Heteroscedasticity	Breusch-Pagan-Godfrey	1.0131**	0.4762
Functional Form	Ramsey Reset	0.9412**	0.3456
Normality	Jarque-Bera	1.1731**	0.5562

** 5% significance level.

Also, the CUSUM plot in Figure 2 and CUSUMSQ plot in Figure 3, show that the parameter estimates of the study fall within the 5% critical bound, indicating that they are not affected by any systemic shocks in the coefficients, hence the data series are stable over the period covered by the study.

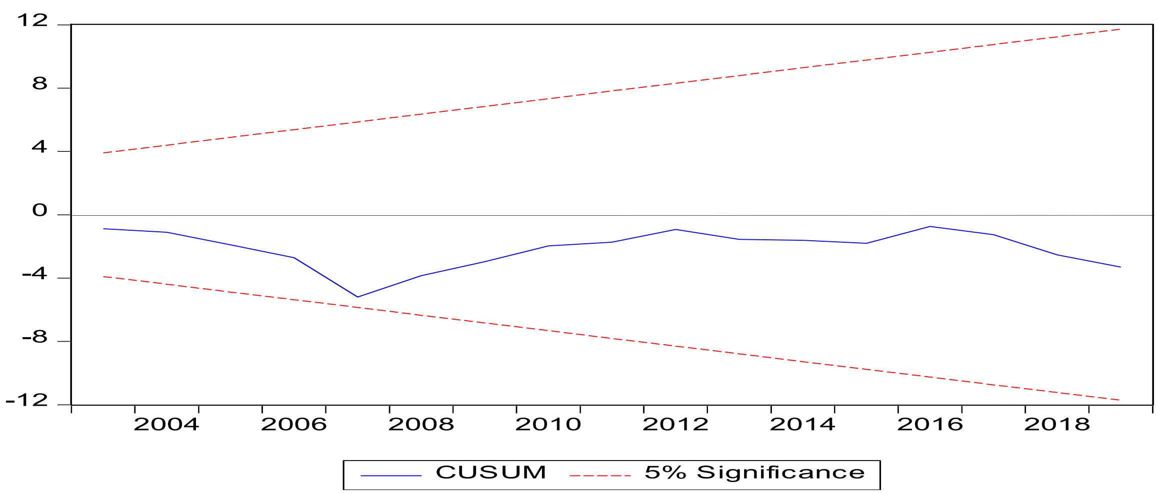

Figure 2: Plot of Cumulative Sum of Recursive Residuals (CUSUM)

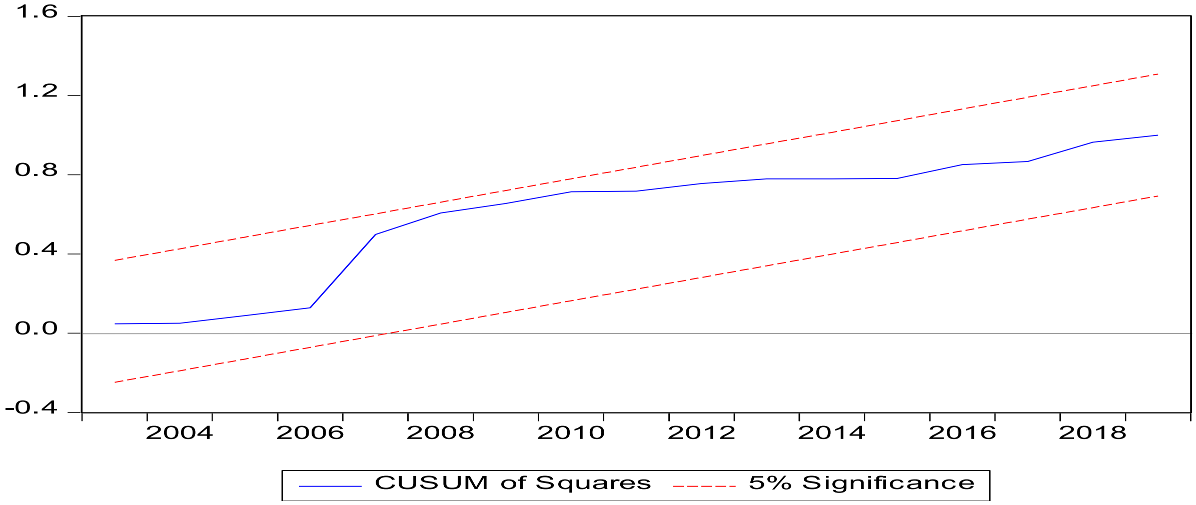

Figure 3: Plot of Cumulative Sum of Squares of Recursive Residuals (CUSUMSQ)

4. Discussion of Findings

4.1 Energy Price

The positive and highly significant relationship between energy price and environmental welfare both in the short run and long run makes energy price one of the most fundamental variables for decision making in the ongoing energy transition.

National budgets of sub-Saharan African governments are under serious strain due to soaring prices of fossil fuel globally. The continent faces a high risk from fluctuations in prices of commodities due to its heavy dependence on fossil fuel powered electricity. Currently, not less than 28 African countries depend on fossil fuels for at least 50% of their power needs, among whom 16 derive 80% or more of their power from fossil fuels (BloombergNEF, 2022).

The increases in prices of LPG for instance have constrained attempts to increase the use of clean fuels for cooking in sub-Saharan Africa. From 2019, global prices of LPG increased by over 60%, resulting in local price increases of LPG between 40 and 60%. In Kenya the higher prices cost the poorest households more than 10% of their monthly earnings, with the same group in Nigeria paying 7% of their monthly incomes for LPG (IEA, 2022).

The addition of levelized costs and external costs provides the total economic cost of a source of energy. For electricity obtained from new natural gas, the levelized cost was US$44-US$73/Mwh. If the external cost of new natural gas (US$84/Mwh) is added, the real cost of new natural gas increases by 115-191% (Trinomics, 2020). Currently, based on levelized costs only, natural gas can be said to be reasonably competitive with solar and wind energy in terms of marginal costs. However, if external costs are included, the cost of natural gas becomes at least twice those of solar and wind energy systems. This shows the huge price superiority of solar and wind energy over natural gas (Maisch, 2022).

Following the energy path of the past century means being dependent on fossil fuels as the main energy for development. It would not make economic sense to follow that path in an era when renewable energy has become cheaper than marginal operational costs of fossil fuel sources of energy. In recent times, prices of wind and solar energy have declined significantly as a result of technological improvements. Currently, wind and solar energy are the cheapest sources of energy in the world, on average, even when subsidies are not included (Roach & Harris, 2021). Also, if the externalities generated through fossil fuels were to be internalized, the economic advantage in favor of renewable energy against fossil fuels would be even much greater.

This means it will make economic sense to shut down existing coal, natural gas and nuclear power systems, replacing them with renewable energy systems. This conclusion about the economic superiority of renewable energy to traditional sources of energy has been confirmed by different cost studies in recent times (Roach & Harris, 2021; IRENA, 2020).

4.2 Carbon dioxide emissions

The study found that CO_2 emissions had a negative and significant effect on environmental welfare both in the short run and the long run. This confirms the adverse effect of fossil fuel use on environmental welfare in sub-Saharan Africa.Compared to other parts of the world, Africa has the highest energy intensity, showing how inefficient energy use is on the continent (IEA, 2022). Almost 75% of global GHG emissions are caused by the energy sector.

Only about 0.04% of world emissions of CO_2 has been attributed to Ghana currently. Also, per capita emissions stand at 1.57TCO2e, which is about 24% of the global mean emission. The problem, however, has to do with the steep increase in emissions. Emissions increased from 35.2MtCO2e to about 48.8MtCO2e between 2010 and 2019, making the increase in emissions based on GDP growth prior to 2035 about 62% (World Bank, 2022).

Ghana's electricity production has increasingly become fossil fuel dependent since 1992, with renewable energy being minimally used despite falling costs of solar systems and wind energy. In addition to compounding the total emission flow, burning of waste openly, transportation and fuel-wood use produce pollutants that are toxic, creating significant adverse effects on human health in the country. For instance, the yearly average PM2.5 concentration levels in the country are about 600% more than what the guideline of WHO accepts as normal, causing 425,931 disability-adjusted life years and about 11, 739 premature deaths annually (WHO, 2016).

Currently, Africa has only 7.6% consumption of modern renewable energy (UN, 2021), with just 2% of renewable energy investments over the past 20 years (IRENA & AfDB, 2022). However, Africa possesses very substantial potential resources for solar, wind and hydropower energy systems. Also, while Africa hosts 60% of the world's best resources for solar energy, it has just 1% capacity of photovoltaic (PV) installed (IEA, 2022). Therefore, quick transition to renewable energy is needed for the survival and sustainable development of Africa.

4.3 Indebtedness and Fossil Fuel

Increasing indebtedness for debt distressed economies means lower per capita GDP in the future due to debt service burden sharing. From the finding of this study, a decrease in per capita GDP will result in a decrease in environmental welfare. Excessive reliance on debt to finance fossil fuel projects has been a stumbling block to transition to renewable energy in Africa. For instance, Ghana's inability to transition quickly has been due to binding fossil fuel energy agreements, which must be kept far into the future and is currently causing increasing indebtedness and a burden for state coffers.

In his 2023 budget speech, Ghana's minister of finance stated that the nation's petroleum and crude oil import bill of US$400 million a month was difficult to meet, in addition to finding about US$1.0 billion to keep workplace and home lights on annually (MOF, 2022). The country now seeks an IMF bailout of US$3 billion, with implications of about 30% losses in earnings of investments of foreigners. The bailout is less than its debt servicing obligations of US$3.5 billion due by 2023 (Munshi et al*.,* 2022).

Take-or-pay energy agreements that set up about 4,600 MW thermal plant capacity between 2013 and 2015 saddled the country with payments of US$500 million annually for electricity it does not need. Indebtedness for fuel supplies to feed the plants and commitments to operators are estimated to be up to US$12.5 billion by 2023. In addition, government proposals to restructure its US$21 billion debt in bonds is causing discomfort among local and international bondholders (Munshi et al*.,* 2022).

The structure of Ghana's debt does not offer any opportunity for it to continue to borrow for the development of fossil fuel and nuclear energy infrastructure, as it has stated in its energy transition policy. As at now, Eurobond issuances are disallowed for the country (World Bank, 2022). Thus the policy does not conform to the financial reality in Ghana and requires a change in favor of a quick transition to renewable energy.

The African continent has the greatest advantage in the ongoing global energy transition, given its abundant renewable energy resource stock. However, it has not sufficiently positioned itself to tap into the vast opportunities available, as it lags seriously behind all other regions in the world by its current posture towards energy transition (BloombergNEF, 2022). Africa's inertia towards the global energy transition denies it benefits from possessing the best mean long-term practical output in terms of utility scale installations for solar energy. The continent has on average about 4.51 kilowatt hours potential output for every kilowatt of technology installed per day (World Economic Forum, 2022).

Based on its natural endowment, Africa is capable of meeting 25% of its energy requirements from indigenous renewable sources as early as 2030. Up to 50% of Africa's total capacity to generate electricity could be provided for by 310 GW of modern renewable energy. Compared to its 2021 available capacity of 56GW, this will be an increase of 600% (IRENA, 2019). Also, capacity for a realization of 50% renewables in its electricity generation mix share exists, providing the opportunity for a 1000% increase in renewables capacity over 2013 energy sector levels in Africa (IRENA, 2015). This means a quick transition to renewable energy will make further indebtedness due to energy requirements unnecessary.

4.4 Climate change

Greenhouse gas emissions, especially carbon dioxide and methane, cause about 90 percent of global climate change. Thus the finding of negative and statistically significant relationship between CO_2 emissions and environmental welfare depicts a corresponding relationship between climate change and environmental welfare.

Ghana has seen significant climate change damage to its natural, physical and human capital resources. These have been manifested through extreme weather conditions of drought, floods, heat stress, crop failure, sea erosion, loss of property and infrastructure, loss of livelihoods and human lives. About 32 major climate change disasters were recorded from 1968 to 2021, where flooding was followed by drought (World Bank, 2022). About 45,000 people are affected by floods annually, with 50% of the country's 550-kilometre coastline being affected by sea-level rise related floods and erosion (Rentschler & Salhab, 2020; Rozenberg & Fay, 2019).

Damages related to climate change have been projected to increase substantially in Ghana beyond 2050 (World Bank, 2022). Current climatic effects are estimated to be responsible for droughts affecting 13% of the population, especially within the northern parts of the country. Some climate models estimate a total yearly decline in total rainfall of about 12% by 2050, with expected effect on average annual losses (AALs) due to droughts increasing to US$325 million annually from US$95 million between 2020 and 2050 (UNDRR and CIMA, 2019). The transition from fossil fuel to renewable energy is one of the main ways to mitigate climate change, which will deliver increased environmental welfare. This provides one of the most effective ways of avoiding and reversing the adverse effects of climate change in sub-Saharan Africa.

Even though Africa's contribution to climate change has been the least globally, it faces extreme climate change effects with severe drought and flooding. As a consequence, 250 million Africans are finding it increasingly life threatening to live off the land in Africa (Macron et al., 2022). Falling costs of renewable energy offers a great advantage for future prospects in Africa to both mitigate and adapt to climate change.

4.5 Investments in sub-Saharan African Fossil Fuel

There is currently a gradual move to cancel the availability of funding for projects on fossil fuels worldwide (IEA, 2022). Nigeria, a major fossil fuel producer has been struggling with uncertainties due to fiscal and high risk issues related to investments in oil. Other sub-Saharan African countries like Senegal, Uganda, Ghana and Kenya are facing challenges related to fossil fuel production.

The projection points to a contraction of fossil fuel production in sub-Saharan Africa by about 25% from 2021 to 2023, while falling world fossil fuel demand pulls down investments in new oil field activities. It is worth noting that net exports of oil in Africa decreased by 40% to 2.4mb/d between 2010 and 2020 because of declining output and falling demand. Africa will thus become a net oil importer in the middle of the 2030s following this trend projected by the International Energy Agency (IEA, 2022).

The choice sub-Saharan Africa is making, to continue to upscale fossil fuels will clash with global efforts to cut down on emission intensities of fossil fuel activities. Currently, investors consider projects for investment that reduce fossil fuel GHG emission footprints. If sub-Saharan African countries choose to engage in goods produced with high GHG emission footprints, they will be adversely affected by the punitive regulations put in place to encourage transition to renewable energy. Thus, sub-Saharan African exports will face high carbon taxes, making them uncompetitive.

5. Conclusion and Policy Implications

The desire for environmental welfare and energy security globally are driving a transition to renewable sources of energy. This study assessed the economic implications of the transition for sub-Saharan Africa, based on empirical data from Ghana, one of its leading countries in electricity access. The study found that global energy prices, CO_2 emissions, GDP per capita and industrialization significantly influence environmental welfare in Ghana and as such constitute drivers for the ongoing energy transition in sub-Saharan Africa.

The current price hikes and energy insecurity are a clear sign for sub-Saharan Africa to transition to renewable energy, where it has the best advantage globally before it is too late. Africa will have to come to terms, early enough, with the reality that developing its fossil fuels which are losing in investments and financial competitiveness, will only aggravate its indebtedness and deprivation. It will also have to take a cue from the fact that the countries from which it hopes to seek financial assistance to develop its fossil fuels are themselves speedily transitioning to renewable energy because it is most efficient and equitable to do so, given the social, economic and environmental insecurity posed by dependence on fossil fuels.

Transition to renewable energy will also help alleviate the effects of CO_2 environmental damage and climate change cost, which are currently hurting several African communities which are highly vulnerable to droughts, floods and famine. The transition will help solve perennial indebtedness and release resources for growth and development, since substantial portions of sub-Saharan Africa's indebtedness are attributable to fossil fuel related activities. Thus to secure the welfare of its people and break from debt distress, a quick transition to renewable energy is recommended for sub-Saharan Africa.

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