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Effects of energy consumption on human development and industrial sector performance in selected Sub-Saharan Africa and OECD countries: comparative analysis

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ABSTRACT

The objectives of this study are to implicitly investigate the relationship that exist between energy consumption (renewable and non-renewable energy) and human development (with the Human Development Index as proxy); and energy consumption and industrial sector performance (with industrial output as proxy) in selected sub-Saharan Africa and the Organization for Economic Co-operation and Development (OECD) countries. Four groups of models were specified and estimated using Panel data for 21 countries according to income criteria from 1990 to 2022. These data were analyzed using Panel Ordinary Least Square (OLS) before which they were filtered with the use of Augmented Dickey Fuller (ADF) unit root test while the Johansen cointegration test was used to justify the long-run relationship among all included variables. The findings of this study revealed that energy consumption was positively related and statistically significant in explaining changes in human development and industrial sector performance in the selected sub-Saharan Africa and the OECD countries. However, changes in Human Development Index (HDI) were not statistically significant in explaining changes in industrial sector performance in both regions. The results of the estimated models revealed a three-way directional causality among the selected variables. Additionally, it was established that a significant gap exist in human development, energy consumption and industrial sector performance, in favour of the selected OECD countries. Furthermore, it was also established that energy consumption and industrial output are potent determinants of human development in the selected OECD and sub-Saharan African Countries.

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Introduction

The importance of energy consumption on human development and industrial sector performance cannot be overemphasized. This is because industries require energy and quality human resources to operate optimally. Human development requires affordable renewable and non-renewable sources of energy to be more productive. However, efficient, reliable, affordable and sustainable energy consumption has the capacity of enhancing human welfare and social development in different ways. Simple energy form like electricity enables humans store their food, drugs and vaccines for a longer period in a refrigerator and other cooling devices (Pambudi et al. 2022). Constant and affordable power supply encourage longer hours of study and research using computers, televisions and the internet, which can improve adult literacy rate. Energy is also useful in heating, security, entertainment and sanitation, which are capable of improving quality of life (Bauchner et al. 2020). Renewable energy like solar with zero carbon emission can mitigate climate

change, and is gradually replacing coal, traditional biomass and other non-renewable sources (Holechek et al. 2022).

Optimal utilization of energy can also enhance industrial sector performance by reducing the cost of production and it is a prerequisite for optimal output. On the other hand, the increasing demand and use of non-renewable energy due to industrialization, urbanization and the rising world population, has brought about greenhouse gases accumulation in the atmosphere. This has negatively affected human health and resulted to a large-scale ecological damage which has been a major topic of debate in the series of the Conference of Parties (COP) among world leaders (Manisalidis et al. 2020). It is an irony that despite sub-Saharan Africa renewable and non-renewable energy endowment, most parts of the region are still wallowing in energy poverty. This is because the sub-region lacks the required technology and skilled manpower to optimally utilize these resources for the benefit of human development. The case is different for the Organisation for

Economic Cooperation Development (OECD) countries. Globally, approximately 2.8 billion people have limited access to various energy sources. From these, about 1.8 billion, mostly from Africa, depend on solid fuel like coal, charcoal and wood (Stoner et al. 2021). The uncontrolled population of the sub-Saharan Africa countries has been a major concern for the rising energy demand in the region. Report from Oxfam and the Renewable and Appropriate Energy Laboratory at the University of California, Berkeley revealed that the sub-Saharan Africa region currently have the lowest energy generation capacity and experience the most acute forms of energy poverty in the world and this has adversely affected human development and industrial output over the years (Mukhtar et al. 2023). Research by Oubda et al. (2022) revealed that Africa is capable of generating approximately 1.2 terawatts without solar source but higher than 10 terawatts with solar power, of which the continent is most endowed with. Most sub-Saharan African countries are not industrialized. Their exports major on primary products with huge imports on consumer goods coupled with the energy poverty suffered by the region. Industrial contributions to the GDP have been significantly low over the years (Ndiaya and Lv 2018). Unlike the OECD countries, sub-Saharan Africa countries have a weak industrial base, thereby lacking the appropriate structural change and diversification necessary for sustainable growth and development. But the extent of the sub-Saharan industrial crisis is more far-reaching than this. Two questions are sources of controversies. First, why has the level of industrial achievements been so low? More specifically, have the import substitution policies followed by most sub-Saharan African countries failed? Second, which policies should be adopted in future?

Although affordable and reliable energy supply is necessary for human and industrial development, the deprived populations represent a huge commercial opportunity for the weak sub-Saharan African utilities. So, why aren't these potential consumers connected to the formal grid or what is the relationship between total primary energy consumption and human development in the countries under study? The demand for energy is expected to skyrocket due to rising population, urbanization and economic productivity. The continent is experiencing low energy consumption access arising from the inadequate installed capacity. So, does energy consumption significantly influence human development and industrial sector performance in the selected sub-Saharan Africa and OECD countries? The use of expensive generators with high rate of CO₂ emission and noise pollution are common with the commercial sectors to cover the energy supply gap in sub-Saharan Africa. With the weaker value of sub-Saharan African currencies, the aggregate cost of

generators are higher than grid power prices. Businesses operating in sub-Saharan Africa have higher operational cost than those in the OECD countries. Energy considerably consume a larger portion of incomes of households and industries in Africa. So, has human capital significantly influenced industrial output in the selected countries under study? The broad objective of this study is to implicitly investigate the effects of energy consumption on human development and industrial sector performance in selected sub-Saharan Africa and OECD countries.

Review of related literature

Previous literature has reported fewer correlations between human development and energy consumption; industrial sector performance and energy consumption; and human development and industrial sector performance in the selected sub-Saharan Africa and OECD countries. The study carried out by Sarkodie and Adams (2020) concluded that countries with higher level of energy consumption per capita attain higher rank of economic activities. The study of Dai et al. (2022) revealed that life is better as more energy is consumed, especially in the form of electricity. The study of Bjornlund et al. (2020) revealed that energy consumption is a major element for an improved welfare in sub-Saharan African and OECD countries. The study of Kruk et al. (2018) revealed that energy consumption is capable of improving health, education and other economic and social benefits to mankind. Gradín and Wu (2020) employed the Gini Coefficient, Theil Index, and the Lorentz Curve to demonstrate the energy consumption inequality among the low, middle- and high-income countries. The study of Zheng and Wang (2022) measured the impact of renewable energy consumption on Human Development Index (HDI) in 28 OECD countries using a simultaneous equation system approach and describes the interrelations between renewable energy and pollution emissions and found that renewable energy, human and physical capital are important determinants influencing sustainable development.

In their research Smith et al. (2013) discovered that the efficient utilization of the available energy sources has added great value to human welfare and industrial performance in the world at large. This is in consonance with the findings of Broadberry and Gardner (2022) that a direct relationship exist between government expenditure on education, health and the level of productivity in sub-Saharan Africa. On the contrary, the study of Manasseh et al. (2022) revealed that government capital expenditure is inversely related to growth, and government recurrent expenditure is positively related to growth in sub-Saharan Africa countries. The findings from the study conducted by Hassan et al. (2022) show that health and education are

salient factors of human development but the health sector suffers from inadequate funding than education in sub-Saharan Africa's region. The findings from the study of Nnyanzi and Kilimani (2018) show that schooling, stock of physical capital and health exhibited a positive relationship while tertiary and secondary enrolment were inversely related with growth in selected sub-Saharan African countries. The findings from the study of Akinlo and Oyeleke (2020) revealed a strong and significant relationship between human development and sub-Saharan Africa economies. Conversely, the study carried out by Wang et al. (2021) revealed that no causality exist between investment in human development and sub-Saharan African economic development. The study recommended an increase in budgetary percentage to the health and education sectors with the provision of basic and related infrastructure to further boost human development in Malawi. Husnain et al. (2022) examined the relationship between energy consumption and gross domestic product of South Africa and found the existence of a bi-directional causality between gross domestic product and electricity consumption. Similarly, Olarinde and Adeniran (2018) examined the relationship between energy consumption and real output in Nigeria and their findings revealed a long-run relationship between the usage of electricity power and Nigeria's economic growth.

The empirical research carried out by Filimonova et al. (2021) analyzed the long-run relationship among energy consumption in households and industries; and net energy imports and primary energy production. The results revealed causality between all energy variables and real Gross Domestic Product (GDP) growth. Qualitatively analyzing data on Gross Domestic Product (GDP) and energy consumption using the environmental Kuznets curve. Gielen et al. (2019) reported that energy use is related to most aspects of human development including nutrition, education, health, clean and portable water, wealth, infrastructure, etc. Looking at the effects of energy consumption and poverty reduction in 12 African countries, the findings from the study of Ashagidigbi et al. (2020) show the existence of an inverse relationship between energy consumption and the general poverty level. This finding stressed the importance of the consumption of energy, political stability and capital stock as veritable factors in alleviating poverty in the 12 African countries. The study carried out by Keji (2021) on the effects of human capital development on economic growth in Nigeria, adopted a bounds test approach and finds a long-run relationship between human capital development and economic growth in Nigeria. The study of Rajaguru and Khan (2021) examined the effects of energy consumption on human development in the OECD countries and found

a negative relationship between primary schooling and energy intensity.

Human development is a multidimensional concept. The three variables used by United Nations (UN) in Human Development Index (HDI) constitutes the key dimensions of human development. These key dimensions are: a long and healthy life, being knowledgeable and have a decent standard of living. When these key dimensions are made available and accessible, progress and improvement opportunities in other areas of human life will also grow (Behera et al. 2022). However, in more recent times, substantial progress have been made to adequately capture a more realistic picture of the elements of human development which include enhanced educational attainment, improved primary health care delivery systems, standard and balanced nutrition, treated safety nets that protect the most vulnerable in the society, modern medicines and therapy, vaccination and immunization programs amongst others (Behera et al. 2022). It is sacrosanct that human development is a crucial aspect of economic growth and embraces investment in people and energy in general. This is because human development is a function of energy consumption. This becomes relevant in the light of constructing a more equitable framework that is required not only for alleviating poverty, but for the nurturing of an enterprising, creative and competitive human capital that are capable of influencing growth in a positive way (Kabeyi and Olanrewaju 2022). Furthermore, human development has been defined as the process of enlarging people's opportunities and freedom and improving their well-being. Thus, human development is about the real freedom the ordinary people have to decide who to be, what to do and how to live. A conducive atmosphere that promotes growth and development is a pre-requisite for human development in every economy. Human development involves a process where the people have equal opportunities to the resources and basic amenities of their nation and positive effects on their well-being that is sustained over a long period of time (Behera et al. 2022).

Literature evaluation

Many studies have examined issues relating to the relationship between energy consumption and human development, but a very few or none have captured the comparative study on the tri-directional linkages between energy consumption and human development; energy consumption and industrial output; and human development and industrial output, in the selected sub-Saharan Africa and Organization for Economic Cooperation and Development (OECD) countries. For instance, the study carried out by Wang et al. (2022) on the effect of energy consumption and human capital on

economic growth: an exploration of oil exporting and developed countries, employed the Generalized Method of Moment (GMM) and found that energy consumption supports higher growth, and education and health capital significantly affect growth. As a gap the study did not show how renewable energy consumption influences human development and industrial output in the selected countries.

A similar comparative analysis was carried out by Amna Intisar et al. (2020) on the effects of foreign trade, energy consumption and human capital on Gross Domestic Product (GDP) in several candidate developed countries and developing countries. Their study revealed that energy consumption, imports, exports and labour are positively related to, and significantly influenced, changes in output. As a gap the study did not capture the combined effects of renewable energy consumption and human development on output.

Furthermore, the causality test of the study of Pablo-Romero and Sánchez-Braza (2015) on productive energy use and economic growth: energy, physical and human capital relationships revealed the existence of a long-run relationship among GDP, capital stock, labour (level of employment) and total energy consumption. The study did not capture the interrelationships among relevant variables that influence output like renewable energy and labour.

Theoretical framework

This research expands the models of the Endogenous growth theory in some regards. The theory is distinguished from the neoclassical theory of growth by emphasizing that growth is an endogenous outcome of an economic system and not the results of forces that are exogenous (Ucak 2015). These endogenous factors include innovation, human development and investment capital. Hence, improvement in productivity can be tied directly to faster innovation and more investment in human and allied capital. The theory advocates for government and private sector institutions to nurture innovation initiatives and offer incentives for individual and businesses to be more creative, such as Research and Development (R & D).

The convergence theory postulated that developing countries will catch up with developed countries in the long run, but today the New Growth Theory (Endogenous Theory) explains why instead of catching up with the developed countries, these countries are moving away from developing countries in terms of development (Paprotny 2021). According to the New Growth Theory, the developed countries did invest not only on labour and capital for optimal output but also on Research and Development (R & D) and human capital development, through education, good health, etc.

The specified models used in this research are variants from the Endogenous Growth Model by the inclusion of Total Primary Energy Consumption (TPEC), Energy Consumption Per Capita (ECPA) and Industrial Output (IND) as explanatory variables while the endogenous variable is the Human Development Index (HDI).

Hence, the New Growth Theory is specified as:

$$Y = b_0 + b_1L + b_2K + b_3IE + b_4IH + b_5INFR + b_6TPEC + b_7ECPA + b_8IND + u_t$$

Where L=Labour; K= Capital; IE=Investment in Education; IH=Investment in Health; INFR= Investment in Infrastructure; u_t = error term.

As a vacuum, the New Growth Theory neglects the functions of energy consumption and industrial output which this study adequately captures. This is because it is expected that the quality of energy consumption, especially electricity and industrial output are to be positively related to the quality of human development in sub-Saharan Africa and OECD countries.

In consonance with the New Growth Theory, data from the International Energy Statistics reveals that the gap between Africa and the developed world is getting wider when it comes to affordable, reliable and efficient energy supply and industrial output (Lattacher et al. 2021). This widening gap is also distinct in human quality of both regions. Most industries in sub-Saharan African countries rely on a mix of fossil fuels, such as coal, natural gas and crude oil, and biomass, while industries in the OECD countries rely on renewable sources like wind, hydro, geothermal and solar, which are more reliable, efficient and environmental friendly.

Materials and methods

This study adopted the ex post facto research design. The panel data (1990 to 2022) employed covered eleven (11) sub-Saharan Africa and ten (10) OECD countries in a balanced panel data structure. It contains both time-varying and time-constant entity characteristics. The selection of both cross-section and time dimension of the panel data was determined by the data availability and consistency of the series. The study employed the Panel Ordinary Least Squares (OLS) to analyze the data, and the Augmented Dickey Fuller (ADF) unit root test was used to test the stationarity of the data. The Johansen cointegration test was used to justify the long-run relationship among all included variables. The Fully Modified Ordinary Least Square (FMOLS) was used to analyze the level of non-exogeneity and serial correlation in the models. The selected OECD countries include Australia, Austria, Poland, France, Iceland, Italy, Japan, Luxembourg, Poland and Spain. The selected Sub-Saharan Africa countries include Benin Republic, Congo (Brazzaville), Cote d' Ivoire, Ethiopia, Gabon, Ghana, Guinea Bissau, Kenya, Mozambique, Nigeria and Niger Republic. These

selected countries cut across low-income, lower-middle income, upper-middle income and high-income countries (Pramesh et al. 2022).

Research hypotheses

The relationship that exists between energy consumption, human development and industrial sector performance can be tested with the use of the following hypotheses:

H₀₁: There is significant relationship between energy consumption and human development in the selected sub-Saharan African and OECD countries.

H₀₂: There is significant relationship between industrial sector performance and human development in the selected sub-Saharan African and OECD countries.

H₀₃: There is significant relationship between industrial sector performance and energy consumption in the selected sub-Saharan African and OECD countries.

Definition and measurement of variables

The endogenous and exogenous variables employed in this study are defined and measured in Table 1.

Description of expected relationships

This sub-section previews the relationship of the variables generated from the proposed data sources as

Table 1. Variables and expected relationship.

Models	Dependent Variables	Explanatory Variables	Expected Relationship
Model 1 $HDI = f(labour_{it}, capital_{it}, TPEC_{it})$	HDI	Labour force participation rate, Gross Fixed Capital Formation and Total Primary Energy Consumption	Labour (positive relationship) Capital (positive relationship) TPEC (positive relationship)
Model 2 $HDI = f(labour_{it}, capital_{it}, ECPA_t)$	HDI	Labour force participation rate, Gross Fixed Capital Formation and Energy Consumption per capita	Labour (positive relationship) Capital (positive relationship) ECPA (positive relationship)
Model 3 $IND = f(labour_{it}, capital_{it}, HDI_t)$	IND	Labour force participation rate, Gross Fixed Capital Formation and Human Development Index	Labour (positive relationship) Capital (positive relationship) HDI (positive relationship)
Model 4 $IND = f(labour_{it}, capital_{it}, ECPA_t)$	IND	Labour force participation rate, Gross Fixed Capital Formation and Energy Consumption per capita	Labour (positive relationship) Capital (positive relationship) ECPA (positive relationship)

Source: Authors' compilation.

mentioned. Table 2 presents a description for the dependent and explanatory variables and their expected relationships.

Models specification

Using four models the effects of energy consumption on human capital development can be functionally expressed as:

Model 1: human capital development - total primary energy consumption

$$HDI_{it} = f(Labour_{it}, Capital_{it}, TPEC_{it}) \quad (1)$$

Transforming Equation 1 into its explicit form;

$$HDI_{it} = \alpha_0 + \alpha_1 Labour_{it} + \alpha_2 Capital_{it} + \alpha_3 TPEC_{it} + \varepsilon_t \quad (2)$$

Model 2: human capital development - energy consumption per capita

$$HDI_{it} = f(Labour_{it}, Capital_{it}, ECPA_{it}) \quad (3)$$

Transforming Equation 3 into its explicit form;

$$HDI_{it} = \beta_0 + \beta_1 Labour_{it} + \beta_2 Capital_{it} + \beta_3 ECPA_{it} + \varepsilon_t \quad (4)$$

Model 3: industrial sector performance - human capital development

$$IND_{it} = f(labour_{it}, Capital_{it}, HDI_{it}) \quad (5)$$

Transforming Equation 5 into its explicit form;

$$IND_{it} = \beta_0 + \beta_1 Labour_{it} + \beta_2 Capital_{it} + \beta_3 HDI_{it} + \varepsilon_i \quad (6)$$

Model 4: industrial sector performance – energy consumption per capita

$$IND_{it} = f(labour_{it}, Capital_{it}, ECPA_{it}) \quad (7)$$

Transforming Equation 7 into its explicit form;

$$IND_{it} = \beta_0 + \beta_1 Labour_{it} + \beta_2 Capital_{it} + \beta_3 ECPA_{it} + \varepsilon_i \quad (8)$$

Where:

HDI_{it} = Human Development Index (Adopted as a composite statistic of education, life expectancy at birth, and living standard indicators with each dimension ranging between 0 and 1.)

$TPEC_{it}$ = Total primary Energy Consumption (Primary energy consumption constitutes energy at their raw state yet to pass through any transformation process.

Table 2. Definition and measurement of variables.

S/N	Variables	Definition of Variables	Measurement of Variables
1	Human Development Index (HDI)	The Human Development Index is a composite statistic that measures life expectancy, living standard and literacy level (education). This statistic is used to measure the well-being of humans in both Sub-saharan Africa and OECD countries. Unlike the traditional Gross National Income (GNI), the HDI reflects the quality of human life and provides a detailed evaluation of human development in health, quality education and a decent living standard.	The living standard is measured by GNI per capita. The HDI is measured via the geometric mean of life expectancy, education and living standard. Human health is measured by life expectancy at birth, education is measured via the average number of school years completed adults as well as the number of school years expected to be completed by children and a decent standard of living is measured by the GNI per capita which provides an estimate of the annual national income per man in the two regions.
2	Gross Fixed Capital Formation (GFCF)	Gross fixed capital formation constitute the acquisition of assets for production and private use minus disposals. GFCF includes additions to the value of non-produced assets realised by producers or institutional units.	Gross Fixed Capital Formation measures the total assets acquired for production purpose after deducting disposal of fixed assets plus some additions to the value of non-productive assets. GFCF measures resident producers' investments deducting disposals in fixed assets. Thus, GFCF measures the value of acquisition of new or existing fixed assets by the industrial sectors, governments and households in both regions, minus disposals of fixed assets.
3	Industrial Output (IND)	Industrial output are the total production from industrial establishments in the selected sub-Saharan African and OECD countries over the period of this study.	Industrial output measures the output of the industrial sectors such as mining, manufacturing and electricity. Industrial output is an indicator measured in an index based on the period under study, and it expresses changes in the volume of production in the selected sub-Saharan African and OECD countries.
4	Labour Force Participation Rate (LAB)	This is measured by dividing the total labour force by the total working- age population from 15 years to 64 years.	This index is broken to different age groups and it is measured as a percentage of the different age group.
5	Total Primary Energy Consumption (TPEC)	Total primary energy consumption involves consumption from the energy sector itself and losses from the transformation and distribution process of energy and the final consumption by end users.	Total primary energy consumption measures the total renewable energy demand in the selected Sub-saharan African and OECD countries in Tonne of oil equivalent (toe)
6	Energy Consumption per capita (ECPA)	Energy consumption per capita describes how much energy is used by each person in selected sub-Saharan Africa and OECD countries during the period under study.	Energy consumption per capita is measured in Kilowatt (kWh) per person per year. It measures the total amount of non-renewable energy consumed, divided by the total population of the selected countries under study.

Source: Authors' Compilation from IEA, 2022.

IND_{it} = Industrial Output

$ECPA_{it}$ = Energy Consumption per capita

$Labour_{it}$ = Labour (proxy by Labour force participation rate)

$Capital_{it}$ = Capital Stock (proxy by Gross fixed capital formation)

Methods of data analysis

The Augmented Dickey Fuller (ADF) test was employed to test for the stationarity of the data. The co-integration test was used to test the long-run relationship of the variables. The granger causality test was also employed to test whether the series are useful for forecasting one another. Co-integration analysis was done for the panel of the selected Sub-Saharan and Organization for Economic Co-operation and Development (OECD) countries, being narrowed down to country specific time series for each country to clearly depict the causal relationship between human development, industrial sector performance and energy consumption in both regions.

Data presentation and analysis

Descriptive statistics

With respect to each variable, the descriptive statistics clearly analyze the features of the data. Running descriptive statistics on our data set is very crucial before the process of conducting inferential statistics. This helps to screen and clean our data which makes us sure that the data meets the assumptions required for a more robust statistical test. This include the mean, maximum value, median, minimum value, skewness, standard deviation, kurtosis, Jarque-Bera and probability.

Table 3 presents the descriptive statistics for the full sample as well as for OECD and sub-Saharan sub-regions.

The mean of human development is significantly different across OECD and sub-Saharan countries as shown in the mean values of (0.840) for OECD and (0.435) for sub-Saharan countries, representing more than half in human development improvement within the period under study. This reflects the fact that there is improvement in human development in OECD sub-region as compared to sub-Saharan sub-region. For

instance, data released by the World Bank (2018) revealed that per capita GDP (an indicator for HDI) of sub-Saharan Africa in 2018 was \$1,585.8US while that of the OECD countries was \$2804.2US. On average 61% of the adults in sub-Saharan Africa can read and write with understanding, one of the lowest adult literacy rates in the world. The data revealed that the absolute number of adult illiterates continue to rise because of high population growth, from 133 million in 1990 to around 144 million in 2018, which unmatched the poor, inadequate and moribund infrastructural facilities, especially in the educational and health sectors of sub-Saharan African countries. More than 60% of the illiterates are women, the data revealed. Furthermore, measuring the HDI through urbanization rate in the regions, data from the OECD iLibrary show that 39.54% of sub-Saharan Africa total population lived in urban areas and cities in 2018 while two-third (about 67%) of the countries of OECD population lived in urban areas. Measuring the Human Development Index (HDI) with life expectancy at birth (year of age), data revealed that sub-Saharan Africa is by far the region of the world with the highest level of mortality. Overall life expectancy at birth is 46 years in sub-Saharan Africa, whereas it is 79 years on average, in OECD countries. Table 3 further depicts minimum and maximum values of 0.578 and 0.852 for OECD countries respectively and 0.197 and 0.722 for sub-Saharan Africa respectively, for HDI. These values show that there are no outliers in the data and no data-entry error. A comparison of both values revealed that the data are normally distributed. The standard deviation values of 0.068 and 0.111 for OECD and sub-Saharan Africa, respectively, explained that the data are normally distributed from the mean of 0.840 and 0.435 respectively.

According to the Labour Market Statistics (2018), the labour force participation rate is calculated as the labour force divided by the total working-age population. The working-age population refers to people aged 15 to 64. This indicator is broken down by age group, and it is measured as a percentage of each age group. Average level of labour participation rate also varies significantly across the two sub-regions with

mean values of 46.599 for OECD countries and 51.633 for sub-Saharan African countries. This implies that the percentage of the working population to total population in OECD sub-region is about 46.6% as against 51.6% in sub-Saharan countries. Data shows that the average labour participation rate across sub-Saharan Africa is relatively higher with 79% on the average. This is because majority of the rising population of sub-Saharan African countries are actively engage in primary production of basic goods and services, especially in the rural communities. This statistic is a bit lower in OECD countries under study due to high level of automation and capital-intensive method of production adopted in the region. The minimum and maximum values from Table 3 are 14.599 and a maximum value of 85.353 respectively. These values show that there are no outliers in the data set and no data-entry error. A comparison of both values shows that the data are normally distributed. The standard deviation values of 14.599 and 85.353 for OECD and 13.209 and 87.730 for sub-Saharan Africa respectively, show that the data are normally distributed from the means of 46.599 and 51.633 for OECD and sub-Saharan Africa respectively.

The mean values for Capital Formation (CAP) of 23,269 and 21,350 for OECD countries and sub-Saharan Africa respectively, show that OECD countries has more capital accumulation for investment as compared to Sub-Saharan countries which thus enhances growth. This is in consonance with the data released by the World Bank via her World Data Atlas in 2018, that Gross Fixed Capital Formation (current US\$) of sub-Saharan Africa increased from 79,522 million in 1999 to about 362,959 million in 2018, growing at an average annual rate of 8.81% while data for the OECD member countries stands at 690,110 million in 2018. The minimum and maximum values from Table 3 are 9.718 and 43.672 respectively, for OECD countries and 0.000 and 73.900 respectively, for sub-Saharan Africa countries. These values show that there are no outliers in the data set and no data-entry error. A comparison of both values shows that the data are normally distributed. The standard deviation values of 4.202 and

Table 3. Summary of descriptive statistics for OECD and sub-Saharan Africa sub-regions.

Variables	Sample	Obs.	Mean	Std. Dev	Statistics (Non-log values)		Skewness	Kurtosis	Jarque-Bera	Prob.
					Minimum	Maximum				
Human Development Index (HDI)	OECD	986	0.840	0.068	0.578	0.852	-0.886	3.616	144.767	0.000
	Sub-Saharan	899	0.435	0.111	0.197	0.722	0.307	2.593	391.318	0.000
Labour (LAB)	OECD	986	46.599	14.599	14.599	85.353	0.055	2.320	19.501	0.000
	Sub-Saharan	899	51.633	16.409	13.209	87.730	-0.273	2.400	24.689	0.000
Capital (CAP)	OECD	986	23.269	4.202	9.718	43.672	0.733	5.144	277.254	0.000
	Sub-Saharan	899	21.350	9.400	0.000	73.900	1.115	6.079	541.642	0.000
Total Primary Energy Consumption (TPEC)	OECD	986	68.503	96.892	1.700	530.896	2.742	11.583	4262.667	0.000
	Sub-Saharan	899	5.599	20.454	0.014	144.135	5.269	30.429	32344.53	0.000
Energy Consumption per capita (ECPA)	OECD	986	4.005	2.284	0.922	18.001	2.691	14.508	6631.858	0.000
	Sub-Saharan	899	10.084	7.724	2.056	57.988	2.487	11.237	3468.825	0.000
Industrial Output (IND)	OECD	986	15.777	4.580	4.766	45.527	0.337	4.763	146.550	0.000
	Sub-Saharan	899	9.293	4.563	0.000	33.345	0.919	4.680	232.475	0.000

Source: Authors' Computation.

9.400 for OECD and sub-Saharan Africa respectively show that the data are normally distributed from the means of 23.269 and 21.350 respectively.

Data from the World Bank (2018) show that due to the high rate of industrialization in the OECD countries, primary energy consumption in the region is approximately \$1040 million US in 2018. This is in consonance with results from Table 3. Average level of primary energy consumption is significantly higher in OECD countries as compared to sub-Saharan African countries, and as revealed in their respective mean values of (68.503) and (5.599) respectively. However, energy consumption per capita is lower in OECD countries compared to countries within sub-Saharan African sub-region as shown in their mean values of (4.005) and (10.084) respectively. The mean of Energy Consumption Per Capita for sub-Saharan African countries is more than double that of OECD countries which is 10.084 and 4.005 respectively. Measured in KiloWatt (KW/h), Energy Consumption Per Capita for sub-Saharan Africa was 486 KW/h in 2014, while it stood at 201 KW/h for OECD countries. This disparity stems from the fact that OECD countries employ more of renewable energy like solar and wind power, while sub-Saharan Africa employ more of non-renewable sources of energy like coal, oil and gas, and fossil fuels, especially in rural communities.

Industrial output was measured in terms of output of industrial establishments and cover sectors such as mining, manufacturing, electricity, gas and steam and air-conditioning. This indicator was measured in an index based on a reference period that expresses change in the volume of production output. The mean value for OECD countries stood at 15.777 as against 9.293 for sub-Saharan Africa. This explains why the average level of industrial production is significantly higher in OECD countries when compared to countries within the sub-Saharan African sub-region. Despite a higher proportion of labour participation rate in sub-Saharan Africa countries, industrial output remains lower when compared to OECD countries. The implication is that higher proportion of the active labour force is engaged in primary production.

The skewness measures the asymmetry of the distribution of the series around the mean. From the analysis above, ECPA, HDI, IND and TPEC for OECD countries and sub-Saharan African countries are normally skewed and are distributed around the mean. The kurtosis value for HDI is 2.593 for sub-Saharan African and 3.616 for OECD countries, LAB is 2.320 for sub-Saharan African and 2.400 for OECD countries and IND is 3.616 for OECD and 4.763 for sub-Saharan African countries. These are normally distributed because their values are close to 3. The probability values are lower than the respective Jarque-Bera values, which mean that all the variables are normally distributed.

Panel unit root test

The panel unit root tests; results are reported for in Tables 4, 5, 6 and 7 which represent unit root results at level and at first difference for the selected countries in OECD and sub-Saharan sub-region.

The unit root test from Table 4 suggests that at 5% significance level, industrial production was non-stationary at all levels of test (Levin et al. 2002), Breitung, IPS, ADF (Fisher type) and PP (Fisher type), which implies that the null hypothesis of a unit root cannot be rejected at level. For other variables such as human development index (HDI), Labour (LAB), Capital (CAP), Total primary energy consumption (TPEC) and energy consumption per capita (ECPA), we reject the null hypothesis of no unit root test, implying that the afore-mentioned variables are stationary at level. Based on the conclusion of the unit root tests at level and the non-stationarity of industrial output, the first difference unit root test was conducted for the OECD sub-region.

The unit root tests are presented in Table 5 after first difference. The tests aimed to establish the presence of another unit roots, so as to determine the integration order of the data. The results revealed the series are stationary and are integrated at order one.

Table 4. Summary of unit root test (at levels).

Test	OECD sub-region					
	HDI	LAB	CAP	TPEC	ECPA	IND
Levin, Lin & Chu (<i>t</i> -statistics)	200.532 (0.000)**	124.326 (0.000)**	139.954 (0.000)**	388.915 (0.000)**	88.622 (0.047)**	65.030 (0.579)
Breitung (<i>t</i> -statistics)	3.911 (1.000)	0.818 (0.793)	-4.332 (0.000)**	0.876 (0.809)	2.552 (0.994)	4.068 (1.000)
Im, Pesaran and Shin (<i>W</i> -statistics)	0.698 (0.757)	-0.291 (0.385)	-4.170 (0.000)**	-1.952 (0.025)**	0.089 (0.535)	2.989 (1.000)
ADF-Fisher (χ^2)	87.901 (0.052)***	90.244 (0.036)**	123.946 (0.000)**	146.326 (0.000)**	99.864 (0.007)**	56.941 (0.828)
PP-Fisher (χ^2)	200.532 (0.000)**	124.326 (0.000)**	139.954 (0.000)**	388.915 (0.000)**	88.622 (0.047)**	65.030 (0.579)

** (***) denote statistical significance at the 5% (10%) level. The optimal lag length was automatically selected using the Akaike Information Criterion. Source: Authors' Computation.

Table 5. Summary of unit root test (at first difference).

Test	OECD sub-region					
	HDI	LAB	CAP	TPEC	ECPA	IND
Levin, Lin & Chu (<i>t</i> -statistics)	-10.242 (0.000)**	-5.149 (0.000)**	-11.724 (0.000)**	-7.811 (0.000)**	-8.151 (0.000)**	-9.941 (0.000)**
Breitung (<i>t</i> -statistics)	-7.206 (0.000)**	-10.404 (0.000)**	-11.984 (0.000)**	-8.527 (0.000)**	-9.078 (0.000)**	-10.801 (0.000)**
Im, Pesaran and Shin (<i>W</i> -statistics)	-11.403 (0.000)**	-9.508 (0.000)**	-14.127 (0.000)**	-12.942 (0.000)**	-10.831 (0.000)**	-9.427 (0.000)**
ADF-Fisher (χ^2)	252.597 (0.000)**	214.756 (0.000)**	309.234 (0.000)**	288.888 (0.000)**	241.845 (0.000)**	217.198 (0.000)**
PP-Fisher (χ^2)	492.793 (0.000)**	933.414 (0.000)**	742.874 (0.000)**	1373.36 (0.000)**	773.540 (0.000)**	371.531 (0.000)**

Source: Authors' Computation. ** (***) denote, at the 5% (10%) level, statistical significance. The optimal lag length was selected automatically using the Akaike Information Criterion.

Table 6. Summary of unit root test (at levels).

Test	Sub-Saharan Africa sub-region					
	HDI	LAB	CAP	TPEC	ECPA	IND
Levin, Lin & Chu (<i>t</i> -statistics)	-1.947 (0.025)**	-3.419 (0.000)**	-1.433 (0.075)**	3.213 (0.999)	-1.119 (0.131)	-0.252 (0.400)
Breitung (<i>t</i> -statistics)	4.178 (1.000)	2.343 (0.990)	-4.075 (0.000)**	9.547 (1.000)	2.364 (0.991)	1.134 (0.871)
Im, Pesaran and Shin (<i>W</i> -statistics)	2.552 (0.994)	0.158 (0.563)	-3.147 (0.000)**	3.178 (0.993)	-0.888 (0.187)	0.656 (0.774)
ADF-Fisher (χ^2)	54.914 (0.726)	79.920 (0.062)**	101.197 (0.001)**	57.840 (0.626)	106.801 (0.000)**	68.210 (0.274)
PP-Fisher (χ^2)	51.150 (0.835)	53.702 (0.764)	138.577 (0.000)**	70.835 (0.206)	120.589 (0.000)**	58.595 (0.589)

Source: Authors' Computation. ** (***) denote, at the 5% (10%) level, statistical significance. The optimal lag length was automatically selected with the Akaike Information Criterion.

Table 7. Summary of unit root test (at first difference).

Test	Sub-Saharan Africa sub-region					
	HDI	LAB	CAP	TPEC	ECPA	IND
Levin, Lin & Chu (<i>t</i> -statistics)	-1.768 (0.038)**	-1.613 (0.053)**	-13.842 (0.000)**	-4.704 (0.000)**	-12.768 (0.000)**	-11.328 (0.000)**
Breitung (<i>t</i> -statistics)	-2.714 (0.003)**	-2.747 (0.003)**	-11.794 (0.000)**	1.426 (0.923)	-12.277 (0.000)**	-12.068 (0.000)**
Im, Pesaran and Shin (<i>W</i> -statistics)	-3.255 (0.000)**	-2.324 (0.010)**	-15.737 (0.000)**	-12.109 (0.000)**	-11.993 (0.000)**	-13.339 (0.000)**
ADF-Fisher (χ^2)	116.912 (0.000)**	88.572 (0.015)**	327.921 (0.000)**	261.909 (0.000)**	252.386 (0.000)**	280.898 (0.000)**
PP-Fisher (χ^2)	488.415 (0.000)**	123.094 (0.015)**	1657.76 (0.000)**	704.112 (0.000)**	464.756 (0.000)**	1474.08 (0.000)**

Source: Authors' Computation. ** (***) denote, at the 5% (10%) level, statistical significance. The optimal lag length was automatically selected using the Akaike Information Criterion.

The unit root results from Table 6 suggests that at 5% level of significance, industrial production and total primary energy consumption were non-stationary at all levels of test (Levin et al. 2002), Breitung, IPS, ADF (Fisher type) and PP (Fisher type), which implies that the null hypothesis of a unit root cannot be rejected at level. For other variables such as HDI, LAB, CAP, TPEC and ECPA, we reject the no unit root null hypothesis test implying the aforementioned variables are stationary at level. Based on the conclusion of the unit root tests at level and the non-stationarity of industrial output, the first difference unit root test was conducted for the Sub-Saharan sub-region.

The unit roots test from Table 7 show the first difference of the series which established the presence

of additional unit roots and determine the order of integration of the data. The results show the difference series are stationary and integrated at order one, I (1) for sub-Saharan sub-region.

Panel cointegration test

Having established, through the panel unit root test, that Industrial Output (IND), Human Development Index (HDI), Labour (LAB), Capital (CAP), Total Primary Energy Consumption (TPEC) and Energy Consumption Per Capita (ECPA), for both regions, are stationary after first difference, i.e. integrated of the same order, I (1), a test for a long-run relationship between the variables is required.

The panel cointegration estimation results are presented in [Tables 7 and Table 8](#). The null hypothesis of no cointegration within dimension is rejected which includes the panel v-statistics, panel rho-statistic, panel PP and ADF-statistic and between dimension which includes group rho-statistic, group PP-statistic and ADF statistic.

In [Table 7](#) the relationship between Total Primary Energy Consumption (TPEC) and Human Development Index (HDI) for both OECD and sub-Saharan sub-regions (HDI versus TPEC) allows us to reject the null hypothesis of no cointegration despite the possible existence of cross-country dependence. This result further implies that there is a long-run relationship between the two variables in both regions.

The relationship between Human Development Index (HDI) and Energy Consumption Per Capita (ECPA) for both sub-regions, (HDI versus ECPA) also allows us to reject the null hypothesis of no

cointegration, which implies that a long-run association exists between HDI and ECPA.

From [Table 8](#), the relationship between Industrial Sector Performance (IND) and Human Development Index (HDI) for both sub-regions (IND versus HDI) allows us to reject the null hypothesis of no cointegration. This long-run relationship implies that there is a long-run association between both variables in both sub-regions.

A long-run relationship also is found to exist between IND and ECPA for both sub-regions for the period under review.

Long-run relationship estimation

The establishment of the existence of a long-run relationship between Human Development Index (HDI) and Total Primary Energy Consumption (TPEC); Human Development Index (HDI) and Energy

Table 8. Pedroni panel cointegration test.

	OECD sub-region		Sub-Saharan sub-region	
	Statistic	p-value	Statistic	p-value
Model 1: Human Development versus Total Primary Energy Consumption (HDI vs TPEC)				
Within-dimension				
Panel v-statistic	24.963**	0.000	7.384**	0.000
Panel rho-statistic	1.513	0.934	4.391**	0.000
Panel PP-statistic	-1.501***	0.066	3.030**	0.000
Panel ADF-statistic	-2.121**	0.017	2.826**	0.006
Between-dimension				
Group rho-statistic	3.681	0.999	5.887**	0.000
Group PP-statistic	-0.352	0.362	3.818**	0.000
Group ADF-statistic	-2.973**	0.001	1.060	0.855
Model 2: Human Development versus Energy consumption per capita (HDI vs ECPA)				
Within Dimension				
Panel v-statistic	33.154**	0.000	8.880**	0.000
Panel rho-statistic	1.067	0.857	4.468**	0.000
Panel PP-statistic	-1.990**	0.023	3.298***	0.009
Panel ADF-statistic	5.717	0.000**	2.581***	0.095
Between – dimension				
Group rho-statistic	3.048***	0.008	5.766**	0.000
Group PP-statistic	-1.109	0.133	4.119**	0.000
Group ADF-statistic	3.696***	0.009	2.262***	0.088
Model 3: Industrial sector performance versus Human Development (IND vs HDI)				
Within-dimension				
Panel v-statistic	2.442***	0.007	-1.476	0.930
Panel rho-statistic	-1.482***	0.069	2.974***	0.008
Panel PP-statistic	-3.540**	0.000	-0.191	0.424
Panel ADF-statistic	2.507**	0.003	-2.717**	0.003
Between-dimension				
Group rho-statistic	3.010**	0.000	3.537**	0.000
Group PP-statistic	-0.051	0.479	-3.034**	0.001
Group ADF-statistic	0.736	0.769	-3.404**	0.000
Model 4: Industrial sector performance versus Energy consumption per capita (IND vs ECPA)				
Within-dimension				
Panel v-statistic	2.927**	0.001	-0.802	0.788
Panel rho-statistic	-1.018	0.154	0.559	0.712
Panel PP-statistic	-4.999**	0.000	-2.975**	0.001
Panel ADF-statistic	-3.704**	0.000	-4.678**	0.000
Between-dimension				
Group rho-statistic	3.926**	0.000	3.398**	0.000
Group PP-statistic	0.706	0.759	-1.255	0.104
Group ADF-statistic	-1.879**	0.030	-1.943**	0.026

** (***) denote statistical significance at the 5% (10%) level. The optimal lag length was selected automatically using the Akaike Information Criterion

** (***) denote, at the 5% (10%), statistical significance level. The optimal lag length was automatically selected with the Akaike Information Criterion.

Consumption Per Capita (ECPA); Industrial Sector Performance (IND) and Human Development Index (HDI); and Industrial Sector Performance (IND) and Energy Consumption Per Capita (ECPA), for both OECD and sub-Saharan sub-regions qualifies this study to estimate the Fully Modified Ordinary Least Square (FMOLS) which can incorporate serial correlation and non-exogeneity. The FMOLS also offers efficient cointegration and consistent vectors estimation.

The estimates from Table 9, model 1 show that labour, capital and Total Primary Energy Consumption (TPEC) are statistically significant, at 5% level of significance, in explaining changes in the dependent variable – Human Development Index (HDI), in both regions. The coefficient 0.008 for TPEC for OECD sub-region implies that one million tonne of oil equivalent (Mtoe) increase in energy consumption causes 0.008-point increase in human development. In other words, a positive relationship exists between TPEC and HDI, in the OECD region.

With respect to sub-Saharan sub-region, a one million tonne of oil equivalent (Mtoe) increase in energy consumption triggers a 0.454-point increase in HDI. In other words, a positive relationship exist between TPEC and HDI in the selected sub-Saharan Africa region. Comparatively, the selected sub-Saharan African countries have higher TPEC to HDI development ratio than the selected OECD countries. The afore-stated results are in accordance with the studies of Hopewell et al. (2009) for 16 countries in Asia, Mata Pérez et al. (2019) for EU member countries and Nigeria (Maltby 2013). Also, the coefficient of 0.003 means a \$US1 capital formation increase leads to \$US0.003 significant increase in HDI for sub-Saharan African countries as compared to a \$US0.048 significant reduction in HDI for OECD countries.

The estimates from model 2 in the OECD sub-region revealed that the coefficient of ECPA is statistically significant at 5% significance level while labour and capital are statistically insignificant, in explaining changes in HDI. The coefficient of 0.164 for ECPA explains that a mega joule at Purchasing Power Parity (PPP) to GDP ratio rise in energy consumption causes a 0.164-unit rise in HDI in the selected OECD countries. On the contrary, a one mega joule at PPP to GDP ratio increase in ECPA causes a 0.0004-unit decline in HDI in the selected sub-Saharan African countries. The findings follow the studies of Hoang et al. (2021) for Tunisia, Hewitt et al. (2019) for New Zealand and Fawzy et al. (2020) for different income groups. Also, the coefficients of 0.007 and 0.005 increase in LAB and CAP, respectively, lead to a significant increase in HDI for sub-Saharan sub-region as compared to the estimated results for the selected OECD countries.

Furthermore, the estimates from model 3 in Table 9 focuses on the HDI effect on industrial sector performance in the selected OECD and sub-Saharan African countries. All the independent variables (LAB, CAP and HDI) predict a positive but insignificant outcome to industrial sector performance in the selected OECD countries. Similarly, LAB, CAP and HDI predict positive outcome, but with only LAB exhibiting significant effect on IND. This means that sub-Saharan sub-region is a labour-driven region. Therefore, improvement in labour participation rate enhances improvement in industrial sector performance (IND).

The estimates from model 4, show that Energy Consumption Per Capita (ECPA) is statistically significant in explaining changes in industrial sector performance (IND) in both OECD and sub-Saharan sub-regions.

Table 9. FMOLS estimation for OECD and sub-Saharan sub-region.

Variables	OECD sub-region		Sub-Saharan sub-region	
	Coefficient	t-statistic	Coefficient	t-statistic
Model 1: Human Development versus total primary energy consumption (HDI vs TPEC)				
LAB	0.059	2.918**	0.004	24.042**
CAP	-0.048	-2.367**	0.003	10.412**
TPEC	0.008	2.676**	0.454	11.505**
$HDI_{it} = a_1 labour_{it} + a_2 capital_{it} + a_3 TPEC_{it} + e_{it}$				
Model 2: Human Development versus Energy consumption per capita (HDI vs ECPA)				
LAB	0.037	1.403	0.007	15.139**
CAP	-0.028	-1.043	0.005	13.688**
ECPA	0.164	17.331**	-0.0004	-0.213
$HDI_{it} = \beta_1 labour_{it} + \beta_2 capital_{it} + \beta_3 ECPA_{it} + e_{it}$				
Model 3: Industrial sector performance versus Human Development (IND vs HDI)				
LAB	0.037	0.065	0.154	7.031**
CAP	0.353	0.617	0.011	0.577
HDI	1.616	1.322	1.362	0.576
$IND_{it} = \gamma_1 labour_{it} + \gamma_2 capital_{it} + \gamma_3 HDI_{it} + e_{it}$				
Model 4: Industrial sector performance versus Energy consumption per capita (IND vs ECPA)				
LAB	-0.450	-0.573	0.141	8.023**
CAP	0.724	0.913	-0.006	-0.348
ECPA	1.264	5.057**	0.408	3.508**
$IND_{it} = \lambda_1 labour_{it} + \lambda_2 capital_{it} + \lambda_3 ECPA_{it} + e_{it}$				

Source: Authors' Computation** indicates 5% significance level.

Specifically, as ECPA increases by 1%, IND increases by an average of 1.264% in OECD region and 0.408% in sub-Saharan African region.

These findings provide consistent evidence for positive and significant effects of ECPA on IND, as they are in line with the study of Elfaki et al. (2021).

Test for slope heterogeneity

Given our models with a large number of cross-sectional units N , and a large number of time periods T ,

$$HDI_{it} = \beta_0 + \beta_1 Labour_{it} + \beta_2 Capital_{it} + \beta_3 ECPA_{it} + \beta_4 IND_{it} + u_i \quad (9)$$

In this paper, we assume that the error term contains multifactor structures:

$$u_i = F\lambda_i + \varepsilon_i, i = 1, \dots, N, \quad (10)$$

We consider estimating the model (10) with factor structure (9) under the null and alternative hypotheses, respectively. Under the null hypothesis, we can estimate the common slope coefficient β by using the procedure in Chen and Yan (2023). Under the alternative, we employ the estimation procedure in Bai and Wierzbicki (2010). Given the number of common factors r , we minimize the least-squares objective function:

$$\ell(\beta_1, \dots, \beta_N, F, \Lambda) = \sum_{i=1}^N \|HDI_{it} - \beta_1 Labour_{it} - \beta_2 Capital_{it} - \beta_3 ECPA_{it} - \beta_4 IND_{it} - F\lambda_i\|^2 \quad (11)$$

subject to the constraints on the factors and its loadings. The number of common factors can be selected by the Cp criterion, proposed in Anon (2009). Thus, we can compare the restricted and unrestricted estimators of the slope coefficients.

To test slope homogeneity, we consider Swamy's test statistic. The test of slope homogeneity calculates the dispersion of individual slope estimates from a suitable pooled estimator (Poi 2003). In our setting, Swamy's test statistic applied to the slope coefficients can be written as:

$$\Gamma = \frac{T(\beta^\wedge - \beta^{-1}N)'(S^\wedge - 1/NL^\wedge)\Omega - 1(S^\wedge - 1/NL^\wedge)(\beta^\wedge - \beta^{-1}N) - Np}{\sqrt{2Np}} \quad (12)$$

where $\beta^\wedge' = (\beta^\wedge_1, \dots, \beta^\wedge_N)$, $\beta^{-1}N = (\beta^{-1}_1, \dots, \beta^{-1}_N)$, $\beta^{-1} = \sum_{i=1}^N \beta^\wedge_i/N$, and $\beta^\wedge_i$ are obtained by minimizing (11).

$S^\wedge$ is an $Np \times Np$ block diagonal matrix with ith block and

$L^\wedge$ is an $Np \times Np$ matrix with ij -th block $\hat{a}_{ij}$ with $\hat{a}_{ij} = \lambda^\wedge_i (\Lambda^\wedge, \Lambda^\wedge/N)^{-1} \lambda^\wedge_j$ and

Ω is the variance – covariance estimator of Ω

We can conclude that our test statistic Γ in (12) is asymptotically normal with $\hat{\mu}$ mean 0 and standard deviation 1, when the null hypothesis of slope homogeneity is satisfied. Therefore, we reject the

null hypothesis if the absolute value of our test statistic exceeds the critical value at α based on the normal distribution.

Granger causality test

To infer the causal relationships between the variables, a panel long-run model is estimated to perform the Granger-causality tests for the selected OECD and sub-Saharan African countries.

From Table 10, we find a unidirectional long-run Granger causality running from HDI to TPEC in the OECD sub-region at 5% significant level, while there was no causal relationship between HDI and TPEC in the sub-Saharan sub-region. The findings indicate that in the long run, improvement in HDI will trigger the demand for energy (TPEC) in the selected OECD countries.

From Table 11, we find a unidirectional long-run Granger causality running from HDI to TPEC in the selected OECD sub-region at 5% significant level, while in sub-Saharan sub-region, there was evidence of a unidirectional causal relationship between HDI and ECPA, running from ECPA to HDI at 5% significant level.

From Table 12, we find a unidirectional long-run Granger causality running from HDI to IND in the selected OECD and sub-Saharan African countries at 5% significant level, implying that HDI enhancement results in increasing productivity and industry value added.

From Table 13, we find a unidirectional long-run Granger causality running from ECPA to IND in the selected OECD sub-region at 5% significant level, while there was no causal relationship between ECPA and HDI in selected sub-Saharan African countries. The evidence of a unidirectional causality indicates that changes in ECPA explains changes in IND. This is an expected consequence as the industrial sector is the biggest consumer of energy in both sub-regions. Thus, a shortfall in the supply of energy will certainly result in a downturn in industrial sector performance measured in its relative output

From the Granger causality results, improvement in HDI triggers increases in energy consumption as revealed in Tables 10 and 11. From Table 10, HDI triggers increase in IND and consequently energy consumption triggers increase in IND in the selected OECD countries as revealed in Table 13. For sub-Saharan sub-region, energy consumption triggers improvement in HDI as in Table 10. Similarly, enhancement in HDI triggers increase in IND as in Table 11. There was no causal relationship between energy consumption and industrial performance as in Table 13.

This points to the fact that energy generation is vital for improving industrial productivity, but sub-Saharan African

Table 10. Summary of causality test for OECD and sub-Saharan Africa.

Null Hypothesis	OECD sub-region		Sub-Saharan sub-region	
	F-statistic (prob.)	Direction of causality	F-statistic (prob.)	Direction of causality
Model 1: Human Development versus Total Primary Energy Consumption (HDI vs TPEC)				
LAB does not Granger cause HDI	5.148 (0.006)**	$LAB \Leftrightarrow HDI$	2.383 (0.092)**	$LAB \rightarrow HDI$
HDI does not Granger cause LAB	10.561 (3×10^{-5})**		0.045 (0.955)	
CAP does not Granger cause HDI	4.401 (0.012)**	$CAP \Leftrightarrow HDI$	2.471 (0.085)***	$CAP \Leftrightarrow HDI$
HDI does not Granger cause CAP	15.520 (2×10^{-5})**		3.678 (0.025)**	
TPEC does not Granger cause HDI	0.605 (0.549)	$HDI \rightarrow TPEC$	0.010 (0.989)	No causality
HDI does not Granger cause TPEC	11.904 (8×10^{-6})**		0.996 (0.369)	
CAP does not Granger cause LAB	12.563 (4×10^{-6})**	$CAP \rightarrow LAB$	0.789 (0.454)	No causality
LAB does not Granger cause CAP	1.221 (0.295)		0.269 (0.763)	
TPEC does not Granger cause LAB	1.257 (0.284)	No causality	17.648 (3×10^{-8})	$TPEC \rightarrow LAB$
LAB does not Granger cause TPEC	0.551 (0.576)		0.671 (0.511)	
TPEC does not Granger cause CAP	1.897 (0.166)	$CAP \rightarrow TPEC$	0.392 (0.675)	No causality
CAP does not Granger cause TPEC	2.626 (0.073)***		0.433 (0.648)	

Source: Authors' Computation.

Table 11. Summary of causality test for OECD and sub-saharan sub-region.

Null Hypothesis	OECD sub-region		Sub-Saharan sub-region	
	F-statistic (prob.)	Direction of causality	F-statistic (prob.)	Direction of causality
Model 2: Human Development versus Energy Consumption Per capita (HDI vs ECPA)				
LAB does not Granger cause HDI	5.149 (0.006)**	$LAB \Leftrightarrow HDI$	2.383 (0.092)**	$LAB \rightarrow HDI$
HDI does not Granger cause LAB	10.561 (3×10^{-5})**		0.045 (0.955)	
CAP does not Granger cause HDI	4.401 (0.012)**	$CAP \Leftrightarrow HDI$	2.471 (0.085)***	$CAP \Leftrightarrow HDI$
HDI does not Granger cause CAP	15.520 (2×10^{-7})**		3.678 (0.025)**	
ECPA does not Granger cause HDI	1.510 (0.221)	$HDI \rightarrow ECPA$	5.451 (0.004)**	$ECPA \rightarrow HDI$
HDI does not Granger cause ECPA	2.944 (0.053)***		2.123 (0.120)	
CAP does not Granger cause LAB	12.563 (4×10^{-6})**	$CAP \rightarrow LAB$	0.789 (0.454)	No causality
LAB does not Granger cause CAP	1.221 (0.295)		0.269 (0.763)	
ECPA does not Granger cause LAB	5.061 (0.006)**	$ECPA \Leftrightarrow LAB$	1.141 (0.319)	No causality
LAB does not Granger cause ECPA	4.940 (0.007)**		0.147 (0.862)	
ECPA does not Granger cause CAP	0.589 (0.555)	$CAP \rightarrow ECPA$	1.492 (0.225)	$ECPA \rightarrow CAP$
CAP does not Granger cause ECPA	3.701 (0.025)**		12.579 (4×10^{-6})	

Source: Authors' Computation.

Table 12. Summary of causality test for OECD and sub-Saharan sub-region.

Null Hypothesis	OECD sub-region		Sub-Saharan sub-region	
	F-statistic (prob.)	Direction of causality	F-statistic (prob.)	Direction of causality
Model 3: Industrial sector performance versus Human Development (IND vs HDI)				
LAB does not Granger cause IND	3.909 (0.020)**	$LAB \Leftrightarrow IND$	1.848 (0.158)	No causality
IND does not Granger cause LAB	2.992 (0.050)***		1.973 (0.139)	
CAP does not Granger cause IND	7.675 (0.000)**	$CAP \Leftrightarrow IND$	1.556 (0.2116)	No causality
IND does not Granger cause CAP	16.748 (7×10^{-8})**		2.119 (0.120)	
HDI does not Granger cause IND	2.325 (0.098)***	$HDI \rightarrow IND$	2.792 (0.061)***	$HDI \rightarrow IND$
IND does not Granger cause HDI	1.614 (0.199)		0.569 (0.566)	
CAP does not Granger cause LAB	12.563 (4×10^{-6})**	$CAP \rightarrow LAB$	0.789 (0.454)	No causality
LAB does not Granger cause CAP	1.221 (0.295)		0.269 (0.763)	
HDI does not Granger cause LAB	10.561 (3×10^{-5})**	$HDI \rightarrow LAB$	0.045 (0.955)	$LAB \rightarrow HDI$
LAB does not Granger cause HDI	1.221 (0.295)		2.381 (0.092)***	
HDI does not Granger cause CAP	15.520 (2×10^{-7})**	$HDI \Leftrightarrow CAP$	3.678 (0.025)**	$HDI \Leftrightarrow CA$
CAP does not Granger cause HDI	4.401 (0.012)**		2.471 (0.085)***	

Source: Authors' Computation.

Table 13. Summary of causality test for OECD and sub-Saharan sub-region.

Null Hypothesis	OECD sub-region		Sub-Saharan sub-region	
	F-statistic (prob.)	Direction of causality	F-statistic (prob.)	Direction of causality
Model 4: Industrial Sector Performance versus Energy Consumption per Capita (IND vs ECPA)				
LAB does not Granger cause IND	3.909 (0.020)**	$LAB \Leftrightarrow IND$	1.848 (0.158)	No causality
IND does not Granger cause LAB	2.992 (0.050)***		1.973 (0.139)	
CAP does not Granger cause IND	7.675 (0.000)**	$CAP \Leftrightarrow IND$	1.556 (0.211)	No causality
IND does not Granger cause CAP	16.748 (7×10^{-8})**		2.119 (0.120)	
ECPA does not Granger cause IND	2.541 (0.079)***	$ECPA \rightarrow IND$	0.306 (0.736)	No causality
IND does not Granger cause ECPA	0.011 (0.988)		1.348 (0.260)	
CAP does not Granger cause LAB	12.563 (4×10^{-6})**	$CAP \rightarrow LAB$	0.789 (0.454)	No causality
LAB does not Granger cause CAP	1.221 (0.295)		0.269 (0.763)	
ECPA does not Granger cause LAB	5.061 (0.006)**	$ECPA \rightarrow LAB$	1.141 (0.319)	No causality
LAB does not Granger cause ECPA	4.940 (0.007)**		0.147 (0.862)	
ECPA does not Granger cause CAP	0.589 (0.555)	$CAP \rightarrow ECPA$	1.492 (0.225)	$CAP \rightarrow ECPA$
CAP does not Granger cause ECPA	3.701 (0.025)**		12.579 (4×10^{-6})**	

Source: Authors' Computation.

countries suffer from serious infrastructural deficit capable of driving industrial performance in the sub-region.

Conclusion

It is necessary to comprehend the relative influence energy consumption has on human development and industrial sector performance to enable policy makers predict and forecast the outcomes of implementing

energy and industrial policies on the improvement of human welfare over time. Based on the relationship between the variables, it was revealed that there were feedback effects between energy consumption, human development and industrial performance in the selected OECD countries. However, in the selected sub-Saharan countries, there were feedback effects of energy consumption and human development, human development and industrial sector

performance, but no effect between energy consumption and industrial sector performance. The latter results are not far from reality as many countries within the sub-Saharan region are less industrialized, energy deficient and humanly inefficient. Besides, most clinics, secondary schools, and hospitals in sub-Saharan Africa lack access to reliable and affordable electricity, which have been a bane to human development in the sub-region. Energy bills are eating up a reasonable percentage of earnings of the low income households, especially in the rural parts of sub-Saharan Africa. Progress made to provide reliable, affordable and efficient power in sub-Saharan Africa has not been effective.

To streamline the adverse effects of energy deficiency on human development and industrial output, various governments from the sub-Saharan Africa region have embraced privatization of their energy sectors. However, the positive effects of privatization have been painfully slow. This is due to poor and inconsistent renewable and non-renewable energy policies, corruption and mismanagement of public funds and to mention a few. As slow as the benefits of privatization seem to be, they are quite far from the common man, especially in the rural areas of the region.

Recommendations

The study recommends the following.

- (i) To cultivate and maintain a high HDI, efficient energy targeting policies are required at industry and domestic based level while encouraging efficient energy-related technologies that are country specific. These policies should embrace alternative energy sources, the current industrial structure, energy mix and invariable global actions in climate change mitigation.
- (ii) To build a sound electricity grid system, sub-Saharan Africa countries should develop and utilize her renewable and non-renewable resources. In particular the implementation of electrical engineering in rural areas can provide the necessary conditions for human development. Moreover, to improve the electricity power-supplying capacity of recipient regions in sub-Saharan Africa, cooperation and the process of international aid are key steps to take.
- (iii) To alleviate the effects of environmental hazards brought about by energy consumption, sub-Saharan Africa countries should aim to develop green energy that is clean, renewable and low cost. This should be applicable to new technologies when utilizing nuclear energy, wind power, biomass energy and water power to generate

electricity. Promotion of low-cost energy-saving technology should be encouraged.

- (iv) Besides accelerating the construction of electrification, concerted efforts must be made to eliminate poverty, make education universal and improve health conditions to create conditions that are compatible with human development.
- (v) To achieve a reliable, affordable and efficient energy sub-Saharan African leaders must improve their collaboration with the private sector in the provision of sustainable, reliable, affordable and efficient energy for two broad groups:
 - (1) Those low-income groups living closer to the grid but face high cost or other forms of barriers of accessing power supply. These groups should be offered lower connection fees and a convenient installment payment plans which can help encourage others to the grid.
 - (2) For those living far from the transmission and distribution system, a decentralized method should be used, such as home solar-panels system, as an efficient and cost-effective way to provide energy.

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Author contributions

EA, BI, GE were responsible for the conception and design of the study.

GE, FO, performed data collection. EA, GE performed data analysis and drafted the article. BI supervised the study, contributed to data analysis, interpretation, and critical revisions. All authors approved the final manuscript.

References

- Akinlo T, Oyeleke OJ. 2020. Human capital formation and economic growth in Sub-Saharan African Countries: an empirical investigation. *Indian Econ J.* 68(2):249–268. doi: [10.1177/0019466220972848](https://doi.org/10.1177/0019466220972848).

- Amna Intisar R, Yaseen MR, Kousar R, Usman M, Makhdum MSA. 2020. Impact of trade openness and human capital on economic growth: a comparative investigation of Asian countries. *Sustainability*. 12(7):2930. doi: [10.3390/su12072930](https://doi.org/10.3390/su12072930).
- Ashagidigbi WM, Babatunde BA, Ogunniyi AI, Olagunju KO, Omotayo AO. 2020. Estimation and determinants of multi-dimensional energy poverty among households in Nigeria. *Sustainability*. 12(18):7332. doi: [10.3390/su12187332](https://doi.org/10.3390/su12187332).
- Bai Y, Wierzbicki T. 2010. Application of extended Mohr–coulomb criterion to ductile fracture. *Int J Fract*. 161(1):1–20. doi: [10.1007/s10704-009-9422-8](https://doi.org/10.1007/s10704-009-9422-8).
- Bauchner H, Fontanarosa PB, Livingston EH. 2020. Conserving supply of personal protective equipment—A call for ideas. *JAMA*. 323(19):1911. doi: [10.1001/jama.2020.4770](https://doi.org/10.1001/jama.2020.4770).
- Behera BK, Prasad R, Shyambhavee. 2022. Primary health-care goal and principles. *Healthc Strateg Plan Soc Incl Dev*. 221–239. doi: [10.1016/B978-0-323-90446-9.00008-3](https://doi.org/10.1016/B978-0-323-90446-9.00008-3).
- Bjornlund V, Bjornlund H, Van Rooyen AF. 2020. Why agricultural production in sub-saharan Africa remains low compared to the rest of the world – a historical perspective. *Int J Water Resour Dev*. 36(sup1):S20–S53. doi: [10.1080/07900627.2020.1739512](https://doi.org/10.1080/07900627.2020.1739512).
- Broadberry S, Gardner L. 2022. Economic growth in Sub-Saharan Africa, 1885–2008: evidence from eight countries. *Explor Econ Hist*. 83:101424. doi: [10.1016/j.eeh.2021.101424](https://doi.org/10.1016/j.eeh.2021.101424).
- Chen Q, Yan G. 2023. On the two algorithms for estimating interactive fixed effects models in. *Econ Lett*. 233:111395. doi: [10.1016/j.econlet.2023.111395](https://doi.org/10.1016/j.econlet.2023.111395).
- Dai L, Jia R, Wang X. 2022. Relationship between economic growth and energy consumption from the perspective of sustainable development. *J Environ Public Health*. 2022:1–10. doi: [10.1155/2022/6884273](https://doi.org/10.1155/2022/6884273).
- Elfaki KE, Handoyo RD, Ibrahim KH. 2021. The impact of industrialization, trade openness, financial development, and energy consumption on economic growth in Indonesia. *Economies* 2021. 9(4):174. doi: [10.3390/economies9040174](https://doi.org/10.3390/economies9040174).
- Fawzy S, Osman AI, Doran J, Rooney DW. 2020. Strategies for mitigation of climate change: a review. *Environ Chem Lett*. 18(6):2069–2094. doi: [10.1007/s10311-020-01059-w](https://doi.org/10.1007/s10311-020-01059-w).
- Filimonova IV, Nemov VY, Komarova AV, Mishenin MV, Kozhevnikov VD. 2021. Relationship of renewable energy consumption to economic, environmental and institutional factors in Europe. *Energy Reports*. 7:358–365. doi: [10.1016/j.egyr.2021.07.115](https://doi.org/10.1016/j.egyr.2021.07.115).
- Gielen D, Boshell F, Saygin D, Bazilian MD, Wagner N, Gorini R. 2019. The role of renewable energy in the global energy transformation. *Energy Strateg Rev*. 24:38–50. doi: [10.1016/j.esr.2019.01.006](https://doi.org/10.1016/j.esr.2019.01.006).
- Gradín C, Wu B. 2020. Income and consumption inequality in China: a comparative approach with India. *China Econ Rev*. 62:101463. doi: [10.1016/j.chieco.2020.101463](https://doi.org/10.1016/j.chieco.2020.101463).
- Hassan E, Groot W, Volante L. 2022. Education funding and learning outcomes in Sub-Saharan Africa: a review of reviews. *Int J Educ Res Open*. 3:100181. doi: [10.1016/j.ijedro.2022.100181](https://doi.org/10.1016/j.ijedro.2022.100181).
- Hewitt RJ, Bradley N, Baggio Compagnucci A, Barlagne C, Ceglaz A, Cremades R, McKeen M, Otto IM, Snee B. 2019. Social innovation in community energy in Europe: a review of the evidence. *Front Energy Res*. 7. doi: [10.3389/fenrg.2019.00031](https://doi.org/10.3389/fenrg.2019.00031).
- Hoang AT, Nižetić S, Olcer AI, Ong HC, Chen W-H, Chong CT, Thomas S, Bandh SA, Nguyen XP. 2021. Impacts of COVID-19 pandemic on the global energy system and the shift progress to renewable energy: opportunities, challenges, and policy implications. *Energy Policy*. 154:112322. doi: [10.1016/j.enpol.2021.112322](https://doi.org/10.1016/j.enpol.2021.112322).
- Holechek JL, Geli HME, Sawalhah MN, Valdez R. 2022. A global assessment: can renewable energy replace fossil fuels by 2050? *Sustainability*. 14(8):4792. doi: [10.3390/su14084792](https://doi.org/10.3390/su14084792).
- Hopewell J, Dvorak R, Kosior E. 2009. Plastics recycling: challenges and opportunities. *Philos Trans R Soc B Biol Sci*. 364(1526):2115–2126. doi: [10.1098/rstb.2008.0311](https://doi.org/10.1098/rstb.2008.0311).
- Husnain MIU, Syed QR, Bashir A, Khan MA. 2022. Do geopolitical risk and energy consumption contribute to environmental degradation? Evidence from E7 countries. *Environ Sci Pollut Res*. 29(27):41640–41652. doi: [10.1007/s11356-021-17606-z](https://doi.org/10.1007/s11356-021-17606-z).
- Kabeyi MJB, Olanrewaju OA. 2022. Sustainable energy transition for renewable and low carbon grid electricity generation and supply. *Front Energy Res*. 9. doi: [10.3389/fenrg.2021.743114](https://doi.org/10.3389/fenrg.2021.743114).
- Keji SA. 2021. Human capital and economic growth in Nigeria. *Futur Bus J*. 7(1):49. doi: [10.1186/s43093-021-00095-4](https://doi.org/10.1186/s43093-021-00095-4).
- Kruk ME, Gage AD, Arsenaault C, Jordan K, Leslie HH, Roder-DeWan S, Adeyi O, Barker P, Daelmans B, Doubova SV, et al. 2018. High-quality health systems in the sustainable development goals era: time for a revolution. *Lancet Glob Heal*. 6(11):e1196–e1252. doi: [10.1016/S2214-109X\(18\)30386-3](https://doi.org/10.1016/S2214-109X(18)30386-3).
- Lattacher W, Gregori P, Holzmann P, Schwarz EJ. 2021. Knowledge spillover in entrepreneurial emergence: a learning perspective. *Technol Forecast Soc Change*. 166:120660. doi: [10.1016/j.techfore.2021.120660](https://doi.org/10.1016/j.techfore.2021.120660).
- Levin A, Lin C-F, James Chu C-S. 2002. Unit root tests in panel data: asymptotic and finite-sample properties. *J Econom*. 108(1):1–24. doi: [10.1016/S0304-4076\(01\)00098-7](https://doi.org/10.1016/S0304-4076(01)00098-7).
- Maltby T. 2013. European Union energy policy integration: a case of European Commission policy entrepreneurship and increasing supranationalism. *Energy Policy*. 55:435–444. doi: [10.1016/j.enpol.2012.12.031](https://doi.org/10.1016/j.enpol.2012.12.031).
- Manasseh CO, Abada FC, Okiche EL, Okanya O, Nwakoby IC, Offu P, Ogbuagu AR, Okafor CO, Obidike PC, Nwonye NG, et al. 2022. External debt and economic growth in Sub-Saharan Africa: does governance matter? Vasa L, editor. *PloS ONE*. 17(3):e0264082. doi: [10.1371/journal.pone.0264082](https://doi.org/10.1371/journal.pone.0264082).
- Manisalidis I, Stavropoulou E, Stavropoulos A, Bezirtzoglou E. 2020. Environmental and health impacts of air pollution: a review. *Front Public Health*. 8. doi: [10.3389/fpubh.2020.00014](https://doi.org/10.3389/fpubh.2020.00014).
- Mata Pérez MDLE, Scholten D, Smith Stegen K. 2019. The multi-speed energy transition in Europe: opportunities and challenges for EU energy security. *Energy Strateg Rev*. 26:100415. doi: [10.1016/j.esr.2019.100415](https://doi.org/10.1016/j.esr.2019.100415).
- Mukhtar M, Adun H, Cai D, Obiora S, Taiwo M, Ni T, Ozsahin DU, Bamisile O. 2023. Juxtaposing Sub-Saharan Africa's energy poverty and renewable energy potential. *Sci Rep*. 13(1):11643. doi: [10.1038/s41598-023-38642-4](https://doi.org/10.1038/s41598-023-38642-4).
- Ndiaya C, Lv K. 2018. Role of industrialization on economic growth: the experience of Senegal (1960–2017). *Am J Ind Bus Manag*. 8(10):2072–2085. doi: [10.4236/ajibm.2018.810137](https://doi.org/10.4236/ajibm.2018.810137).
- Nyanzi JB, Kilimani N. 2018. Estimation of disaggregated impacts of education expansion on economic growth in Sub-Saharan Africa. *Mod Econ*. 9(12):2119–2149. doi: [10.4236/me.2018.912132](https://doi.org/10.4236/me.2018.912132).

- Olarinde O, Adeniran A. 2018. Addressing the energy consumption-economic growth nexus: the Nigerian case. *J Sustain Dev Law Policy*. 9(2):84. doi: [10.4314/jsdlp.v9i2.6](https://doi.org/10.4314/jsdlp.v9i2.6).
- Oubda D, Ouédraogo S, Diasso A, Kébré MB, Zougmore F, Koalga Z, Ouattara F. 2022. Renewable energies in Africa, context and socio-economic challenge. *Open J Appl Sci*. 12(11):1856–1872. doi: [10.4236/ojapps.2022.1211128](https://doi.org/10.4236/ojapps.2022.1211128).
- Pablo-Romero MDP, Sánchez-Braza A. 2015. Productive energy use and economic growth: energy, physical and human capital relationships. *Energy Econ*. 49:420–429. doi: [10.1016/j.eneco.2015.03.010](https://doi.org/10.1016/j.eneco.2015.03.010).
- Pambudi NA, Sarifudin A, Gandidi IM, Romadhon R. 2022. Vaccine cold chain management and cold storage technology to address the challenges of vaccination programs. *Energy Reports*. 8:955–972. doi: [10.1016/j.egyr.2021.12.039](https://doi.org/10.1016/j.egyr.2021.12.039).
- Paprotny D. 2021. Convergence between developed and developing countries: a centennial perspective. *Soc Indic Res*. 153(1):193–225. doi: [10.1007/s11205-020-02488-4](https://doi.org/10.1007/s11205-020-02488-4).
- Poi BP. 2003. From the help desk: Swamy's random-coefficients model. *Stata J Promot Commun Stat Stata*. 3(3):302–308. doi: [10.1177/1536867X0300300307](https://doi.org/10.1177/1536867X0300300307).
- Pramesh CS, Badwe RA, Bhoo-Pathy N, Booth CM, Chinnaswamy G, Dare AJ, de Andrade VP, Hunter DJ, Gopal S, Gospodarowicz M, et al. 2022. Priorities for cancer research in low- and middle-income countries: a global perspective. *Nat Med*. 28(4):649–657. doi: [10.1038/s41591-022-01738-x](https://doi.org/10.1038/s41591-022-01738-x).
- Rajaguru G, Khan SU. 2021. Causality between energy consumption and economic growth in the presence of growth volatility: multi-country evidence. *J Risk Financ Manag*. 14(10):471. doi: [10.3390/jrfm14100471](https://doi.org/10.3390/jrfm14100471).
- Sarkodie SA, Adams S. 2020. Electricity access, human development index, governance and income inequality in Sub-Saharan Africa. *Energy Reports*. 6:455–466. doi: [10.1016/j.egyr.2020.02.009](https://doi.org/10.1016/j.egyr.2020.02.009).
- Smith KR, Frumkin H, Balakrishnan K, Butler CD, Chafe ZA, Fairlie I, Kinney P, Kjellstrom T, Mauzerall DL, McKone TE, et al. 2013. Energy and human health. *Annu Rev Public Health*. 34(1):159–188. doi: [10.1146/annurev-publhealth-031912-114404](https://doi.org/10.1146/annurev-publhealth-031912-114404).
- Stoner O, Lewis J, Martínez IL, Gumy S, Economou T, Adair-Rohani H. 2021. Household cooking fuel estimates at global and country level for 1990 to 2030. *Nat Commun*. 12(1):5793. doi: [10.1038/s41467-021-26036-x](https://doi.org/10.1038/s41467-021-26036-x).
- Ucak A. 2015. Adam Smith: the inspirer of modern growth theories. *Procedia - Soc Behav Sci*. 195:663–672. doi: [10.1016/j.sbspro.2015.06.258](https://doi.org/10.1016/j.sbspro.2015.06.258).
- Wang Y, Huang J, Cai X. 2022. The effect of human capital on energy consumption: evidence from an extended version of STIRPAT framework. *Chinese J Popul Resour Environ*. 20(2):136–146. doi: [10.1016/j.cjpre.2022.06.004](https://doi.org/10.1016/j.cjpre.2022.06.004).
- Wang Q-S, Hua Y-F, Tao R, Moldovan N-C. 2021. Can health human capital help the Sub-Saharan Africa out of the poverty trap? An ARDL model approach. *Front Public Health*. 9. doi: [10.3389/fpubh.2021.697826](https://doi.org/10.3389/fpubh.2021.697826).
- Zheng J, Wang X. 2022. Impacts on human development index due to combinations of renewables and ICTs –new evidence from 26 countries. *Renewable Energy*. 191:330–344. doi: [10.1016/j.renene.2022.04.033](https://doi.org/10.1016/j.renene.2022.04.033).