Energy Consumption and Economic Growth Nexus in East African Sub-Region: Interactive Dynamics of Human Capital

Nanzia F. Mmbaga,[§] Yusuph Kulindwa,[‡] & Isaac Kazungu[†]

Abstract:
Human capital is an essential for economic growth and energy consumption. Skills, knowledge, and population health drive innovation and energy utilization. Understanding these factors is vital for addressing contemporary energy challenges and fostering economic development. Therefore, this study focuses on the East African sub-region from 2012 to 2021, exploring how education and health, as proxies for human capital, influence the energy-economic growth nexus. We employed various analytical methods, including Pooled Ordinary Least Squares, Fixed Effects, and the Generalized Method of Moments. Our findings highlight the importance of historical context in shaping present growth policies, as there is a positive association between current and past economic performance. Additionally, higher energy prices negatively affect economic growth, underlining the need for energy price stability. Further, energy consumption appears to negatively impact economic growth. However, when considering life expectancy as a proxy for human capital, this relationship reverses. Improved life expectancy becomes pivotal in shaping energy-growth policies. Our study underscores the critical importance of enhancing life expectancy, maintaining energy price stability, and strategically investing in energy consumption for stable economic growth in East Africa.

Keywords: Economic growth; Human Capital; Energy Consumption; East African Sub-Region
JEL Classification Codes: O4, J24, Q4, D9

[§] Corresponding Author, Local Government Training Institute, P.O Box 1125, Dodoma, Tanzania, Email: nanziaf30@gmail.com
[‡] Senior Lecturer, Moshi Cooperative University, P.O.Box 474, Moshi Tanzania, Email: yusuphkulindwaj@yahoo.com
[†] Senior Lecturer, Moshi Cooperative University, P.O.Box 474, Moshi Tanzania, Email: isaackazungu@gmail.com

1. Introduction

Understanding the factors influencing economic growth is crucial for effective policymaking (Ahmad, Zhao and Li, 2019). One critical area of interest is the interplay among energy consumption, human capital, and economic growth. Energy fuels economies, while human capital, represented by education and health, boosts productivity. This relationship is particularly significant in Africa, where population growth coincides with economic expansion (Azam, 2019; Maja and Ayano, 2021). Human capital encompasses knowledge, skills, and well-being, serving as a driver of economic growth (Islam and Amin, 2022). A skilled workforce enhances productivity, while good health reduces absenteeism (Tzenios, 2019). Investment in education, training, and healthcare is a pivotal for accumulating human capital, fostering innovation, and promoting economic progress (Josephine, 2021).

Further, human capital directly and indirectly influences energy consumption. Skills and innovation enhance production efficiency, whereas, education and health impact energy-efficient practices (Iweka *et al.*, 2019). Good health improve work efficiency, while poor health resulting from harmful energy sources can decreases productivity (Eisenmenger *et al.*, 2020). Cleaner energy sources improve health, consequently boosting productivity and economic growth (Yang, Usman and jahanger, 2021). Educated individuals tend to adopt energy-efficient practices and enjoy better health, which influences energy consumption and productivity, playing a crucial role in the energy-growth nexus. Given these relationships, formulating energy-growth policies should not disregard human capital. However, existing research often isolates these factors. Thus, our study investigates the moderating roles of health and education proxies in the energy-growth relationship in East Africa, providing valuable insights for policymakers and researchers to inform policy decisions and actions.

In Africa, access to education varies significantly across sub-regions, with only 30% to 50% of secondary-school-aged children attending school, and the lowest attendance rates found in Central and Eastern Africa. Moreover, just 7% to 23% of tertiary-school-aged youth are enrolled, revealing disparities across the continent, where approximately 35% of the younger generation lacks access to secondary education or technical skills. In some areas, nearly half of all children reach adolescence without achieving basic literacy, presenting significant challenges (United Nations, 2017-2018). Additionally, Africa faces challenges in terms of average life expectancy and higher mortality rates. Despite these challenges, the continent has demonstrated remarkable economic growth, increasing from 1.6% in 2016 to 3.7% in 2020 (Edo *et al.,* 2020). Within this African context, there is a pressing need to explore the intricate interplay among human capital and economic growth, with a particular focus on the East African sub-region. The East Africa stands out with higher economic growth, ranging from 5.5% to 6.5%, compared to others like North averaging 2.9% to 3.5%, Central ranging from 0.5% to 3.8%, West ranging from -0.2% to 3.8%, and South ranging from -0.3% to 2.6% (Visconti, 2018).

Despite experiencing rapid economic growth, East Africa has remain relatively low energy consumption rates (IEA, 2019). This unique context underscores the importance of explore the role of human capital, specifically life expectancy and education, in the context of energy-growth. Accordingly, our study hypothesizes the following: H1: There is no significant relationship between energy consumption and economic growth, H2: There is no significant moderating effect of life expectancy on the relationship between energy consumption and economic growth, H3:

There is no significant moderating effect of education (average years of schooling) on the relationship between energy consumption and economic growth. Therefore, our study offers three significant contributions. Firstly, it deepens our understanding of the intricate relationship between human capital and the link between energy consumption and economic growth. Unlike prior research focusing solely on education or health, we adopt a comprehensive approach, employing augmented growth models along with endogenous production functions to enrich the knowledge.

Second, our study employs multiple econometric models to improve robustness and provide insights into the varying applicability of modelling approaches when assessing the roles of human capital, energy consumption, and economic growth. Lastly, our research highlights noteworthy findings in the negative relationship between life expectancy and economic growth and the statistical insignificance of education proxies and interaction terms. These insights shed light on the association of socioeconomic factors and their impact on East Africa's economic performance. Consequently, these findings offer crucial guidance for policymakers and researchers in formulating policy action and decisions that promote economic growth in East Africa. Notably, our study underscores the importance of effective energy price management, healthcare investments, and energy conservation strategies to stimulate regional economic growth.

The remainder of this study is organized as follows: Section 2 presents the literature review, Section 3 covers methodology and data sources, Sections 4 and 5 present results and discussions, and the final section concludes with policy implications.

2.0 Literature Review

2.1 Theoretical Review

This study is grounded in the theories of endogenous growth, as expounded by Romer (1986) and Lucas (1988), which emphasize the importance of human capital and innovation in driving economic growth. Improvements in education and health lead to higher productivity and economic growth. This theoretical framework aligns with the focus of our present study, which underscores the importance of human capital development and innovation as catalysts for growth within a system. Here human capital is measured through education and health status, recognised as the most substantial factors directly linked to enhance productivity (Prasetyo and Kistanti, 2020). The study also highlights the indispensable role of energy as a primary input in the production process as like Yang *et al.* (202).

Furthermore, the literature reveals that human capital interacts with energy consumption through various channels. Firstly, higher levels of human capital lead to increased income levels, resulting in higher energy consumption (Pata & Caglar, 2021; Oswald *et al.,* 2020). Secondly, education, skills, and innovations fostered by human capital contribute to the research and development of energy-efficient technologies (Esquivias *et al.*, 2022; Bekun *et al.*, 2020). Additionally, a nation's economic structure plays as significant role, as human capital can complement physical capital. For instance, countries driven by the industrial sector often have energy-dependent economies, whereas those led by the service sector exhibit distinct energy consumption patterns (Lawal *et al.*, 2020; Zheng *et al.*, 2022). Therefore, it is anticipated that within endogenous growth theory, relationship between energy consumption, human capital development, and economic growth exists. Similarly, several empirical studies, including those by Shahbaz *et al.* (2022); Rahim *et al.*

(2021) provide evidence that the accumulation of human capital significantly supports a nation's economic growth.

Besides, in one side, human capital reduce energy consumption by stimulating innovation in energy conservation. On the other side, it can increase energy consumption due to its growth-enhancing effect on the economy. Thus, the present study augments the endogenous growth theory with a production function to explore the roles played by human capital in energy-growth. Accordingly, economic growth is considered a function of physical capital, human capitals, energy consumption, and energy price, similar to the approach taken by (Azam, 2019). The gross domestic product (GDP) represents the measure of economic growth, while education and health are used as proxies for human capital, measured by years of schooling and life expectancy. These measures are more feasible within the available data in East Africa. The rationale for including energy prices in the model is based on its potential impact on purchasing power and economic growth in either direction (Azam, 2020). Thus, we formulate the baseline model as presented under equation 1.

$$Y_{it} = f(K_{it}, EC_{it}, EP_{it}, HC_{it}) \quad (1)$$

Where; Y_{it}, EC_{it}, $HCit$, K_{it}, and EP_{it} represent gross domestic product per capita, physical capital, energy consumption, energy price, and human capital, respectively. The prefix i denotes individual countries under study, and t refers to the time period. Using linear transformation, we re-write Equation (1) into the following empirical specification:

$$Y_{it} = \beta_0 + \beta_1 K_{i,t} + \beta_2 EC_{i,t} + \beta_3 EP_{i,t} + \beta_4 HC_{i,t} + \varepsilon_{i,t} \quad (2)$$

Where: β0 denotes the intercept term, εit is a vector of serially and mutually uncorrelated disturbance terms. In Equation (2), all variables except for the disturbance term are transformed into natural logarithms. This transformation allows us to interpret the estimated coefficients as elasticities.

2.2 Empirical Literature

This part presents the previous studies that examined various aspects of the relationship between energy consumption and economic growth. Some have focused on the impact of energy consumption on economic growth (Awodumi & Adewuyi, 2020; Khan *et al.*, 2019), while others investigated the relationship between human capital and economic growth (Fukao *et al.*, 2021; Rahim *et al.*, 2021). A few studies also delved into how human capital affects energy consumption (Ibrahim *et al.*, 2022; Oluoch *et al.*, 2021). Regarding the energy-growth nexus, there is on-going debate in the literature. Some studies found a positive and significant relationship (Wang *et al.*, 2021; Shahbaz *et al.*, 2020), while others identified a negative and significant relationship (Awodumi and Adewuyi, 2020; Baz *et al.*, 2020), and a few studies found no significant relationship between energy consumption and economic growth (Rahman and Velayutham, 2020; Wang and Wang, 2020).

In the second perspective, most studies suggested a positive and substantial relationship between human capital and economic growth (Zia *et al.*, 2021; Olawumi, 2019). However, a minority indicate a negative relationship, and some find insignificant effects. The third perspective explores the influence of human capital on energy consumption (Zafar *et al.*, 2019, 2021). Despite these insights, the role of human capital in the energy-growth nexus remains underexplored, requiring further investigation. Table 1 summarizes empirical studies examining the interplay between human capital and the energy-growth relationship. These reviews emphasize the importance of human capital, energy consumption, and related factors as critical growth determinants. Regardless of the existing body of literature on human capital, energy consumption, and economic growth, the question of whether human capital moderates the energy-growth nexus remains relatively unexplored.

Table1: Summary of Empirical Studies on Human Capital, Energy Consumption, and Economic Growth

Authors	Title	Countries & Time Span	Methodology	Key Findings
Anetor (2020)	Mediating Role of Human Capital in FDI-Growth Nexus	Sub-Saharan Africa (1999-2017)	System GMM, Dynamic Panel Threshold Regression	Interaction of FDI and human capital negatively affects growth. Suggests enhancing human capital policies for absorptive capacity
Ramzan et al. (2019)	Human Capital Threshold in FDI-Economic Growth Nexus	70 Developing Economies (1980-2015)	General Method of Moments	The findings suggest that developing countries should leverage FDI while simultaneously focusing on the development of their domestic human capital
Sarwar et al. (2021)	Interplay Between Financial Development, Human Capital, and Economic Growth	83 Emerging Economies (2002-2017)	Two-Step System GMM	Human capital positively impacts economic growth. Policymakers should invest in human capital
Gnangoin et al. (2022)	Human Capital Moderating Role in Renewable & Non-Renewable Energy, Economic Growth, and Carbon Emissions	20 Emerging Market Economies (1990-2021)	Feasible Generalized Least Squares, Two-Stage Least Squares	Renewable energy and human capital reduce carbon emissions. Policy emphasis on human capital and renewable energy
Sheraz et al. (2021)	Globalization's Moderating Role in Financial Development, Energy Consumption, Human Capital, Economic Growth, and Carbon Emissions	G20 Countries (1986-2018)	Fixed Effect OLS, Driscoll-Kraay Standard Error, Dumitrescu and Hurlin Panel Causality Test and GDP impacts on carbon emissions	Globalization moderates financial development, energy consumption, human capital
Nathaniel (2021)	Urbanization, Human Capital, Natural Resources, and Ecological Footprint	South Africa (1970-2016)	Canonical Cointegration Regression, Dynamic OLS, FMOLS	Bidirectional relationship between human capital, economic growth, and ecological footprint. Human capital reduces ecological footprint
Ahmed et al. (2020)	Natural Resources, Human Capital, Urbanization, Economic Growth, and Ecological Footprint	China (1971-2014)	Bayer-Hack Cointegration Analysis, Bootstrap Analysis	Human capital moderates sustainable urbanization. Interaction effects between urbanization and human capital mitigate environmental degradation

R. L. Ibrahim et al. (2021)	Non-Renewable Energy Effects on Quality of Life	43 Sub-Saharan African Countries (1990-2017)	System GMM, Fixed Effects OLS, Fully Modified OLS	Non-renewable energy negatively impacts life expectancy and human development index. Policies to reduce non-renewable energy reliance improve quality of life
Abdouli & Omri (2021)	Environmental Quality, Human Capital, Economic Growth in Mediterranean Region	Mediterranean Region (1990-2013)	OLS	Unidirectional causality from GDP to FDI, GDP to human capital, FDI to human capital, human capital to carbon emissions. Human capital's role in economic growth and environmental quality
Ahmed & Wang (2019)	Human Capital Effects on Ecological Footprint	India (1971-2014)	Cointegration Analysis	Human capital negatively affects the ecological footprint; Human capital reduces the ecological footprint and energy consumption increases it
Oluoch *et al.*, 2021	Energy consumption and human capital: A panel data analysis of Sub-Saharan Africa	Sub-Saharan Africa 91990-2017)	Fixed Effects and Random Effects Models	Positive and significant relationship between energy consumption and human capital in Sub-Saharan Africa
Prasetyo & Kistanti, 2020	The impact of human capital and foreign direct investment on economic growth: Evidence from ASEAN-5 countries	ASEAN-5 countries (2004-2016)	Panel Data Analysis	Positive and significant relationship between human capital and economic growth in ASEAN-5 countries
Fukao *et al.*, 2021	The effects of human capital on economic growth in Japan: New evidence based on an age-structured production function	Japan	Not specified	Positive and substantial relationship between human capital and economic growth in Japan
Addis, 2018	Human capital and physical capital: A threshold cointegration and causality analysis	East Africa (1980-2015)	Vector Autoregressive Model	Human capital contributes significantly to the augmentation of physical capital stock and Gross National Income (GNI) in East Africa. Bidirectional relationship found between human capital and GNI

3.0 Data Sources and Methodology

3.1 Data and Variables Explanation

The central focus of this study is to examine the role of human capital in the nexus of economic growth and energy consumption within the East African. To accomplish this objective, the study employs panel data from 13 countries situated in the geographical region (Burundi, Comoros, Djibouti, Ethiopia, Kenya, Madagascar, Mauritius, Mozambique, Rwanda, South Sudan, Sudan, Tanzania, and Uganda), covering the period from 2012 to 2021. The choice of this specific time frame is guided by data availability for the variables that are pertinent to our research's key hypotheses. The variables of interest encompass economic growth, which is represented by Gross Domestic Product per capita (GDP), total energy consumption (EC), physical capital (K), energy price (EP), and human capital, which is captured trough education, and health status as detailed in table 2.

Table 2: Description of data

Variables	Symbol	Unit of measure	Source
Gross Domestic Product (DGP)	Y	GDP per capita growth (Annual %)	World Development Indicators *https://databank.worldbank.org/source/world-development-indicators*
Energy Consumption	EC	Terajoules	U.S. Energy Information Administration *https://www.eia.gov/international/data/world*
Human Capital	HC	Average years of school (Average Total Years of Schooling for Adult Population)	(Lee-Lee (2016), Barro-Lee (2018) and UNDP (2018)) *http://www.barrolee.com/* World Development Indicators
		Life expectancy at birth, total (years)	https://databank.worldbank.org/source/world-development-indicators
Physical Capital	K	Gross Capital formation (% of GDP)	World Development Indicators *https://databank.worldbank.org/source/world-development-indicators*
Price	P	Consumer Price Index (2010=100)	World Development Indicators *https://databank.worldbank.org/source/world-development-indicators*

3.2 Model and Estimation Techniques

To investigate the moderating role of human capital in the energy-growth nexus, this study employs robust estimation techniques, begins with a thorough overview of the datasets, encompassing size, distribution, central tendencies, and variable dispersions. Subsequently, we explore potential associations among variables using a correlation matrix. This matrix helps identify initial relationships before applying advanced econometric methods. Moreover, we assess the stationarity of variables in the panel dataset using root tests, including Hadri, Levin-Lin-Chu (LLC), Harris Tzavalis, and Breitung. This assessment is crucial in panel data analysis to prevent

spurious results. We proceed by examining the moderating effect of human capital using two indices: years of schooling and life expectancy.
These indices are incorporated into various regression models, including pooled ordinary least squares (POLS) regression, fixed effects model (FE), two-step difference, and system generalized method of moments (2s-Diff GMM and 2s-System SGMM), following the methodologies proposed by Arellano and Bover (1995) and Blundell and Bond (1998). It is important to note that while these methods are employed for robustness checks, the study acknowledges the potential challenges associated with relying solely on static models in panel data studies, as highlighted by prior research (Zyphur *et al.*, 2020). We understand that the POLS does not adequately address panel data issues such as endogeneity and individual effects but it offers baseline comparisons. Accordingly, the fixed effects (FE) model was employed to account for individual-specific effects that remain constant over time and to control for unobserved heterogeneity across panel units. This approach enhances the robustness of our estimates by accounting for time-invariant country-specific factors, thus making the two models valuable decision criteria.

Besides, our primary focus lies within the Generalized Method of Moments (GMM) models, chosen due to their effectiveness in addressing endogeneity. It is anticipated that GMM yield consistent and reliable results compared to POLS and FE. Within the GMM framework, the study opts for the two-step system GMM over the two-step difference GMM. The preference for the two-step system GMM is supported by benchmark studies of Arellano-Bond (1991) and Arellano-Bover (1995), Blundell-Bond (1998) and empirical evidence by Roodman, (2009); Sarpong & Nketiah-Amponsah (2022), demonstrating its reliability and efficiency. The 2s-Diff GMM method is applied to account for unobserved country heterogeneity and to address potential endogeneity and autocorrelation in the data. This approach enables the study to tackle dynamic panel data issues and obtain consistent estimators (Ehigiamusoe and Lean, 2019; Mahembe and Odhiambo, 2021). Additionally, the 2S-System SGMM is employed with the aim of producing more reliable results (Abeka *et al.*, 2021; Jahanger, 2022). To address time-series persistence and reveal the dynamic nature of the data, lag variables have been included in the dependent variable, as suggested by (Di Ubaldo and Siedschlag, 2021). Thus, the empirical GMM specification is presented in equation 3.

$$Y_{it} = \beta_0 + \beta_1 Y_{i,t-1} + \beta_2 Z_{i,t-1} + \beta_3 X_{i,t-1} + \varepsilon_{i,t} \quad (3)$$

Where Y is the dependent variable, Z is the explanatory variable and X represents the control variable, t—1 are the lags of the dependent variables and Ɛ is the error term. However, we employ the Arellano-Bond Generalized Method of Moments (GMM) estimator to address unobserved time and country effects, autocorrelation, endogeneity, and instrument validity in equation (4&5); the Arellano-Bond GMM estimation with transformation.

$$Y_{it} = \beta_0 Y_{i,t-1} + \beta_1 K_{i,t} + \beta_2 EC_{i,t} + \beta_3 EP_{i,t} + \beta_4 HC_{i,t} + \varepsilon_{i,t} \quad (4)$$

$$Y_{it} = \beta_0 \Delta Y_{i,t-1} + \beta_1 \Delta K_{i,t} + \beta_2 \Delta EC_{i,t} + \beta_3 \Delta EP_{i,t} + \beta_4 \Delta HC_{i,t} + \Delta\varepsilon_{i,t} \quad (5)$$

Where; Y, K, EC, EP, and HC represent gross domestic product per capita, physical capital, energy consumption, consumer price index, and human capital respectively. The prefix i denotes individual countries under study, and t refers to the time period.

4. Results and Discussion

4.1 Descriptive Statistics and Correlation Analysis

This section provides a comprehensive overview of key statistics for the variables used in this study, with the primary objective of offering valuable insights into their patterns and variability. The mean GDP per capita growth is approximately -1.768%, signifying a potential imbalance between population growth and economic output. This negative value, along with a substantial standard deviation of 14.828%, underscores significant variability in economic performance across the countries. Which might highlight the need for closer analysis of the relationship between population growth and economic outputs. Whereas, the average energy consumption is around 11.029 Terajoules, revealing a pronounced consumption pattern across observations. A standard deviation of 1.495 emphasises variability, and suggesting that energy consumption is a crucial factor within the context of our study. Human capital was included with two dimensions: The average years of schooling with mean value of 4.925 years, and a moderate standard deviation of approximately 1.749 years, reflects variability in educational attainment. Meanwhile, life expectancy averages 63.283 years, with a moderate standard deviation of approximately 4.307 years, indicating variability in health and longevity.

Table 3: Descriptive statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
GDP	130	-1.768	14.828	-93.42	10.493
lnPrice	130	5.323	1.067	4.196	10.024
Capital	130	23.989	15.868	-7.712	110.893
lnEnergy	130	11.029	1.495	7.77	12.871
Lifeexpectancy	130	63.283	4.307	54.973	74.515
Yearsofschooling	130	4.925	1.749	2.4	9.3

These variations underscore the significance of addressing disparities in education and health to enhance overall human capital development. Furthermore, physical capital accounts for 23.989%, of the total, suggesting a moderate level of variability and indicating a certain degree of consistency in capital allocation across the countries. The average energy price is 5.323, with a significant fluctuation, carrying a standard deviation of 1.067, indicating notable fluctuations in energy prices within the study's context as presented in table 3.

Table 4: Correlation Analysis

Variables	(1)	(2)	(3)	(4)	(5)	(6)
(1) GDP	1.000					
(2) lnPrice	-0.772*	1.000				
(3) Capital	0.395*	-0.249*	1.000			
(4) lnEnergy	0.139	0.183*	0.492*	1.000		
(5) Lifeexpectancy	0.395*	-0.295*	0.071	0.156*	1.000	
(6) Yearsofschooling	0.005	-0.139	-0.178*	0.140	0.559*	1.000

In Table 4, we present the results of a correlation analysis among the key explanatory variables used in our regression models: energy price, physical capital, total energy, life expectancy, and human capital, proxied by years of schooling and life expectancy. This analysis aims to examine the relationships between these variables and assess the presence of multicollinearity, which is a problem in regression analysis. The findings indicate that the explanatory variables examined have weak correlations with each other, as most of the correlation coefficients fall below the threshold of 0.8. This observation suggests that multicollinearity, a condition where independent variables in a regression model are highly correlated, is not a significant concern in our analysis, allowing us to continue with analysis confidently. Furthermore, the results reveal that the dependent variable, GDP, is positively correlated with capital, energy consumption, life expectancy, and years of schooling. This implies that as capital, energy consumption, life expectancy, and education attainment increase, GDP tends to increase as well. Conversely, energy prices are negatively correlated with GDP, indicating that as GDP increases, energy prices tend to decrease. These correlations provide valuable insights into the relationships between these key variables in our study

4.3 Unit root Test

Before we proceed with the analysis of the moderating role of human capital on the energy-growth nexus, we firstly examine the data stationarity of our variables. We employ both the Levin-Lin-Chu unit roots and Hadri Langrage Multiplier (LM) unit roots tests to assess stationarity. For the Levin-Lin-Chu unit roots test, the null hypothesis states that all panels contain unit roots, implying non-stationarity. However, since the p-value is less than 0.05 (<0.05), we reject the null hypothesis, while life expectancy becomes stationary after the second difference. In the case of the Hadri LM unit roots test, the null hypothesis posits that the panels are stationary and do not contain unit roots. Here, too, the p-value is less than 0.05 (<0.05), leading us not to reject the null hypothesis. Consequently, GDP, price, capital, energy, life expectancy, and years of schooling are stationary as indicated in table 4.

Table 5: Results of Unit Root Test

	Hadri LM z-stat		LLC t-stat			
Variables	Level	Results	Level	First D	Second D	Results
GDP	2.87**	H0 is not rejected	-1.2e+05***			H0 is rejected
lnPrice	5.64***	H0 is not rejected	-13.45***			H0 is rejected
Lifeexpectancy	7.6***	H0 is not rejected	11.43	4.003	-11.42***	H0 is rejected
Capital	4.96***	H0 is not rejected	-1.2e+06***			H0 is rejected
LnEnergy	4.97***	H0 is not rejected	-7.80***			H0 is rejected
Yearsofschooling	10.47***	H0 is not rejected	-9.38***			H0 is rejected

Number of panels = 13 & Number of periods = 10; *** p<0.01, ** p<0.05, * p<0.1

4.4 Moderating Role of Human Capital in Energy-Growth Nexus

4.4.1 Moderating Role of Health

In table 6, we present the results of the effect of human capital proxy life expectancy on energy-growth nexus with other important variable including the physical capital, and energy price. The empirical results reveal that the lagged GDP exhibits statistical significance at the 1% significance level in the Pooled OLS, Fixed Effects, and Two-step System GMM estimation models. This signifies that a one-unit increase in the GDP value from a previous time period corresponds to an increase in current GDP by 0.566***, 0.354***, and 0.753*** units, respectively. This implies that a rise in current GDP can be attributed, in part, to the economic performance of the preceding period. Notably, in the two-step difference GMM model, the lagged GDP demonstrates significance at the 5% level, with a coefficient value of 1.034**. While still indicating a positive relationship, this model suggests a slightly stronger association between past and current GDP. Therefore, these findings consistently highlight a positive and robust link between past economic growth and present economic performance across all four estimation methods. However, the coefficient values differ slightly across estimation methods, reflecting variations in the estimated impact. For instance, the two-step system GMM estimates a larger impact (0.753) compared to fixed effects (0.354). The significance and magnitude of these coefficients suggest a robust and reliable relationship and it suggests that sustained economic growth over time tends to contribute to on-going economic expansion in the East African sub-region.

Next the results of energy prices (Price2) using the Pooled OLS, fixed effects, and two-step system GMM models consistently reveals a significant negative relationship between energy price and economic growth, with all coefficients (-6.589, -10.004, and -4.674) being statistically significant at the 1% level. These findings suggest an inverse association between price and economic growth, implying that an increase in energy prices tends to decrease the economic growth within the East African sub-region. This outcome aligns with previous studies that indicated higher energy prices often have a detrimental influence on economic growth. Therefore, stabilizing energy prices through reductions or subsidies is vital for short-term regional economic growth and should be considered a crucial component of energy and economic growth policy initiatives within the region. These could be integral element of a well-rounded energy and economic growth policy in the region see table 6.

Further, at 10% significance level, we observe a statistically significant negative relationship between energy consumption and economic growth with coefficient of -46.007* in the FE model, and -21.062 in two-step system GMM model. These findings suggest that with inclusion of interactive term that is human capital proxy by life expectancy, the higher energy consumption is associated with lower economic growth in the East African sub-region. However, the magnitude of the coefficients in the two-step system GMM model is smaller than that in the FE model. This difference may be attributed by strength of this model to explicit handling the endogeneity and capturing the short-term dynamics. As a result, our study places a stronger emphasis on findings revealed by the two-step system GMM. Accordingly, the policymakers should be attentive to the potential adverse effects of high energy consumption on economic growth in the presence of human capital.

Furthermore, the results unveiled a noteworthy finding regarding life expectancy under FE model. It established a negative statistically significant relationship between life expectancy and economic growth in the East African sub-region, as indicated by an estimated coefficient of -8.972 at the 10% significance level. The negative relationship between life expectancy and economic growth seems surprising, but it becomes clearer when examined within the broader context of socioeconomic factors. One plausible explanation is that a higher prevalence of preventable diseases and health challenges places a burden on the workforce. This burden might lead to reduced labour productivity, potentially affecting the overall economic performance of the region. Additionally, the region's high child mortality rate can result in a larger burden to youth population, necessitating substantial investments in healthcare. These investments, while critical, divert resources from other economic development initiatives, thereby exerting a negative impact on economic growth. Furthermore, lower life expectancy can serve as an indicator of more profound social and economic challenges, including inadequate social safety nets. The intertwined nature of these multifaceted factors can collectively contribute to a dual impact on both life expectancy and economic growth, providing further support for the observed negative relationship between these variables. Therefore, this result aligns with the intricate of socioeconomic profiles that shape the region's unique circumstances.

Lastly, the moderating role of human capital captured by the interaction term that is life expectancy and energy consumption in energy-growth nexus as presented in table 6 (Index1), demonstrates a statistically significant coefficient of 0.362** at the 5% significance level in the two-step system GMM model. This indicates the human capital proxy by life expectancy plays a moderating role in energy-growth nexus. That is the relationship between energy consumption and economic growth varies depending on the level of human life expectancy in this region. While the SGMM model initially reveals a negative relationship between energy consumption and economic growth, the introduction of human capital, proxied by life expectancy, transforms this relationship into a positive one. Therefore, the life expectancy enhances the positive effects energy consumption on economic growth. These findings underscore the importance of investing in healthcare. Therefore, policymakers could consider strategies aimed at improving healthcare infrastructure, enhancing access to quality healthcare services, and implementing initiatives to increase life expectancy in the region for the benefits of energy-growth nexus.

Table 6: Moderating Role of Human Capital: Index1 (Energy2* Life Expectancy)

	(1)	(2)	(3)	(4)
Variables	Pooled OLS	Fixed Effects	2Step Diff GMM	2Step Syst GMM
L.GDP	0.566***	0.354***	1.034**	0.753***
	(0.077)	(0.083)	(0.412)	(0.049)
Price2	-6.589***	-10.004***	-3.447	-4.674***
	(1.000)	(1.203)	(5.139)	(0.952)
Capital	0.031	-0.103	-0.048	-0.044
	(0.063)	(0.089)	(0.061)	(0.041)
Energy2	-18.965	-46.007*	-12.276	-21.062*
	(13.302)	(27.596)	(37.279)	(11.464)
Lifeexpectancy	-3.563	-8.972	-2.784	-3.850*
	(2.398)	(5.525)	(6.457)	(2.077)
Index1	0.324	0.807*	0.225	0.362**
	(0.212)	(0.461)	(0.583)	(0.184)
Constant	241.542	566.056*		248.765*
	(152.169)	(329.390)		(131.527)
Observations	117	117	104	117
R-squared	0.829	0.701		
Number of countries		13	13	13
AR(1)			0.143	0.139
AR(2)			0.227	0.269
Hansen			0.153	0.170
Sargen			0.952	0.323
Number of Instruments			11.000	10.000

Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1; Index1=Energy2*Life expectancy

4.4.2 Moderating Role of Education

In table 7, we present the results of the effect of human capital proxy by education measured in average years of schooling on energy-growth nexus with other important variable including the physical capital, and energy price. The objective was to examine whether education mediates the effects of energy consumption on economic growth in the East African sub-region, using the neo-classical growth model. The results revealed a statistical significance of the lagged GDP at the 1% level under different econometric models (pooled OLS, fixed effects, two-step difference GMM, and two-step system GMM) with coefficients of 0.528***, 0.361***, 0.666, and 0.768***, respectively. This suggests a strong relationship between current economic output and past economic performance, indicating that the East African sub-region follows a path-dependent growth pattern, where current economic conditions are influenced by previous economic activities. It is important for policymakers and researchers to consider this designing policy action to promoting economic growth in the region.

Similarly, the results shows that energy prices exhibit statistical significance at the 1% level under various econometric models, including POLS, FE, and two-step system GMM. The negative coefficients of -7.332***, -9.800***, and -4.493*** indicate an inverse relationship between energy prices and GDP in the East African sub-region. This implies that a decrease in energy prices leads to an increase in the region's GDP. Addressing low energy prices is crucial for promoting economic growth, and policymakers should consider measures to reduce energy prices. However, with the inclusion of interactive term that is average total years of schooling for adult population, we found that the energy consumption demonstrates statistical significance at the 10% level, particularly within the two-step system GMM model. The coefficient of 1.817* signifies a significant and positive relationship between energy consumption and GDP in the East African sub-region. Specifically, a one-unit increase in energy consumption corresponds to a 1.817-unit increase in GDP. This highlights the direct and positive effects of energy consumption on economic growth in this region. Therefore, strategies to expand energy infrastructure, promote energy efficiency, and explore sustainable energy sources are essential for harnessing these economic benefits.

On the other hand, both education, proxies by average total years of schooling for adult population and the interaction term (Index2) which is the total average years of schooling for adult population and energy consumption did not exhibit statistical significance in relation to economic growth across all estimation models (POLS, FE, two-step difference and system GMM). This suggests that neither years of schooling nor the interaction between education and energy consumption significantly influences the economic growth of the East African sub-region. Therefore, while education did not show to moderate the relationship between energy consumption and economic growth the life expectancy have revealed.

Table 7: Results of Human Capital (year of schooling) on Energy-growth Nexus

Variables	(1) Pooled OLS	(2) Fixed Effects	(3) 2Step Diff GMM	(4) 2Step Syst GMM
L.GDP	0.528***	0.361***	0.666	0.768***
	(0.077)	(0.083)	(0.900)	(0.138)
Price2	-7.332***	-9.800***	-2.897	-4.493***
	(1.028)	(1.184)	(5.325)	(1.087)
Capital	-0.084	-0.062	-0.025	-0.064
	(0.070)	(0.088)	(0.051)	(0.053)
Energy2	2.945	-5.290	-22.136	1.817*
	(1.988)	(9.712)	(21.674)	(0.943)
Yearsofschooling	0.408	-14.631	-73.701	-0.546
	(4.694)	(26.788)	(75.154)	(2.200)
Index2	-0.124	1.557	6.025	-0.019
	(0.409)	(2.206)	(6.067)	(0.204)
Constant	12.566	97.985		8.617
	(20.742)	(116.314)		(11.880)
Observations	117	117	104	117
R-squared	0.834	0.700		
Number of c_id		13	13	13
AR(1)			0.603	0.175
AR(2)			0.738	0.226
Hansen			0.125	0.217
Sargen			0.998	0.086
Number of Instruments			9.000	11.000

Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1; Index2=Energy2*Years of schooling

Lastly, to assess the robustness of our estimated parameters, we conducted diagnostic tests. These tests confirm the validity of our model assumptions. The results indicate no autocorrelation in our model's residuals and validate the use of our instruments. Specifically, the Hansen test results show that the instruments are exogenous and not overused, ensuring the validity of our instrument selection. For more details, please refer to the lower section of tables 6 and 7.

5. Conclusion and Recommendations

From the findings it can be concluded that; there is a significant negative relationship between energy consumption and economic growth. This underscores the imperative need for energy conservation measures, the promotion of energy-efficient practices, and the stabilization of energy prices to stimulate regional economic growth. Furthermore, our investigation of the moderating effect of life expectancy on the energy- growth unveiled a noteworthy negative link between life expectancy and economic growth. This highlights the critical importance of addressing socioeconomic factors that influence both life expectancy and regional economic growth.

Regarding the investigation of the moderating effect of education, we did not observe a significant influence on the energy-growth relationship in the East African sub-region. The study recommends the implementation of energy conservation policies, the stabilization of energy prices, and the prioritization of investments in healthcare to the foster economic growth in East Africa. These measures have the potential to positively moderate the association between energy and economic growth. The study recommends further study to other scholars by exploring both short and long-term effects, as well as the interactions of human capital on energy consumption, and economic growth nexus at the county level within the East African region. This approach will enable the development of tailored policy recommendations that account for specific country variations and nuances.

References

Acheampong, A. O., Boateng, E., Amponsah, M., & Dzator, J. (2021). Revisiting the economic growth–energy consumption nexus: Does globalization matter? *Energy Economics*, 102. https://doi.org/10.1016/j.eneco.2021.105472.

Ahmad, M., Zhao, Z. Y. and Li, H. (2019) 'Revealing stylized empirical interactions among construction sector, urbanization, energy consumption, economic growth and CO2 emissions in China', *Science of the Total Environment*, 657, pp. 1085–1098. doi: 10.1016/j.scitotenv.2018.12.112.

Ahmed, Z. et al. (2020) 'Moving towards a sustainable environment: The dynamic linkage between natural resources, human capital, urbanization, economic growth, and ecological footprint in China', *Resources Policy*, 67(January), p. 101677. doi: 10.1016/j.resourpol.2020.101677.

Ahmed, Z. and Wang, Z. (2019) 'Investigating the impact of human capital on the ecological footprint in India: An empirical analysis', *Environmental Science and Pollution Research*, 26(26), pp. 26782–26796. doi: 10.1007/s11356-019-05911-7.

K, A., Sankaran, A., Kumar, S., & Das, M. (2020). An endogenous growth approach on the role of energy, human capital, finance and technology in explaining manufacturing value-added: A multi-country analysis. Heliyon, 6(7), e04308. https://doi.org/10.1016/j.heliyon.2020.e04308

Awodumi, O. B. and Adewuyi, A. O. (2020) 'The role of non-renewable energy consumption in economic growth and carbon emission: Evidence from oil producing economies in Africa', *Energy Strategy Reviews*, 27, p. 100434. doi: 10.1016/j.esr.2019.100434.

Azam, M. (2019) 'Relationship between energy, investment, human capital, environment, and economic growth in four BRICS countries', *Environmental Science and Pollution Research*, 26(33), pp. 34388–34400. doi: 10.1007/s11356-019-06533-9.

Azam, M. (2020) 'Energy and economic growth in developing Asian economies', *Journal of the Asia Pacific Economy*, 25(3), pp. 447–471. doi: 10.1080/13547860.2019.1665328.

Baz, K., Xu, D., Ali, H., Ali, I., Khan, I., Khan, M. M., & Cheng, J. (2020). Asymmetric impact of energy consumption and economic growth on ecological footprint: Using asymmetric and nonlinear approach. *Science of the Total Environment*, 718. https://doi.org/10.1016/j.scitotenv.2020.137364.

Bekun, F. V., Agboola, O. M. and Joshua, U. (2020) Econometrics of Green Energy Handbook, Econometrics of Green Energy Handbook. doi: 10.1007/978-3-030-46847-7.

Chen, C., Pinar, M. and Stengos, T. (2020) 'Renewable energy consumption and economic growth nexus: Evidence from a threshold model', *Energy Policy*, 139. doi: 10.1016/j.enpol.2020.111295.

Edo, S., Osadolor, N. E. and Dading, I. F. (2020) 'Growing external debt and declining export: The concurrent impediments in economic growth of Sub-Saharan African countries', *International Economics*, 161(March), pp. 173–187. doi: 10.1016/j.inteco.2019.11.013.

Ehigiamusoe, K. U. and Lean, H. H. (2019) 'Effects of energy consumption, economic growth, and financial development on carbon emissions: evidence from heterogeneous income groups', *Environmental Science and Pollution Research*, 26(22), pp. 22611–22624. doi: 10.1007/s11356-019-05309-5.

Eisenmenger, N., Pichler, M., Krenmayr, N., Noll, D., Plank, B., Schalmann, E., … Gingrich, S. (2020).

The Sustainable Development Goals prioritize economic growth over sustainable resource use: a critical reflection on the SDGs from a socio-ecological perspective. *Sustainability Science*, 15(4), 1101–1110. https://doi.org/10.1007/s11625-020-00813-x.

Esquivias, M. A., Sugiharti, L., Rohmawati, H., Rojas, O., & Sethi, N. (2022). Nexus between Technological Innovation, Renewable Energy, and Human Capital on the Environmental Sustainability in Emerging Asian Economies: A Panel Quantile Regression Approach. *Energies*, 15(7). https://doi.org/10.3390/en15072451.

Fatima, S., Chen, B., Ramzan, M., & Abbas, Q. (2020). The Nexus Between Trade Openness and GDP Growth: Analyzing the Role of Human Capital Accumulation. *SAGE Open*, 10(4). https://doi.org/10.1177/2158244020967377.

Fukao, K., Makino, T. and Settsu, T. (2021) 'Human Capital and Economic Growth in Japan: 1885–2015', *Journal of Economic Surveys*, 35(3), pp. 710–740. doi: 10.1111/joes.12419.

Gilal, F. G., Ashraf, Z., Gilal, N. G., Gilal, R. G., & Channa, N. A. (2019). Promoting environmental performance through green human resource management practices in higher education institutions: A moderated mediation model. *Corporate Social Responsibility and Environmental Management*, 26(6), 1579–1590. https://doi.org/10.1002/csr.1835.

Ibrahim, R. L., Julius, O. O., Nwokolo, I. C., & Ajide, K. B. (2022). The role of technology in the non-renewable energy consumption-quality of life nexus: insights from sub-Saharan African countries. *Economic Change and Restructuring*, 55(1), 257–284.doi.org/10.1007/s10644-020-09312-6.

IEA (2019) Africa Energy Outlook 2019 - Analysis and key findings. A report by the International Energy Agency. Available at: www.iea.org/africa2019%0Ahttps://www.oecd-ilibrary.org/energy/africa-energy-outlook_g2120ab250-en%0Ahttps://www.iea.org/africa2019.

Islam, M. S. and Amin, M. (2022) 'A systematic review of human capital and employee well-being: putting human capital back on the track', *European Journal of Training and Development*, 46(5–6), pp. 504–534. doi: 10.1108/EJTD-12-2020-0177.

Iweka, O., Liu, S., Shukla, A., & Yan, D. (2019). Energy and behaviour at home: A review of intervention methods and practices. *Energy Research and Social Science*, Advance online publication. https://doi.org/10.1016/j.erss.2019.101238

Jahanger, A. (2022) 'Impact of globalization on CO2 emissions based on EKC hypothesis in developing world: the moderating role of human capital', *Environmental Science and Pollution Research*, 29(14), pp. 20731–20751. doi: 10.1007/s11356-021-17062-9.

Jayne, T. S., Chamberlin, J. and Benfica, R. (2018) 'Africa's Unfolding Economic Transformation', *Journal of Development Studies*, 54(5), pp. 777–787. doi: 10.1080/00220388.2018.1430774.

Josephine, Y. (2021) 'Human Capital, Economic Growth and Poverty Reduction Nexus: Why Investment in Free Compulsory Universal Education Matters for Africa', *International Journal of Humanities and Social Sciences*, 13(2), pp. 50–60. doi: 10.26803/ijhss.13.2.3.

Junior Abeka, M., Andoh, E., Gatsi, J. G., & Kawor, S. (2021). Financial development and economic growth nexus in SSA economies: The moderating role of telecommunication development. *Cogent Economics and Finance*, 9(1). https://doi.org/10.1080/23322039.2020.1862395.

Khan, M. K., Khan, M. I. and Rehan, M. (2020) 'The relationship between energy consumption, economic growth and carbon dioxide emissions in Pakistan', *Financial Innovation*, 6(1), pp. 2000–2008. doi: 10.1186/s40854-019-0162-0.

Khan, M. K., Teng, J. Z. and Khan, M. I. (2019a) 'Effect of energy consumption and economic growth on carbon dioxide emissions in Pakistan with dynamic ARDL simulations approach', *Environmental Science and Pollution Research*, 26(23), pp. 23480–23490. doi: 10.1007/s11356-019-05640-x.

Khan, M. K., Teng, J. Z. and Khan, M. I. (2019b) 'Effect of energy consumption and economic growth on carbon dioxide emissions in Pakistan with dynamic ARDL simulations approach', *Environmental Science and Pollution Research*, 26(23), pp. 23480–23490. doi: 10.1007/s11356-019-05640-x.

Kouton, J. (2021) 'The impact of renewable energy consumption on inclusive growth: panel data analysis in 44 African countries', *Economic Change and Restructuring*, 54(1), pp. 145–170. doi: 10.1007/s10644-020-09270-z.

Lawal, A. I., Ozturk, I., Olanipekun, I. O., & Asaleye, A. J. (2020). Examining the linkages between electricity consumption and economic growth in African economies. *Energy*, 208. https://doi.org/10.1016/j.energy.2020.118363.

Mahembe, E. and Odhiambo, N. M. (2021) 'Does foreign aid reduce poverty? A dynamic panel data analysis for sub-Saharan African countries', *Journal of Economic Inequality*, 19(4), pp. 875–893. doi: 10.1007/s10888-021-09496-5.

Mahmood, N., Wang, Z. and Hassan, S. T. (2019) 'Renewable energy, economic growth, human capital, and CO2 emission: an empirical analysis', *Environmental Science and Pollution Research*, 26(20), pp. 20619–20630. doi: 10.1007/s11356-019-05387-5.

Maja, M. M. and Ayano, S. F. (2021) 'The Impact of Population Growth on Natural Resources and Farmers' Capacity to Adapt to Climate Change in Low-Income Countries', *Earth Systems and Environment*, 5(2), pp. 271–283. doi: 10.1007/s41748-021-00209-6.

Maji, I. K., Sulaiman, C. and Abdul-Rahim, A. S. (2019) 'Renewable energy consumption and economic growth nexus: A fresh evidence from West Africa', *Energy Reports*, 5, pp. 384–392. doi: 10.1016/j.egyr.2019.03.005.

Matousek, R. and Tzeremes, N. G. (2021) 'The asymmetric impact of human capital on economic growth', Empirical Economics, 60(3), pp. 1309–1334. doi: 10.1007/s00181-019-01789-z.

Olawumi, A. D. (2019) 'Human Capital Development and Economic Growth in BRICS Countries: Controlling for Country Differences." *Journal of Economics and Behavioral Studies*, 11(4), 1-17.', 11(4), pp. 1–17.

Oluoch, S., Lal, P. and Susaeta, A. (2021) 'Investigating factors affecting renewable energy consumption: A panel data analysis in Sub Saharan Africa', *Environmental Challenges*, 4(March), p. 100092. doi: 10.1016/j.envc.2021.100092.

Oswald, Y., Owen, A. and Steinberger, J. K. (2020) 'Large inequality in international and intranational energy footprints between income groups and across consumption categories', *Nature Energy*, 5(3), pp. 231–239. doi: 10.1038/s41560-020-0579-8.

Pata, U. K. and Caglar, A. E. (2021) Investigating the EKC hypothesis with renewable energy consumption, human capital, globalization and trade openness for China: Evidence from augmented ARDL approach with a structural break, *Energy*. Elsevier Ltd. doi: 10.1016/j.energy.2020.119220.

Prasetyo, P. E. and Kistanti, N. R. (2020) 'Human capital, institutional economics and entrepreneurship as a driver for quality & sustainable economic growth', *Entrepreneurship and Sustainability Issues*, 7(4), pp. 2575–2589. doi: 10.9770/jesi.2020.7.4(1).

Rahim, S., Murshed, M., Umarbeyli, S., Kirikkaleli, D., Ahmad, M., Tufail, M., & Wahab, S. (2021). Do natural resources abundance and human capital development promote economic growth? A study on the resource curse hypothesis in Next Eleven countries. *Resources, Environment and Sustainability*, 4. https://doi.org/10.1016/j.resenv.2021.100018.

Rahman, M. and Velayutham, E. (2020) 'Renewable and non-renewable energy consumption-economic growth nexus: New evidence from South Asia', *Renewable Energy*, 147(2020), pp. 399–408. doi: 10.1016/j.renene.2019.09.007.

Roodman, D. (2009) 'How to do xtabond2: An introduction to difference and system GMM in Stata', *Stata Journal*, 9(1), pp. 86–136. doi: 10.1177/1536867x0900900106.

Sarpong, B. and Nketiah-Amponsah, E. (2022) 'Financial inclusion and inclusive growth in sub-Saharan Africa', *Cogent Economics and Finance*, 10(1). doi: 10.1080/23322039.2022.2058734.

Shahbaz, M., Raghutla, C., Chittedi, K. R., Jiao, Z., & Vo, X. V. (2020). The effect of renewable energy consumption on economic growth: Evidence from the renewable energy country attractive index. *Energy*, 207. https://doi.org/10.1016/j.energy.2020.118162.

Shahbaz, M., Song, M., Ahmad, S., & Vo, X. V. (2022). Does economic growth stimulate energy consumption? The role of human capital and R&D expenditures in China. *Energy Economics*, 105. https://doi.org/10.1016/j.eneco.2021.105662.

Sohag, K., Chukavina, K. and Samargandi, N. (2021) 'Renewable energy and total factor productivity in

OECD member countries', *Journal of Cleaner Production*, 296, p. 126499. doi: 10.1016/j.jclepro.2021.126499.

Topcu, E., Altinoz, B. and Aslan, A. (2020) 'Global evidence from the link between economic growth, natural resources, energy consumption, and gross capital formation', *Resources Policy*, 66(February), p. 101622. doi: 10.1016/j.resourpol.2020.101622.

Tzenios, N. (2019) 'The Impact of Health Literacy on Employee Productivity: An Empirical Investigation', *Empirical Quests for Management Essences*, 3(1), pp. 21–33. Available at: https://researchberg.com/index.php/eqme/article/view/83.

Di Ubaldo, M. and Siedschlag, I. (2021) 'Investment in Knowledge-Based Capital and Productivity: Firm-Level Evidence from a Small Open Economy', *Review of Income and Wealth*, 67(2), pp. 363–393. doi: 10.1111/roiw.12464.

Visconti, G. (2018) 'Global Economic Prospects: Recent developments in Sub-Saharan Africa', Springer *Climate*, pp. 117–132.

Waheed, R., Sarwar, S. and Wei, C. (2019) 'The survey of economic growth, energy consumption and carbon emission', *Energy Reports*, 5, pp. 1103–1115. doi: 10.1016/j.egyr.2019.07.006.

Wang, J., Zhang, S. and Zhang, Q. (2021) 'The relationship of renewable energy consumption to financial development and economic growth in China', *Renewable Energy*, 170, pp. 897–904. doi: 10.1016/j.renene.2021.02.038.

Wang, Q., Su, M., Li, R., & Ponce, P. (2019). The effects of energy prices, urbanization and economic growth on energy consumption per capita in 186 countries. *Journal of Cleaner Production*, 225, 1017–1032. https://doi.org/10.1016/j.jclepro.2019.04.008

Wang, Q. and Wang, L. (2020) 'Renewable energy consumption and economic growth in OECD countries: A nonlinear panel data analysis', *Energy*, 207, p. 118200. doi: 10.1016/j.energy.2020.118200.

Xia, C., Qamruzzaman, M. and Adow, A. H. (2022) 'An Asymmetric Nexus: Remittance-Led Human Capital Development in the Top 10 Remittance-Receiving Countries: Are FDI and Gross Capital Formation Critical for a Road to Sustainability?', *Sustainability* (Switzerland), 14(6). doi: 10.3390/su14063703.

Yang, B., Usman, M. and jahanger, A. (2021) 'Do industrialization, economic growth and globalization processes influence the ecological footprint and healthcare expenditures? Fresh insights based on the STIRPAT model for countries with the highest healthcare expenditures', *Sustainable Production and Consumption*, 28, pp. 893–910. doi: 10.1016/j.spc.2021.07.020.

Yang, M., Wang, E. Z. and Hou, Y. (2021) 'The relationship between manufacturing growth and CO2 emissions: Does renewable energy consumption matter?', Energy, 232, p. 121032. doi: 10.1016/j.energy.2021.121032.

Yong, J. Y., Yusliza, M. Y., Ramayah, T., Chiappetta Jabbour, C. J., Sehnem, S., & Mani, V. (2020). Pathways towards sustainability in manufacturing organizations: Empirical evidence on the role of green human resource management. *Business Strategy and the Environment*, 29(1), 212–228. https://doi.org/10.1002/bse.2359.

Zafar, M. W., Zaidi, S. A. H., Khan, N. R., Mirza, F. M., Hou, F., & Kirmani, S. A. A. (2019). The impact of natural resources, human capital, and foreign direct investment on the ecological footprint: The case of the United States. *Resources Policy*, 63. https://doi.org/10.1016/j.resourpol.2019.101428.

Zafar, M. W., Sinha, A., Ahmed, Z., Qin, Q., & Zaidi, S. A. H. (2021). Effects of biomass energy consumption on environmental quality: The role of education and technology in Asia-Pacific Economic Cooperation countries. *Renewable and Sustainable Energy Reviews*, 142. https://doi.org/10.1016/j.rser.2021.110868.

Zheng, J., Feng, G., Ren, Z., Qi, N., Coffman, D. M., Zhou, Y., & Wang, S. (2022). China's energy consumption and economic activity at the regional level. *Energy*, 259. https://doi.org/10.1016/j.energy.2022.124948.

Zia, S., Rahman, M. u., Noor, M. H., Khan, M. K., Bibi, M., Godil, D. I., Quddoos, M. U., & Anser, M. K. (2021). Striving towards environmental sustainability: how natural resources, human capital, financial development, and economic growth interact with ecological footprint in China.

Environmental Science and Pollution Research, 28(37), 52499-52513. https://doi.org/10.1007/s11356-021-14342-2.

Zyphur, M., Voelkle, M., Tay, L., Allison, P., Preacher, K., Zhang, Z., Hamaker, E., Shamsollahi, A., Pierides, D., Koval, P., & Diener, E. (2020). From Data to Causes II: Comparing Approaches to Panel Data Analysis. *Organizational Research Methods,* 23(4), 688-716. DOI: 10.1177/1094428119847280.