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Exploring Energy Transition-Longevity Nexus in Developing Countries Vulnerable to Climate Change

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Abstract. One of the topical global challenges that jeopardises achieving sustainable future is the increasing carbon emission from many developing countries due to poor environmental regulations, resources shortages and inadequate clean technology to derive an energy transition process, which reduces longevity. This study examines the effect of energy transition on life expectancy in low and lower-middle income developing countries heavily affected by numerous environmental calamities due to weak institutions and resource shortage. Also, the study examines the moderating role of institutional quality and income growth on the energy transition-longevity nexus. This study uses the Cross Section Autoregressive Distributive Lag (CS-ARDL) estimator, and the Dynamic Common Correlated Effect (DCCE) as a robust estimator. The study uses data from 60 countries, with available data from 1996 to 2022. The findings revealed that energy transition promotes an increase in life expectancy; higher institutional quality and income growth significantly enhance the positive effect of energy transition on longevity in the selected developing countries. The results from the robust estimator confirmed our result, except for the magnitude of the coefficients being higher in the CS-ARDL estimator. To increase the life expectancy in developing countries, policymakers should adopt energy transition wholistically as an important policy option so that to reduce environmental pollution and achieve a higher life expectancy.
Keywords: Renewable energy, air pollution, longevity, sustainability.

1. Introduction

Addressing the pressing global challenges of an infamous *Greenhouse Gas Emission* (GHG) that threatens sustainable development necessitates the current global call for a transition toward renewable energy such as solar, wind, hydropower, and geothermal power, as a significant policy tool to achieve carbon neutrality (Hmida & Rey, 2023).

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Human activities, along with non-renewable energy use, which formed more than 80% of energy use in the production process globally, continue to deplete our natural resources, pollute environment, displace millions of people and farm lands annually, while destroying biodiversity and the overall ecosystem. The 2023 Paris Conference (COP28) in Dubai was the biggest of all time (UN, 2024), which marked the end of the first 'global stock-take' to mitigate greenhouse emission, and achieved the target of carbon neutrality by 2050. However, the highlights of the COP28 reported slow commitments by the member countries, especially, by the poor(er) developing countries, in lowering GHG, enhancing resilience, and a failure was observed on the part of rich countries in providing financial and technological support to them, hence exacerbating the situation (UN, 2024). The compendium of the COP28 like all others in the recent past, maintained that adopting sustainable practices is not hindrance to economic prosperity, if countries can invest massively on the renewable energy sector, and clean technology, to expedite transition from fossil fuel to renewable energy.

Renewable energy is now at the forefront of the global call for energy transition to achieve carbon neutrality by 2050, and the urgent need to achieve sustainable development goals. Integration of clean energy sources – such as solar, wind, geothermal, and hydropower – is considered as a way out of the current global warning and pollution, which results from heavy and continuous reliance on fossil fuels by most developing and emerging markets in their attempt to achieve higher economic growth (Wang et al., 2023). When people have difficulty with getting efficient and affordable clean energy resources, they frequently turn to hazardous fossil fuels for their daily needs that exacerbate health issues such as respiratory and cardiovascular conditions due to air pollution, and waterborne infections caused by water pollution, which deteriorates life expectancy in developing countries. In contrast, industrialized countries have a greater level of life expectancy due to strong institutions, ideal infrastructures (e.g., better healthcare systems), resources, and technical know-how to undertake energy transition and mitigate the disastrous effect of air pollution (Hmida & Rey, 2023).

Energy transition from non-renewable to renewable sources directly or indirectly mitigate air, water and land pollution, which increases access to clean water, improves air quality, and promotes sustainable use of resources (Alavijeh et al., 2024). Thus, energy transition that can provide clean, renewable, and cost-effective energy will facilitate achieving sustainable development goals of good health and wellbeing (goal 3), affordable and clean energy (goal 7), and climate action (goal 13) – which promote quality living, and higher longevity (Aksan & Chakraborty, 2023). Despite the calls on transition to renewable energy at various regional and international environmental summits, nevertheless, developing countries continue to rely heavily on fossil fuels as major energy sources for industrial, as well as household cooking and heating. Also, many developing countries still practice bush-burning agriculture, indiscriminate dumping of refuse in land and waterways, and urban congestion, which contributes to the current level of environmental degradation, loss of biodiversity, and sustainable future (UN, 2024; Karaş, 2025).

Over 3.6 billion people are currently residing in regions that are extremely vulnerable to environmental disasters, heat waves, and poor air quality, which is expected to cause 250,000 additional deaths mostly in low-income developing countries, if the current GHG emission continues unchecked. In vulnerable parts of developing countries, the death rate from adverse weather conditions has increased nearly fifteen-fold over the last decade, due to extreme heat strokes, diarrhoea, asthmatic attacks, cardiovascular attacks, and draught (Bate & Rasmussen, 2023); as a result, life expectancy is significantly reduced, which harms progress in sustainability in developing countries. Even though most of the GHG emissions emanate not from low-income developing countries, they are mostly at the receiving ends in terms of its catastrophic effect, due to a shortage of resources and technical ability to mitigate its dangers, and undertake energy transition (Kamalu & Ibrahim, 2023). Moreover, energy transition to affordable renewable and sustainable energy is largely driven and facilitated by institutions, which can shape – either directly or indirectly – energy transition to achieve a higher life expectancy (Li et al., 2023).

This study examines the effect of energy transition on life expectancy (longevity) in developing countries. Achieving carbon neutrality through energy transition is one of the fundamentals of achieving 3 out of the 17 sustainable development goals believed to promote longevity, and the overall human development. However, available empirical findings present an opportunity to further explore the energy transition-life expectancy nexus due to inadequately thorough research in the area. In addition, this study explores the moderating role of quality institutions and per-capita income on the effect of energy transition on longevity in developing countries. Quality governance is an important determinant of energy transition, as it formulates and enforces regulatory laws and policies that will induce the use of clean technology in the production process, facilitates research and development, implements fiscal measures such as environmental tax(es), subsidy and concessions intended to encourage carbon emission abatement, and facilitate adoption of renewable energy for sustainable future, and consequently, for higher longevity.

Moreover, income per capita plays a significant role in shaping energy transition toward promoting higher life expectancy. Most developing countries have issues of a low income, and more pronounced income inequality, which results in energy poverty and inequality. Income growth increases energy consumption, and people with higher income consume more energy and can undertake energy transition than people with low income. Thus, this study argues that an increase in income may enhance the energy transition-longevity nexus in developing countries. This study seeks to make contribution to the literature in three vital ways. Firstly, this study examines the heterogenous dynamic relationship between energy transition and life expectancy in developing countries, and compare it with the developed countries. Secondly, this current study uses institutional quality and income per capita to moderate the energy transition-longevity nexus in developing countries. Thirdly, it uses the *Cross-Sectional Autoregressive Distributive Lag* (CS-ARDL) techniques, which provides short-run and long-run estimators, with the *Dynamic Common Correlated Effect* (DCCE) as a robust estimator. These methods produce efficient and consistent estimators as it solves the issue of endogeneity, and accounts for cross-sectional dependency (Chudik et al., 2016).

2. Literature Review

Theoretical literature explores the significance of energy transition to achieving sustainable health care outcomes globally (Li et al., 2023; Liu & Zhong, 2022; Majeed et al., 2021). The switch from fossil fuels to renewable energy sources is an essential way to slow down climate change and its harmful impacts on human health (Hernandez et al., 2020). The argument is that moving from energy that produces greenhouse gas to renewable energy that is considered to have a near-zero greenhouse emission can have a dramatic benefit on public health, which can subsequently have a significant effect on longevity (Aksan & Chakraborty, 2023). Increasing the adoption of renewable energy in manufacturing industries, transportation sector, and households can significantly reduce the incidences of cardiac disorders, respiratory illnesses, and other chronic health issues that result from environmental pollution (Liu & Zhong, 2022). In their study, (Kamalu & Ibrahim, 2023) argue that climate change is the apparent reality which continues to disrupt food and water supplies, biodiversity and natural habitats, which causes draught, rapid spread of infectious diseases, and intensifies natural disasters that endanger human well-being. (Azam et al., 2023) uphold the popular view that transitioning to renewable energy would drastically reduce the ever-increasing health sector expenditure, and thereby increase the longevity of the population.

Transition to renewable energy produces clean electricity with less damage on the environment, and enhances air quality, which can speed-up the achievement of the carbon neutrality target. Energy transition can mitigate the effects of climate change on vulnerable populations by limiting the devastating effect of global warming, and by enhancing life expectancy. When compared to the traditional power plants that use water for cooling, renewable energy technologies such as windmills, hydropower and solar power technologies, use less water, while being denoted by minimal and sustainable environmental degradation (Kabeyi & Olanrewaju, 2022). Adoption of sustainable energy sources greatly contributes to the preservation of water quality, saves aquatic habitats, and the incidence of waterborne diseases (Beka et al., 2024), which is crucial for maintaining healthy population. It curbs noise pollution as the traditional machines using fossil fuels make more noise than the clean technology which involves innovative machines with less noise; hence, better mental health outcomes, lower stress levels, and higher-quality sleep are achieved, which, in turn, increases life expectancy (Kalair et al., 2021).

In addition to boosting economic growth and lowering healthcare expenditure for treating diseases linked to air pollution and climate change, the use of renewable energy sources opens up employment opportunities, lessens socio-economic inequalities, and reduces energy poverty (Kamalu & Ibrahim, 2023). Due to its decentralised distribution nature, renewable energy sources can be relied upon even during natural disasters, grid collapses, wildfires, and tsunamis, so that the available health facilities can cater for emergencies (Sayed et al., 2021), and thereby promotes higher life expectancy.

Previous empirical studies examine how the effects of energy transition on longevity have been spurred by the swift global calls for transition to renewable energy as the most powerful tool to achieve sustainable development. Numerous empirical studies reveal how the adoption of renewable energy can have a positive impact on long life, and the overall human development. Studies like Ferhi and Helali (2024) found that renewable energy positively affects human development, healthy life and economic growth. By using the generalised method of the moment (GMM), Rahman and Sultana (2024) found no trade-off between quality environment and human development index in low income countries; hence, renewable energy improves environmental quality. Similarly, many studies reported a significant positive impact of renewable energy on human development (Adekoya et al., 2021; Azam et al., 2023; Hashemizadeh et al., 2022; Sasmaz et al., 2020; Wang et al., 2021).

Studies like Leitão (2024) used data from G7 countries and analysed with the Fully Modified OLS (FMOLS) and Dynamic OLS (DOLS). They found that renewable energy promotes clean air quality, and mitigates greenhouse emissions. Wang et al. (2023) found that there is a heterogenous impact of renewable energy on life expectancy in studies that involve 121 countries. The results show that the effect is stronger in higher-income countries than in lower-income countries. Similar studies carried out by Suryant and Patunru (2022) in Sub-Saharan Africa, Liu and Zhong (2022) in China, Rahman and Alam (2022) in Anzus Benelux countries, Majeed et al. (2021) in 155 countries of the world, Rodriguez-Alvarez (2021) in European countries found that energy transition promotes a higher life expectancy. In addition, Adom et al. (2021) show that renewable energy solved the issue of energy poverty, and that it greatly improves life expectancy, while also promoting human capital development. Others found that renewable energy promotes economic growth (Chen et al., 2022; Rusiadi et al., 2024; Wang, Dong et al., 2022; Wang et al., 2022). The study by Li et al. (2023) revealed that financial development and government financing of development projects promote energy transition.

Contrarily, studies like Rahman and Sultana (2024) reported a negative effect of renewable energy on human development. Adekoya et al.'s (2021) findings show that renewable energy does not promote human development in MENA and Western Hemisphere, while the impact is positive and insignificant in Africa. Zheng and Wang, (2022) reveal an insignificant impact of renewable energy and information technology on human development in the short- and long-run periods. Similarly, Ozcan and Ozturk (2019) show that renewable energy has a positive but insignificant effect on GDP per capita growth in emerging economies. Thus, the negative and positive coefficients of the renewable energy-life expectancy nexus led to inconsistent conclusion, which may be due to different methods, proxies, and study location.

3. Methodology

This study evaluates the effect of energy transition from non-renewable to renewable energy on life expectancy in 60 lower-middle and low-income developing countries, with available data from 1996 to 2022. The study selected 60 countries that have complete data, especially institutional data, whereas many countries with incomplete data such as Sudan, Afghanistan, Somalia, Yemen, and Central African Republic were dropped. The countries were selected based on the World Bank's income categorization of 2023. Also, the study examines the moderating role of institutional quality and income per capita on the energy transition-longevity nexus in developing countries. The study uses life expectancy as a dependent variable, and the energy transition proxy by renewable energy as a variable of interest. Based on the theoretical literature, we chose five control variables which include institutional quality, access to finance, non-renewable energy, government spending, and income growth. The data were obtained from the world development indicators (WDI), the World Bank database. Moreover, we employ the CS-ARDL estimator, and DCCE as a robust category, to estimate our models after performing the required diagnostic checks on the data.

Table 1. Measurements and sources of data

s/n	Variable	Measurements	Sources
1	Life expectancy (LE)	Life expectancy at birth	WDI
2	Energy Transition (RE)	Renewable energy consumption as a percentage of total energy consumption	WDI
3	Institutional quality (INQ)	The average of rule of law, control of corruption, and voice and accountability	WGI
4	Non-renewable energy (CO_2)	Total carbon emission (CO_2)	WDI
5	Access to finance (AF)	Number of bank accounts per 1000 people	WDI
6	Government spending (GE)	Government final consumption expenditure	WDI
7	Income Growth (INC)	GDP per capita growth	WDI

3.1. Methods of analysis

The Cross-Sectional Autoregressive Distributed Lag (CS-ARDL) approach has become a potent instrument for examining correlations between variables when dealing with panel data. This approach provides a strong framework that allows for the inclusion of endogeneity and cross-sectional dependence for estimating short- and long-run dynamics of a system of variables. Short-run dynamics refers to situation where some economic conditions are fixed, while all being varied in the long run. When studying relationships in heterogeneous panels, where variables may show varying degrees of integration or cointegration, the CS-ARDL technique works very well. Moreover, the approach is flexible in modelling the dynamic interactions between variables. Unlike traditional linear models, the CS-ARDL approach allows for the possibility of asymmetric responses, where the effects of positive and negative shocks on the dependent variable may differ in magnitude and direction, especially in the non-linear model. Thus, the CS-ARDL method provides consistent and efficient estimators when variables manifest a random walk, have a heterogenous slope, endogeneity and cross-sectional dependency (Chudik et al., 2016). The CS-ARDL model, as provided in Chudik et al. (2016) is given by the following:

$$y_{it} = \alpha_i + \sum_{j=1}^{p} \omega_{ij}\, y_{it-j} + \sum_{j=0}^{q} \beta_{ij}\, X_{it-j} + \sum_{j=0}^{r} \acute{\gamma}_{ij}\, \overline{W}_{it-j} + \mu_{it} \quad (1)$$

Equation (1) is the CS-ARDL model which includes the lagged dependent variable (y_{it-j}) as one of the regressors, and $\overline{W}_{it-j}$ is the cross-sectional averages of the regressors (X_{it-j}) and the lagged dependent variable (y_{it-j}) for the short run model.

Whereas,

$$X_{it} = (energy\ transition, institution\ quality_{it}, access\ to\ finance_{it}, carbon\ emission_{it},\ govt\ spending_{it}\ \ income_{it}) \quad (2)$$

$$\overline{W}_t = [\overline{\Delta energy\ transition_{it}}, \overline{\Delta institution\ quality_{it}}, \overline{\Delta access\ to\ finance_{it}}, \overline{\Delta carbon\ emission_{it}}, \overline{\Delta govt\ spending_{it}}, \overline{\Delta income_{it}}] \quad (3)$$

Equation (2) is the vector of the regressors, and Equation (3) is the vector of cross-sectional averages for the regressors, which determines the value of life expectancy (y_{it}) at birth.

4. Results and Discussions

The results of the descriptive statistics presented in Table 2 show that all the variables have an equal number of observations (1,620), with the mean value, minimum and maximum observations, as well as standard deviations that are within the range, without any outlier among the observations. In Table 3, the results of the Pesaran CD test rejected the null of cross sectional independence, and confirmed the existence of cross-section dependency in all the variables at 1% level of significance; hence, the only method that accounts for cross-sectional dependence will produce consistent estimators (Sarafidis & Wansbeek, 2012). Also, Table 3 presents the results of the Pesaran and Yamagata (2008) homogenous test, which failed to accept the null of homogenous slope at 1% level for all the variables; hence, our variables have heterogenous slope coefficients. In Table 4, the results of the stationarity tests conducted for the Maddala and Wu and CIPS tests failed to reject the null hypothesis of unit root at level, while failing to accept the same null of unit root at the first difference at 1%. The results reveal that all the variables are I (1), which means that all became stationary at the first difference. Moreover, the results of the panel cointegration test by Westerlund (2007) in Table 5 failed to accept the null of no cointegration in three out of the four statistics (Gt, Ga, & Pt) of the test, which confirmed that the variables have a long-run relationship; hence, they move together.

Table 2. Descriptive statistics

Variable	OBS	Mean	Std. Dev.	Min	Max
Life expectancy (LE)	1.620	4.196	0.014	4.129	4.253
Energy Transition (RE)	1.620	3.698	0.079	3.582	3.908
Institutional quality (INQ)	1.620	2.081	1.083	-5.757	5.769
Non-renewable energy (CO_2)	1.620	2.855	1.140	1.004	6.562
Access to finance (AF)	1.620	6.815	0.726	2.441	7.368
Government spending (GE)	1.620	3.397	1.055	2.737	7.475
Income Growth (INC)	1.620	0.621	0.147	0.227	0.948

Note. ***, ** & * stands for 1%, 5% and 10% significance levels.
Source: Authors' calculations

Table 3. Cross-section dependency test

Variables	Pesaran CD Test	Homogenous test	
Life expectancy (LE)	348.42***	Statistics	Value
Energy Transition (RE)	292.20***	**Delta**	41.43***
Institutional quality (INQ)	387.74***	**Adj.**	47.56***
Non-renewable energy (CO_2)	365.19***		
Access to finance (AF)	286.70***		
Government spending (GE)	369.48***		
Income Growth (INC)	385.89***		

Note. ***, ** & * stands for 1%, 5% and 10% significance level.
Source: Authors' calculations

Table 4. Stationarity tests

Variables	Maddala and Wu Test		CIPS Test	
	Level	First Difference	Level	First Difference
Life expectancy (LE)	61.04	398.09***	43.014	-11.23***
Energy Transition (RE)	134.23	415.32***	41.36	13.01***
Institutional quality (INQ)	93.45	196.02***	-54.07	11.58***
Non-renewable energy (CO_2)	75.89	294.20***	43.30	-3.25***
Access to finance (AF)	62.91	211.18**	-0.942	-7.34***
Government spending (GE)	93.45	221.86**	35.02	17.36**
Income Growth (INC)	560.39	1241.27***	41.50	14.36***

Note. ***, ** & * stands for 1%, 5% and 10% significance level.
Source: Authors' calculations

Table 5. Westerlund Panel Cointegration test

Statistics	Gt	Ga	Pt	Pa
Values	-2.65***	-4.89**	-6.23***	-1.624*

Note. ***, ** & * stands for 1%, 5% and 10% significance level.
Source: Authors' calculations

Table 6 presents the results of the three different models estimated with the CS-ARDL estimator. *Life Expectancy* (LE) is the dependent variable in all the three models. Model 1 is the basic model, Model 2 is the interaction model between institutional quality and energy transition (INQ*RE), and Model 3 is the interaction model between income per capita and energy transition (INC*RE). The results from Table 6 (Models 1–3) show that the lagged dependent variable [LE (-)] is statistically significant at 1%, which means that all the three models are dynamic; hence, the CS-ARDL method selected in this study is valid (Chudik et al., 2016). The results of the variable of interest (RE) in Model 1 are negative and significant at 1% in the short and long run, which shows that a 1% increase in energy transition will increase life expectancy by 0.49% (short run) and 0.15% (long run). These findings confirmed the results in Adom et al. (2021) and (Ferhi & Helali, 2024). Similarly, the findings justify the assertion that a reduction of carbon emission through transition to renewable energy will reduce environmental pollution, promote environmental quality, and increase life expectancy (Hmida & Rey, 2023; Inspire, 2023). The results of the control variables in Model 1 (Table 6) show that institutional quality (INQ), access to finance (AF), government spending (GE), and income per capita (INC) have positive and significant effect on longevity (LE) in developing countries (Sotiropoulou, 2025). While greenhouse gas emission has a negative and significant effect on longevity. However, the coefficients of the control variables show higher significance in the short run than in the long run.

Table 6. Results of the CS-ARDL models

Dependent Variable: LE	**CS-ARDL**		
Short Run			
Variables	Model 1	Model 2	Model 3
Lagged DV [LE (-)]	0.487***	0.513***	3.790***
Energy Transition (RE)	0.158**	0.920	0.212*
Institutional quality (INQ)	-0.632*	0.658	0.016**
Non-renewable energy (CO_2)	-0.342***	0.074	-2.420***
Access to finance (AF)	0.539*	0.368*	4.490
Government spending (GE)	0.051***	-0.431	1.250
Income Growth (INC)	0.438	-0.002**	0.113**
Interaction (INQ*RE)		0.074*	
Interaction (INC*RE)			-0.355
Error correction term [ECT (-)]	-0.008***	-0.004***	0.010**
Long Run			
Energy Transition (RE)	0.150***	0.332	-0.950*
Institutional quality (INQ)	0.882***	6.430**	0.343***
Non-renewable energy (CO_2)	-0.002*	0.052	-0.660
Access to finance (AF)	0.740**	-0.230*	0.343**
Government spending (GE)	0.457*	0.433**	0.510*
Income Growth (INC)	0.008**	0.220	0.787
Interaction (INQ*RE)		0.004**	
Interaction (INC*RE)			0.126**

Note. ***, ** & * stands for 1%, 5% and 10% significance level.

Source: Authors' calculations

The results of the interaction model (Model 2) in Table 6 reveals that interaction between institutional quality and energy transition (INQ*RE) is positive and significant in the short run (0.074) at 10% and long run (0.004) at 5% level of significance. These results indicate that institutional quality plays a significant role in enhancing the positive effect of energy transition on longevity in developing countries. Furthermore, the results of the interaction between income per capita and energy transition (INC*RE) show that the coefficients in the short run are negative and insignificant (-0.355) while positive and significant at 5% in the long run (0.126). The result reveals that an increase in the per-capita income conditioned the positive effect of energy transition on longevity in developing countries. The results are similar with the other findings in the literature (Ferhi & Helali, 2024; Wang et al., 2021). Moreover, the findings in Table 6 show that the error correction term [ECT (-)] is negative and significant (Models 1–2), while being positive and significant (Model 3), which indicates that deviation from long run equilibrium can be adjusted at the speed of 4% to 10% (1–2).

Table 7. Results of the DCCE method

Dependent Variable: LE	**DCCE**		
Variables	**Model 1**	**Model 2**	**Model 3**
Lagged DV [LE (-)]	-0.360**	0.494***	0.327***
Energy Transition (RE)	0.105**	0.722*	0.403
Institutional quality (INQ)	-0.082***	-0.110***	0.373
Non-renewable energy (CO_2)	-0.059**	-0.043*	-0.014*
Access to finance (AF)	0.780**	0.292	-0.127
Government spending (GE)	0.022	0.025	0.026
Income Growth (INC)	1.155**	0.182*	-0.550**
Interaction (INQ*RE)		0.086***	
Interaction (INC*RE)			-0.038*
Constant	0.303***	0.337***	0.442*

Note. ***, ** & * stands for 1%, 5% and 10% significance level.
Source: Authors' calculations

The results in Table 7 for Models 1–3 are estimated with the Dynamic Common Correlated Effect (DCCE) estimator proposed in (Chudik & Pesaran, 2015) as a robust methodology. The findings are similar with the findings estimated with the CS-ARDL methodology in Table 6, except for a few control variables. For instance, GE is positive and insignificant in Table 7, while being significant in Table 6. Moreover, the magnitude of the coefficients is higher for the CS-ARDL model for almost all the variables. However, the interaction between income per capita and energy transition (INC*RE) produced a negative and significant coefficient unlike in CS-ARDL models. Thus, the results of CS-ARDL are considered as more powerful than those of the DCCE estimators (Chudik et al., 2016).

5. Conclusion and Policy Implications

Based on the findings, we draw conclusions and provide policy implications

5.1. Conclusion

This study examines the effect of energy transition on longevity using data from 60 lower-middle and low-income developing countries from 1996 to 2022. In this current study, we evaluate the moderating role of institutional quality and income per capita on the energy transition-longevity nexus in developing countries. The CS-ARDL technique is used within this study, and the DCCE method is deemed as robust. The diagnostic tests carried out on the data indicated that the cross-sections have heterogenous slope coefficients, have significant cross-sectional dependency among them, and are cointegrated. The evidence from the CS-ARDL estimator reveals that energy transition promotes life expectancy in developing countries. Also, the institutional quality and income per capita enhances the positive effect of transition to renewable energy on longevity in developing countries.

5.2. Policy implications

Achieving clean and quality environment is the fundamental objective of all the national governments, regional and international agencies, as well as non-governmental organisations. Although developing countries emit low GHG to the ozone layer, the devastating effect of environmental pollution is more glaring in their countries than in the (more) developed ones due to low adoption of clean technology, heavy reliance on fossils fuels, poverty and income gap, urban congestion, illiteracy, weak environmental laws and their enforcement, and resource shortage to undertake large-scale investment in renewable energy sources. The outcomes of this study that energy transition from fossil fuel to renewable energy promotes a longer life expectancy in developing countries has broad policy implications. Despite the challenges of energy transition in developing countries, the findings of this study reveal that building strong institutions that can formulate better environmental policies, laws, and regulations, coupled with strict enforcement, will promote higher environmental quality, mitigate pollution, and promote energy transition for sustainable development.

Furthermore, the findings of this study suggest that the claim that income per capita enhances the positive effect of energy transition on longevity should be traded with caution. Income per capita depends on GDP growth, which is the product of an increase in the production of goods and services. Most of the low-income developing countries depend largely on extractive industries, manufacturing sectors, and foreign direct investment (FDI) to achieve higher economic growth. These kinds of industries in developing countries mostly use crude method of production, which pollutes the environment, and causes serious health issues annually. Therefore, income growth should stem from industries that uses clean technology, and the FDI that promotes environmental sustainability. Basically, policymakers should clearly define its environmental sustainability objectives, set clear and achievable transition targets, and educate people on the vital role of energy transition and sustainable practices in their life. They should also appropriate large capital to invest in transition infrastructures (solar, wind), attract green energy investment, incentivise industries that use clean and renewable energy, impose an appropriate environmental tax to achieve a 'double dividend', and regulate carbon trading efficiently. More importantly, it is the investment in research and development to evaluate the suitable and cost-efficient renewable energy for their environment. In addition, policymakers can reduce or remove subsidies on fossil fuel to reduce its consumption and promote adopting renewable energy to increase the life expectancy. They may introduce programs like targeted subsidies that can make companies and big businesses ineligible to enjoy fuel subsidies, which may compel them to use renewable and clean energy in their production processes.

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Appendix A

Table 1. List of selected countries

S/N	Countries	S/N	Countries	S/N	Countries	S/N	Countries	S/N	Countries
1	Angola	13	Haiti	25	Mauritania	37	Tajikistan	49	Ethiopia
2	Bangladesh	14	Honduras	26	Micronesia	38	Tanzania	50	Eritrea
3	Benin	15	India	27	Myanmar	39	Tunisia	51	Gambia
4	Bolivia	16	Jordan	28	Nepal	40	Uzbekistan	52	Guinea Bissau
5	Cabo Verde	17	Kenya	29	Nicaragua	41	Vietnam	53	Malawi
6	Cambodia	18	Kiribati	30	Nigeria	42	West Bank & Gaza	54	Mali
7	Cameroon	19	Kyrgyzstan	31	Pakistan	43	Zambia	55	Mozambique
8	Comoros	20	Lao PDR	32	Philippines	44	Djibouti	56	Rwanda
9	Congo	21	Lebanon	33	Senegal	45	Morocco	57	Niger
10	Egypt	22	Lesotho	34	Sri Lanka	46	Burkina Faso	58	Sierra Leone
11	Eswatini	23	Ghana	35	Honduras	47	Burundi	59	Togo
12	Ivory Coast	24	Guinea	36	Haiti	48	Chad	60	Uganda