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Renewable Energy Consumption and Health Outcomes: Evidence from Global Panel Data Analysis

Muhammad Tariq Majeed
School of Economics, Quaid-i-Azam University, Islamabad, Pakistan
Email address: tariq@qau.edu.pk

Tania Luni
School of Economics, Quaid-i-Azam University, Islamabad, Pakistan
Email address: tania_luni@yahoo.com

Gulreen Zaka
School of Economics, Quaid-i-Azam University, Islamabad, Pakistan
Email address: gulreenzaka@gmail.com

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Abstract

Energy consumption is an essential part of our daily lives and is considered the backbone of economic development and human welfare. It is widely admitted that energy security ensures access to health, higher efficiency, education, and economic growth. Energy consumption has a profound impact on human health depending on the source used for energy generation. The current study investigates the link between renewable energy and human health for 155 economies by employing panel techniques including pooled ordinary least squares, random effects, fixed effects, two-stage least squares, and generalized method of moments. Empirical findings support improved health from using renewable energy. Renewable energy increases life expectancy and decreases the mortality rate. The positive relationship between clean energy and human health suggests that clean energy helps to control chronic diseases thus leading to high life expectancy, low mortality, and fewer incidence of tuberculosis. It is further concluded that economic growth, trade, and urbanization also produce better health outcomes. The sensitivity analysis also endorses the robustness of the results. Therefore, countries should promote the use of renewable energy which not only improves health outcomes but also helps in achieving climate goals. This study is novel as previous studies ignored the empirical impact of renewable energy on health outcomes.

Keywords: renewable energy consumption, fossil fuel consumption, solid fuels consumption, life expectancy, mortality rate, tuberculosis, urbanization.

1. Introduction

Managing global health outcomes and environmental quality have become the most tenacious issues of the contemporary world. Global warming alters ecosystems and human settlements that threaten human health and well-being. Particularly, extreme weather events such as droughts, floods, heatwaves, and storms destroy millions of lives and livelihoods. Along with this, Gielen et al. (2019) asserted that changing temperatures create tropical diseases such as malaria, dengue fever, and Zika virus. Moreover, air pollution leads to 7 million deaths each year (IAEA, 2018) of which 4.3 million deaths result from household air pollution caused by the combustion of solid fuels and 3.7 million premature deaths caused by outdoor pollution resulting from transport, industry, and power plants (WHO, 2015). Given such a scenario, sustainable development goal 3 emphasizes the improvement in human health and wellbeing.

Climate change affects human health both directly and indirectly. The direct impacts include exposure to heat waves, respiratory and cardiovascular diseases, injuries and death because of extreme weather events such as droughts, floods, heat waves, storms, and wildfires. The indirect effects of climate change on health result from *"*ecological changes, such as food and water insecurity and the spread of climate-sensitive infectious diseases, and also to societal responses to climate change, such as population displacement and reduced access to health services*"* (WHO, 2018). Furthermore, an increase in the length of disease transmission and geographical range can be observed due to changing climatic conditions. Climate change is projected to cause 250,000 deaths per year between 2030 and 2050 due to malarial infection, diarrhea, heat stress and under nutrition (UN DESA, 2020).

The increasing use of conventional energy resources such as fossil fuel, gas, and coal has adverse effects on environmental quality and population health. Mainly, fossil fuel burning (WHO, 2015) is an important factor that comprises 60% of GHG emissions generated from the energy sector (UNDP, 2019). Energy supports basic human needs including heating, cooling, lightning cooking, mobility (Arto et al., 2016), education, employment, and agriculture (Irfan et al., 2019), which enhance human well-being and health status. Further, energy security ensures access to medical care and helps in performing various diagnostic procedures which play a pivotal role in improving health status. Energy is also required to preserve medicines, blood, and vaccines to keep people safe from infectious diseases (Taghizadeh-Hesary et al., 2020).

Along with supporting life, production and consumption of energy generated from conventional sources result in the release of toxins into the environment (Majeed et al., 2020) resulting in environmental deterioration (Majeed and Mazhar, 2019; Saboori and Sulaiman, 2013), ecosystem damage, water pollution (Akella et al., 2009; IAEA et al., 2005), global warming (Irfan et al., 2019; Markandya and Wilkinson, 2007), ozone depletion (Owusu and Asumadu-Sarkodie, 2016), acid precipitation, forest destruction, climate change (Dincer, 2000), and health deterioration (Doughterty et al., 2019). These toxins cause serious health problems including lung, respiratory (Markandya and

Wilkinson, 2007), skin diseases (IAEA et al., 2005), cardiovascular problems (Yu et al., 2018; Markandya and Wilkinson, 2007), mortality (Doughterty et al., 2019; WHO, 2018), morbidity (Kubatko and Kubatko, 2019), and cancer (Taghizadeh-Hesary et al., 2020). Therefore, controlling these emissions requires the availability of affordable clean energy sources.

The literature suggests both positive and negative effects of clean energy on human health. Renewable energy is a clean form of energy and its deployment supports economic growth, increases job availability, controls climate change, and air pollution (IRENA, 2019). Clean and efficient energy sources support human health by improving household cooking practices and mitigating indoor pollution (Ezzati and Kammen 2002; Woodcock et al., 2009; IEA et al., 2019). Further, renewable energy improves human health (Caruso et al., 2020) by supporting the environmental restoration, mitigating water pollution, and improving biodiversity (Haines et al., 2007; Hanif, 2018; Wang et al., 2019). Moreover, clean energy also influences human health by improving the access, price, supply and quality of food and nutrition (IRENA, 2018; FAO, 2018; UN DESA, 2020).

However, some studies also highlight the negative impact of renewable energy on health status by increasing noise pollution, hazard to eyesight from reflectors (solar), land subsidence (that affects life and livelihood), air pollution, aquifer contamination, flooding, and eutrophication (Patel and Shrivastava, 2009). The construction of dams for hydroelectricity generation also has adverse health effects (Haines et al., 2007). Hydropower dam leads to displacement of population, flooding of the natural environment, river body ecology, disturbs ecological continuity of sediment transport and fish migration through dam construction. When areas covered with trees are flooded due to dam construction it leads to methane formation (when plants start rotting) (Owusu and Asumadu-Sarkodie, 2016). Bioenergy can worsen soil, vegetation degradation related to the overexploitation of forest, too exhaustive crop and forest residue removal, and water overuse. Solar energy is land intensive (Capellán-Pérez et al., 2017). Despite these effects, the literature lacks empirical investigation of the impact of renewable energy on health.

Therefore, the current study examines the effects of renewable energy consumption on human health. The objective of the study is to check the effect of renewable energy consumption on health, whether the relationship is positive or negative, and what should be the concerned policies to overcome the health issues. This study is the first of its kind and contributes to the literature in the following ways: First, the study empirically investigated links between renewable energy and health. Second, the study used panel techniques to consider country-specific effects. Third, the study used a large panel of 155 countries to explore renewable energy-health nexus for 1990-2018. Fourth, to overcome the issue of heterogeneity regional dummy variables are incorporated. Fifth, to resolve the issue of endogeneity two-stage least squares (2 SLS), and generalized method of moments (GMM) are used which are ignored by the previous literature. Sixth, the study measures health outcomes using three proxies namely life expectancy, infant mortality, and incidences of tuberculosis. The study can be used to make policies to support the deployment of renewable energy sources and to decrease the negative impact of conventional energy sources and expenditures on health resulting from environmental degradation.

The study is organized in the following manner: Section 2 reviews the literature, section 3 explains the research methodology, empirical model, and data sources. Section 4 provides results and discussion and section 5 concludes the analysis and highlights the policy implications.

2. Literature Review

Theoretical foundations of this study are based on the health production model constructed by Grossman (1972). The model demonstrates the relationship between health inputs and outputs during a certain period. In a recent study, Majeed and Ozturk (2020) extends this model for the environment and health nexus, where environmental quality serves as input for health output. The role of the environment as input relies on sustainable development and ecological modernization theories. The sustainable development theory considers the utilization of finite resources in such a manner that natural resources are not depleted, and the need of future generations is not compromised. The sustainable use of natural resources, in turn, largely depends upon circular economy practices including the use of clean energy sources (Majeed and Luni, 2020). The increasing use of renewable energy helps to clean the atmosphere which plays a vital role in improving population health status (Majeed and Ozturk, 2020).

Ecological modernization theory suggests that initially increasing economic expansion owing to industrialization disrupts ecological quality. However, with further growing demand for the clean environment increases due to increasing public awareness about ecological quality. In the meantime, technological advancements also occur that support sustainable development practices through the adoption of green and eco-friendly technologies. In this scenario, the atmosphere tends to clean and improves health, happiness, and well-being (Majeed and Mumtaz, 2017; Majeed and Mazhar, 2019; Majeed and Tauqir, 2020).

The literature suggests links between energy and health through cooking energy practices. For example, Ezzati and Kammen (2002) reported reduction in respiratory infections in Kenya due to shifting in cooking patterns from wood to charcoal and kerosene. An increase in fuel efficiency and energy transition decreases indoor pollution and improves household health. In another study, Saldiva and Miraglia (2004) confer that long-term exposure to indoor pollution resulting from biomass cook stoves is associated with cardiovascular, respiratory, reproductive and cancer outcomes. Similarly, using "business-as-usual (BSU)" method for African economies, Bailis et al. (2005) suggest that mortality could reach 9.8 million premature deaths by 2030 resulting from indoor pollution.

Similarly, Woodcock et al. (2009) argue that lack of clean fuels and access to clean technologies for cooking results in poor health. Further, they argue that inefficient fuels increase women's workload and decrease their access to the job market. The use of wood, charcoal, coal, kerosene, animal (dung), and crop waste increases air pollution around the house. According to IEA et al. (2019), the population without access to clean cooking is almost 3 billion because of disproportional growth of population than that of growth in access to clean energy in Sub-Saharan Africa. Further, access to clean cooking technologies reduces 3.8 million premature deaths each year (women and children) from indoor air pollution. Contrary to this, clean cooking not only improves health but also saves time spent on the collection of wood or other biomass and the saved time could be used for earning and literacy (IEA *et al.*, 2019). The adverse effect of air pollution on health resulting from conventional sources includes airways inflammation, asthma development, pneumonia through impairment of immune system, anxiety, depression and mental disorders (Taghizadeh-Hesary et al., 2020).

Energy also affects human health by influencing the access, price, supply and quality of food and nutrition. For example, food losses (particularly in developing countries) are increased due to a lack of access to modern and clean energy for storage, processing, transportation, and distribution. Further, energy prices affect food production (inputs), food prices, and time spent by women on household tasks which can free up time for economic activities through the provision of clean energies (IRENA, 2018). The concentration of CO_2 emissions in the atmosphere increases foodborne pathogens by reducing the nutritional value of crops. Further, chemical changes increase the concentration of toxic compounds in agricultural products (FAO, 2018; UN DESA, 2020).

Non-renewable energy consumption increases water insecurity by polluting the water and limiting the supply of clean and safer water. Water insecurity, in turn, has a direct impact on health such as it leads to the outbreak of infectious diseases, and food insecurity. This food insecurity results in "growth defects, developmental abnormalities, or micronutrient deficiency, causing various chronic disorders and also leads to anxiety and depression during pregnancy" (Taghizadeh-Hesary et al., 2020).

Furthermore, renewable energy reduces the burden caused by volatile energy prices as renewable energy is sustainable and countries can generate energy within national boundaries instead of importing thereby decreasing foreign energy and oil dependence and releasing burden on foreign reserves that can be used for better health infrastructure. The use of renewable resources leads to a decline in the thermal population caused by conventional energy sources (Majeed and Luni, 2019). Renewable energy helps in ensuring energy security through increasing access and decreasing energy poverty. The findings of Hanif (2018) provide evidence on the beneficial impact of renewable energy in decreasing mortality and tuberculosis cases in Sub-Saharan Africa.

Along with the positive impact of renewable energy on health some studies also reported the negative impact of renewable energy on health (Capellán-Pérez et al., 2017; Smith et al., 2013; Patel and Shrivastava, 2009). The concern related to solar energy is based on the life cycle of Photovoltaic cells (PV). The mining of silica used in PV is associated with silicosis (pneumoconiosis), and PV manufacturing leads to exposure to toxic metals. Biofuel production leads to a "food versus fuel dilemma", furthermore increasing food prices also threatens the nutritional status of the population facing food insecurity. Biofuel production also leads to freshwater depletion (which can be used for drinking and other uses), water pollution, deforestation, loss of wildlife habitat, and ecosystem damage. Hydropower dam leads to population displacement, infectious disease risk, and disaster associated with dam failure. Wind power is associated with noise pollution causing annoyance, sleep disturbance, and reduced quality of life (Smith et al., 2013).

The empirical literature reports mixed evidence on energy and health nexus. Some studies suggest the health deteriorating effect of energy use. For example, Youssef et al. (2016) supported the strong relationship between energy consumption and health outcomes for 16 African countries over the period 1971-2010. Improving energy efficiency results in a decline in under 5 child mortality and increasing life expectancy. Ensuring access to energy support heating and have positive health effects and reduce school absentees (as children are affected due to poor air quality at home resulting from biomass use). The use of green technologies can improve health conditions in the face of increasing energy demands. Arawomo et al. (2018), also reported increasing death rate and disease incidence in Sub Saharan African economies over the period 1990-2014, owing to their higher dependencies on biomass energy. Similarly, the study of Hanif (2018) discussed that solid fuel and fossil fuel combustion not only increase emissions but also adversely affect health in Sub-Saharan African economies. Therefore, to decrease the emissions clean cooking facilities need to be used which will decrease individual exposure to poisonous gases.

Some studies do not confirm a significant impact of energy on health status. For example, Lim et al. (2012) analyzed the major reason behind the increase in global disease burden in 21 regions between 1990-2010 attributable to 67 risk factors. The three leading factors in global disease burden include high blood pressure, tobacco smoking, and household air pollution from solid fuels in 2010. In 1990 household air pollution from solid fuels was the second major reason behind the increase in global disease burden. Their findings, however, do not support any causality from energy consumption to life expectancy. Similarly, Bayati et al. (2013), reported an insignificant effect of emissions on health in the "Eastern Mediterranean region" for the period 1995-2007.

The above literature review suggests that the literature on health and energy is limited and most of the studies are qualitative and provide evidence from a case study. None of the studies has provided global evidence. The studies mainly focus on nonrenewable energy to explain health outcomes. To the best of the authors' knowledge, the empirical evidence on renewable energy and health outcome is not yet explored. Moreover, the literature predicts quite diverse relationships between energy and health status and therefore empirical analysis is necessary to determine the actual relationship.

3. Methodology and Data

3.1 Theoretical Framework

This study used Grossman's (1972) demand model for health. Grossman's (1972), model is based on the assumption that "health is a capital good". Individuals are born with an initial inventory of health which depreciates over time and health can be improved through the consumption of medical care (Bayati et al., 2013) and improvement in environmental quality (Majeed and Ozturk, 2020). Decrease in health inventory results in death. The health production function can be depicted as

$$H = f(X) \qquad (a)$$

Where, H denotes the measure of health which has been used as a proxy of health outcome and X provides a set of factors determining health, such as earnings, education, health costs, and environment. To conduct a macro-level analysis, the term x can be divided into three sub-sections economic, social and environmental factors (Fayissa and Gutema, 2005).

$$H = f(Y, S, V) \qquad (b)$$

In this study, Y is a vector of economic variables (Gross domestic product per capita and trade), S is a vector of social variable (urbanization) and V is a vector of environmental factors (renewable energy consumption). To control heterogeneity among cross-sectional units, global regional dummies are incorporated in the model.

3.2 Empirical Methodology

The relationship between renewable energy consumption and human health has become an interesting issue after the health crisis of 2018 reported by WHO (2018). Therefore, this study empirically investigated the impact of renewable energy on human health. Life expectancy at birth, infant mortality rate, and incidence of tuberculosis are used as proxies for human health because of their aggregated measure at an individual level (Babones, 2008). Literature also supports these three proxies as a measure of health (Siddique et al., 2018). Renewable energy consumption is used to examine the impact of clean energy on human health, along with energy other factors determining human health includes gross domestic product per capita, trade, and urbanization. The models constructed to describe the impact of renewable energy on health are given below:

$$LE_{it} = \alpha_0 + \alpha_1 lRE_{it} + \alpha_2 lGDP_{it} + \alpha_3 lTR_{it} + \alpha_4 UR_{it} + Z_i + u_t + v_i + \varepsilon_{it} \qquad (1)$$

$$MR_{it} = \alpha_0 + \alpha_1 lRE_{it} + \alpha_2 lGDP_{it} + \alpha_3 lTR_{it} + \alpha_4 UR_{it} + \alpha_5 FS_{it} + Z_i + u_t + v_i + \varepsilon_{it} \qquad (2)$$

$$lTC_{it} = \alpha_0 + \alpha_1 lRE_{it} + \alpha_2 lGDP_{it} + \alpha_3 lTR_{it} + \alpha_4 UR_{it} + Z_i + u_t + v_i + \varepsilon_{it} \qquad (3)$$

Where dependent variables LE, MR, and TC represent life expectancy, mortality rate and tuberculosis, respectively. The independent variable RE, GDP, TR, UR, and FS denote renewable energy consumption, gross domestic product per capita, trade, urbanization, and female education. Z_i represents a row vector of regional dummy variables. The notation "l" indicates log transformation. The notation ν_i captures the country-specific unobservable effects while μ_t captures the temporal effects. The term ε_{it} is the error term. The description of variables used is provided in Table 1.

Renewable energy has been converted into per capita following Rahman and Velayutham (2020), for this purpose the variables used are energy use per capita (kg of oil equivalent) and total population. In the first step total energy consumption is obtained by using the following formula:

$$Total\ Energy\ Consumption = Energy\ Use * Total\ Population$$

After calculating total energy consumption, total renewable energy consumption is calculated as follows:

$$Total\ renewable\ energy\ consumption = \frac{(Total\ energy\ consumption * Renewable\ energy\ consumption)}{100}$$

Renewable energy consumption per capita is obtained by dividing total renewable energy consumption with total population:

$$Renewable\ energy\ consumption = \frac{(Total\ renewable\ energy\ consumption)}{Total\ Population}$$

The data is extracted from World Bank (2019), and analysis is based on 155 countries for 1990-2018. The relationship between renewable energy consumption and human health has been explored using panel techniques including pooled OLS (POLS), fixed effects (FE), and random effects (RE). The reason behind using different panel techniques is the ability of each technique to account for different problems. As pooled estimations do not account for country-specific and time-specific effects, FE and RE models are used. RE considers the absence of correlation between regressors and the error term however in the presence of such correlation results will be misleading. Therefore, FE is used to account for such correlation. FE controls the effect of time-invariant characteristics which remain unchanged overtime while vary across countries. The existence of a bidirectional relationship between the independent and dependent variable leads to reverse causality and estimates obtained will be biased. Therefore, to account for possible simultaneity, 2SLS and GMM have been used. 2SLS provides efficient results in the presence of endogeneity. The validity of the instruments is examined using Sargan and Basmann score. 2SLS is appropriate in the absence of heteroscedasticity. Therefore, to overcome endogeneity and heteroscedasticity GMM is used. The validity of the instruments used in GMM is examined with Hansen's Score.

Table 1: Variable Description

Variables	**Definition of Variables**	**Measurement**	**Source**
Life Expectancy	"Life expectancy (at birth) tells us the number of years a newborn infant could live when prevailing patterns of mortality at the time of birth were to stay the same in its whole life".	"Total years"	World Bank, 2019
Mortality Rate	"Infant mortality is the death of young children under the age of 1. This death toll is measured by the infant mortality rate, which is the number of deaths of children under one year of age per 1000 live births".	"Per 1000 live births"	World Bank, 2019
Tuberculosis Incidence	"It is the estimated number of new and relapse tuberculosis cases arising in a given year, expressed as the rate per 100,000 population".	"per 100,000 people"	World Bank, 2019
Independent Variables (Focused Variables)			
Renewable Energy Consumption	"Renewable energy consumption is the share of renewable energy in total final energy consumption".	"% of total final energy consumption"	World Bank, 2019
Independent Variables (Control Variables)			
Trade	"Sum of exports and imports of goods and services measured as a share of GDP."	"% of GDP"	World Bank, 2019
Urbanization	"Urban population refers to people living in urban areas".	"% of the total"	World Bank, 2019
GDP per capita	"GDP per capita is gross domestic product divided by midyear population".	"Constant of 2010 US$"	World Bank, 2019
Female education	"Net enrollment rate is the ratio of children of official school age who are enrolled in school to the population of the corresponding official school age. Secondary education completes the provision of basic education that began at the	"% net"	World Bank, 2019

	primary level, and aims at laying the foundations for lifelong learning and human development, by offering more subject- or skill-oriented instruction using more specialized teachers”.		
	Other Variables		
Foreign direct investment, net inflows	“It shows net inflows (new investment inflows less disinvestment) in the reporting economy from foreign investors and is divided by GDP”.	“% of GDP"	World Bank, 2019
Education	“Secondary education completes the provision of basic education that began at the primary level and aims at laying the foundations for lifelong learning and human development, by offering more subject- or skill-oriented instruction using more specialized teachers”.	"% gross"	World Bank, 2019
Physicians	“Physicians include generalist and specialist medical practitioners”.	"Per 1,000 people"	World Bank, 2019
Nuclear energy	“Electricity generated by nuclear power plants”.	“% of total”	World Bank, 2019
Fossil fuel energy	“Fossil fuel comprises coal, oil, petroleum, and natural gas products”.	“% of total”	World Bank, 2019
Solid fuel emissions	“Carbon dioxide emissions from solid fuel consumption refer mainly to emissions from use of coal as an energy source”.	“% of total”	World Bank, 2019
Access to Clean fuels	“Access to clean fuels and technologies for cooking is the proportion of total population primarily using clean cooking fuels and technologies for cooking. Under WHO guidelines, kerosene is excluded from clean cooking fuels”.	“% of population”	World Bank, 2019

Oil, coal and gas electricity	“Electricity generated from oil, coal, and gas. Oil refers to crude oil and petroleum products. Gas refers to natural gas but excludes natural gas liquids. Coal refers to all coal and brown coal, both primary and derived”.	“% of total”	World Bank, 2019

3.3 Descriptive Statistics

Descriptive statistics of the variables are given in table 2 and is based on cross-sectional averages over the study period. The maximum life expectancy is in Japan, which is 81.688 years, whereas Nigeria has a minimum life expectancy of 48.768 years. The mortality rate is highest in Sierra Leone which is 124.4517 deaths per 1000 live births while the lowest in Iceland. The incidence of tuberculosis is highest in Eswatini with 1104.947 per 100,000 people and lowest in San Marino with 0.6473 per 100, 000 people. Renewable energy consumption per capita (kg of oil equivalent) has the highest value of 8124.116 per capita for Iceland. Luxembourg has the largest GDP (per capita) of 93929.97 US dollars and the lowest of 287.9805 US dollars for Ethiopia. Trade has a maximum value of 353.847 (% of GDP) for the Singapore whereas the minimum value of 20.0292 (% of GDP) for Myanmar. Urbanization has the highest value of 100 (%) in Singapore, and the lowest value of 14.520 (%) in Nepal. Female education (secondary education) is the highest in Israel with a value of 99.756 (%) while the lowest in South Sudan with a value of 4.293 (%). Foreign direct investment is highest in the Cayman Islands while lowest in Suriname. Cuba has 6.232, the highest number of physicians per 1000 people while its lowest in Malawi. Education (Secondary school) is maximum in Belgium.

Table 2: Descriptive Statistics

Variable	Observations	Mean	Std. Deviation	Minimum	Maximum
Dependent Variables					
Life Expectancy	155	69.43742	8.412277	48.76838 **Nigeria**	81.68843 **Japan**
Mortality	155	34.18406	29.20394	2.944828 **Iceland**	124.4517 **Sierra Leone**
Tuberculosis	155	131.3549	188.887	0.6473684 **San Marino**	1104.947 **Eswatini**
Independent Variable					
Renewable Energy Per Capita	155	332.1068	736.6808	0 **Antigua & Barbuda** **Bahrain** **Oman** **Qatar**	8124.116 **Ice Land**
Control Variables					
GDP Per Capita	155	12672.25	17303.21	287.9805 **Ethiopia**	93929.97 **Luxembourg**
Trade	155	88.95565	50.83516	20.02925 **Myanmar**	353.8479 **Singapore**
Urbanization	155	57.18705	21.96715	14.52097 **Nepal**	100 **Singapore**
Female Education	155	64.98449	27.25022	4.293985 **South Sudan**	99.75603 **Israel**
Foreign Direct Investment	155	9.628448	50.63249	-2.833412 **Suriname**	573.3492 **Cayman Island**
Physicians	155	1.468429	1.316911	0.0212667 **Malawi**	6.232666 **Cuba**
Education	155	72.53955	30.17804	5.93235 **Somalia**	148.9943 **Belgium**

3.4 Correlation Matrix

Table 3 displays the correlation matrix. The results illustrate that life expectancy has a positive correlation of 0.222 with renewable energy consumption, while mortality rate and tuberculosis have a negative correlation of 0.177 and 0.103 with renewable energy. The correlation of life expectancy, child mortality, and incidence of tuberculosis with GDP per capita, trade, and urbanization is also weak suggesting there is no problem of multicollinearity. Our results are consistent with the findings of Hanif (2018).

Table 3: Correlation Matrix

Variables	Life Expectancy	Mortality Rate	Tuberculosis	Renewable Energy Per Capita	GDP	Trade	Urbanization	Female Education
Life Expectancy	1.000							
Mortality Rate	-0.888	1.000						
Tuberculosis	-0.757	0.616	1.000					
Renewable Energy Per Capita	0.222	-0.177	-0.103	1.000				
GDP Per Capita	0.606	-0.536	-0.348	0.323	1.000			
Trade	0.169	-0.253	-0.107	-0.033	0.319	1.000		
Urbanization	0.715	-0.712	-0.541	0.218	0.554	0.156	1.000	
Female Education	0.795	-0.898	-0.501	0.151	0.506	0.232	0.673	1.000

4. Results and Discussion

4.1 Pooled OLS Results

Table 4 presents the results obtained from POLS. The results support the positive impact of renewable energy consumption on life expectancy. Column 1 illustrates that a 1% increase in renewable energy consumption (per capita) causes an increase of 0.357 years in life expectancy. Our results are consistent with Hanif (2018) who also documented the positive effect of renewable energy on health outcomes as renewable energy decreases mortality and incidence of tuberculosis. Wang et al. (2019) also supported a decline in maternal mortality resulting from the use of clean technologies in China. Renewable energy improves life expectancy by lowering carbon emissions in the atmosphere. Renewable energy does not burden the environment which enhances health quality but in contrast environmental pollution adversely affects the quality of life (Woodcock et al., 2009; Lim et al., 2012; Majeed and Ozturk, 2020). The coefficient of GDP per capita is also positively significant and reveals that a 1% increase in GDP per capita will bring 3.036 years increase in the life expectancy at birth. An increase in income leads to an increase in the human ability to improve consumption, access to health and education, and decrease dependency ratio, while lower GDP leads to higher dependency ratio, child mortality, high fertility, poor health, lack of access to education, “impaired cognitive capacity” and lower productivity (IMF, 2004). This finding is consistent with Majeed and Liaqat (2019) who found similar effect for 180 countries. Meer et al. (2003) also support positive effect of wealth on health.

The coefficient of trade is positive and significant suggesting an increase of 0.712 years in life expectancy. Trade supports the inflow of modern knowledge and technologies to improve health. This finding is, however, inconsistent with Qadir and Majeed (2018) who found a negative effect of trade on health for Pakistan. Urbanization will improve life expectancy by 0.0175 years respectively. Our results are in line with the findings of Bayati et al. (2013) who supported improved health in urban areas resulting from better access to medical care, and health information while it is in contrast to Sundquist et al. (2004) who reported an increase in psychosis and depression associated with a higher level of urbanization in Sweden. Likewise, Majeed and Ajaz (2018) reported deteriorated health quality in in a global sample of 61 countries. Regional dummies have been incorporated in the model to control regional heterogeneity and to check the sensitivity of the results. Columns 2-4 presents the results obtained from sensitivity analysis. The results suggest that our model is stable and not sensitive even after controlling for foreign direct investment, number of physicians, and level of education.

Table 4: Pooled OLS Results and Sensitivity Analysis of Life Expectancy

Variables	**(1)**	**(2)**	**(3)**	**(4)**
Dependent Variable: Health (Life expectancy)				
Renewable energy per capita	0.357***	0.344***	0.452***	0.142**
	(0.057)	(0.058)	(0.058)	(0.065)
GDP per capita	3.036***	3.133***	3.162***	2.700***
	(0.091)	(0.093)	(0.095)	(0.099)
Trade	0.712***	0.867***	0.870***	0.491***
	(0.105)	(0.118)	(0.119)	(0.116)
Urbanization	0.0175***	0.0106*	-0.0169**	-0.00648
	(0.006)	(0.006)	(0.007)	(0.006)
Foreign direct investment		0.0120***		
		(0.004)		
Physicians			0.704***	
			(0.081)	
Education				0.0558***
				(0.004)
South Asia	0.388	-	0.568	-
	(0.654)	-	(0.647)	-
Europe & Central Asia	0.186	-0.299	-0.544	-0.712*
	(0.540)	(0.387)	(0.529)	(0.422)
East Asia & Pacific	1.005*	0.548	1.637***	-0.286
	(0.569)	(0.402)	(0.554)	(0.435)
Middle East & North Africa	1.243**	0.800*	2.095***	1.237**
	(0.604)	(0.459)	(0.601)	(0.494)
Sub-Saharan Africa	-11.80***	-12.21***	-10.52***	-10.63***
	(0.577)	(0.371)	(0.588)	(0.416)
Latin America & Caribbean	0.549	-0.0531	1.601***	1.284***
	(0.561)	(0.399)	(0.553)	(0.435)
North America	-	-0.383	-	-0.248
	-	(0.652)	-	(0.661)
Constant	39.56***	38.93***	38.04***	41.99***
	(0.930)	(0.763)	(0.932)	(0.757)
Observations	3148	3041	2187	2326
R^2	0.821	0.826	0.810	0.835
Adjusted R^2	0.821	0.826	0.809	0.834
F-stats	1439.72***	1309.64***	842.20***	1065.66***
Standard errors in parentheses * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$				

We have also examined the impact of renewable energy on the mortality rate (second proxy of health). Table 5 presents the results obtained from the POLS technique. Renewable energy consumption appears with a negative sign which is according to the theory however the coefficient is insignificant. Higher income supports a decrease in child mortality (IMF, 2004). As higher income improves dietary patterns and access to health and education along with the awareness that leads to a decrease in mortality rate. Our results are consistent with Majeed and Liaqat (2019) who documented a decline in mortality resulting from an increase in GDP per capita. Trade also decreases child mortality due to the flow of new technologies and better health facilities thus improving health. Urbanization is associated with an increase in mortality rate consistent with the findings of Hanif (2018). Urban sprawl leads to an increase in the consumption of natural resources thereby leading to negative health effects. Female education contributes to decline in infant mortality.

The results remain the same even after the inclusion of foreign direct investment and physicians. The overall R^2 is 0.85 which shows that 85% variation in infant mortality is explained by the independent variables.

Table 5: Pooled OLS Results and Sensitivity Analysis of Mortality Rate

Variables	(1)	(2)	(3)
Dependent Variable: Health (Mortality Rate)			
Renewable energy per capita	-0.178	-0.199	0.223
	(0.219)	(0.224)	(0.165)
GDP per capita	-5.614***	-5.750***	-4.921***
	(0.346)	(0.353)	(0.268)
Trade	-1.375***	-1.703***	-1.330***
	(0.377)	(0.395)	(0.296)
Urbanization	0.0785***	0.0875***	0.0373*
	(0.023)	(0.023)	(0.019)
Female education	-0.519***	-0.517***	-0.496***
	(0.020)	(0.021)	(0.019)
Foreign direct investment		0.00256	
		(0.011)	
Physicians			-0.831***
			(0.209)
South Asia	-	-	2.645
	-	-	(2.191)
Europe & Central Asia	-4.812***	-4.612***	-0.996
	(1.778)	(1.784)	(1.672)
East Asia & Pacific	-5.028***	-4.979***	-2.318
	(1.764)	(1.765)	(1.781)
Middle East & North Africa	-9.200***	-8.422***	-2.320
	(2.094)	(2.118)	(1.955)
Sub-Saharan Africa	3.862**	4.006**	4.406**
	(1.743)	(1.747)	(2.017)
Latin America and Caribbean	-11.47***	-10.83***	-8.151***
	(1.754)	(1.758)	(1.770)
North America	-2.788	-2.782	-
	(3.007)	(3.009)	-
Constant	116.1***	118.0***	106.2***
	(2.699)	(2.747)	(2.734)
Observations	1270	1238	960
R^2	0.850	0.851	0.885
Adjusted R^2	0.849	0.850	0.883
F-Stats	650.53***	585.25***	606.99***
Standard errors in parentheses * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$			

The study also examined the impact of renewable energy on the incidence of tuberculosis (third proxy of health). Table 6 presents the results obtained from the POLS technique. Renewable energy consumption has a negative and significant effect on the incidences of tuberculosis. The coefficient of renewable energy consumption (per capita) illustrates that a 1% increase in renewable energy consumption (per capita) will lead to a decline in incidences of tuberculosis by 0.048 percent. Similarly, Hanif (2018) also suggests a decline in incidences of tuberculosis resulting from renewable energy consumption in Sub-Saharan Africa. As renewable energy leads to the substitution of fossil fuels, pollutants associated with conventional energy sources are mitigated and the health status of individuals improve (Dougherty et al., 2019; Khan et al., 2020). Green technologies improve environmental quality through emission reduction; therefore, the loss of life and the spread of diseases can be avoided associated with poor air quality (Taghizadeh-Hesary et al., 2020). Hanif (2018) reported a decline in the incidence of tuberculosis from a rise in income in developing economies, lower-middle-income, and low-income economies. As higher income improves dietary patterns and access to health and education along with the awareness that leads to a decrease in mortality rate. The coefficient of trade is insignificant. Urbanization contributes to an increase in incidences of tuberculosis consistent with the findings of Hanif (2018). Urban sprawl leads to an increase in energy and natural resource consumption thereby leading to negative health effects.

The results remain consistent even after controlling for the effect of foreign direct investment, physicians, and education. The overall R^2 is 0.68 which shows that 68% variation in incidences of tuberculosis is explained by the independent variables.

Table 6: Pooled OLS Results and Sensitivity Analysis of Tuberculosis

Variables	(1)	(2)	(3)	(4)
Dependent Variable: Health (Tuberculosis)				
Renewable energy per capita	-0.0488***	-0.0532***	-0.0601***	-0.0622***
	(0.016)	(0.016)	(0.017)	(0.020)
GDP per capita	-0.763***	-0.771***	-0.751***	-0.720***
	(0.026)	(0.026)	(0.028)	(0.031)
Trade	0.0257	0.0191	0.00196	-0.00906
	(0.031)	(0.031)	(0.033)	(0.035)
Urbanization	0.0116***	0.0128***	0.00799***	0.0113***
	(0.001)	(0.001)	(0.002)	(0.002)
Foreign direct investment		-0.00241**		
		(0.0009)		
Physicians			-0.119***	
			(0.024)	
Education				-0.00185
				(0.001)
South Asia	1.336***	1.358***	0.977***	-
	(0.189)	(0.187)	(0.195)	-
Europe & Central Asia	0.670***	0.689***	0.748***	-0.757***
	(0.156)	(0.155)	(0.162)	(0.126)
East Asia & Pacific	1.554***	1.563***	1.417***	0.236*
	(0.164)	(0.163)	(0.169)	(0.130)
Middle East & North Africa	-0.260	-0.266	-0.494***	-1.656***
	(0.175)	(0.173)	(0.182)	(0.149)
Sub-Saharan Africa	1.671***	1.687***	1.360***	0.107
	(0.167)	(0.166)	(0.178)	(0.121)
Latin America & Caribbean	0.258	0.323**	0.114	-1.207***
	(0.162)	(0.161)	(0.171)	(0.128)
North America	-	-	-	-1.469***
	-	-	-	(0.203)
Constant	9.129***	9.188***	9.717***	10.55***
	(0.271)	(0.270)	(0.276)	(0.233)
Observations	2012	1986	1401	1535
R^2	0.689	0.694	0.735	0.689
Adjusted R^2	0.687	0.693	0.733	0.687
F-Stats	443.13***	407.72***	349.55***	307.44***
Standard errors in parentheses * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$				

4.2 Fixed and Random Effects Result

The base of a random effect is an assumption that says, there is no correlation between country-specific features (taken randomly) and the regressors (correlation Xi and ui=0). In contrast, fixed effects assume country-specific feature's correlation. Table 7 presents the results obtained from fixed and random effects estimation of life expectancy. Signs of all the coefficients are according to the expectations and significant which suggest that renewable energy improves life expectancy and decreases mortality rate.

An increase in renewable energy consumption per capita will lead to an increase in life expectancy by 0.335 years in fixed and 0.383 years in random-effects results. Columns 1 and 2 highlight that an increase in GDP per capita, trade, and urbanization is associated with higher life expectancy. Thus, the availability of better health infrastructure and facilities leads to improvement in life expectancy. The value of R^2 indicates that a 53% variation in life expectancy is explained by the independent variables in our model.

For model selection, the Hausman test is applied which checks if there is a systematic difference among the coefficients. The rejection of null supports fixed effects. Thus country-specific features play an essential part in the explanation of the relationship between life expectancy and renewable energy consumption.

Table 7: Fixed and Random Effects Results of Life Expectancy

Variables	**FE**	**RE**
Dependent Variable: Health (Life expectancy)		
Renewable energy per capita	0.335^{***}	0.383^{***}
	(0.0889)	(0.0870)
GDP per capita	4.905^{***}	4.639^{***}
	(0.161)	(0.157)
Trade	0.136	0.204^{**}
	(0.0882)	(0.0889)
Urbanization	0.254^{***}	0.225^{***}
	(0.0108)	(0.0104)
Constant	10.27^{***}	14.10^{***}
	(1.129)	(1.169)
Observations	3148	3148
No of groups	154	154
R^2	0.537	0.551
Adjusted R^2	0.513	
F-stat / Wald chi^2	868.14^{***}	3432.43^{***}
Hausman Test	138.91^{***}	

Standard errors in parentheses * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$;
FE: Fixed effects; RE: Random effects

Table 8 presents the results obtained from fixed and random effects considering the mortality rate as a proxy of health. In table 8, column 1 presents the result obtained from the fixed effects-model and reveals that a 1% increase in renewable energy consumption (per capita) will increase infant mortality by 2.033 at a 1% level of significance. In column 2 results of the random effects-model disclose that a 1% increase in renewable energy consumption increases child mortality by 0.644 child per 1000. The overall R^2 shows that a 45% variation in infant mortality is explained by the independent variables of our model.

Table 8: Fixed and Random effects results of Mortality rate

Variables	FE	RE
Dependent Variable: Health (Mortality Rate)		
Renewable energy per capita	2.033***	0.644*
	(0.433)	(0.370)
GDP per capita	-17.36***	-10.48***
	(1.125)	(0.844)
Trade	0.126	-0.598
	(0.506)	(0.491)
Urbanization	-0.267***	-0.0103
	(0.0757)	(0.0530)
Female education	-0.240***	-0.410***
	(0.0338)	(0.0284)
Constant	200.3***	143.8***
	(7.959)	(5.266)
Observations	1270	1270
Number of groups	129	129
R^2	0.453	0.7346
Adjusted R^2	0.389	
F-stat/Wald chi ^{2}	188.08***	1209.23***
Hausman Test	120.79***	
Standard errors in parentheses* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$; FE: Fixed effects; RE: Random effects		

Table 9 presents the results obtained from fixed and random effects considering the incidence of tuberculosis as a proxy of health. The result obtained from the fixed effects model are presented in column 1 and reveals that a 1% increase in renewable energy consumption (per capita) is associated with a decrease in incidences of tuberculosis by 0.083 percent. The results obtained from the random effects model (in column 2) suggest that a 1% increase in renewable energy consumption causes a decline of 0.074 percent decline in incidences of tuberculosis. The overall R^2 suggests that a 17% variation in incidences of tuberculosis is explained by the independent variables. Hausman test supports fixed effects.

Table 9: Fixed and Random Effects Results of Tuberculosis

Variables	FE	RE
Dependent Variable: Health (Tuberculosis)		
Renewable energy per capita	-0.0839***	-0.0747***
	(0.0167)	(0.0162)
GDP per capita	-0.222***	-0.275***
	(0.0300)	(0.0289)
Trade	-0.0742***	-0.0694***
	(0.0172)	(0.0172)
Urbanization	-0.0207***	-0.0201***
	(0.00232)	(0.00215)
Constant	7.825***	8.151***
	(0.224)	(0.225)
Observations	2012	2012
No of groups	155	155
R^2	0.178	0.453
Adjusted R^2	0.108	
F-stat / Wald chi^2	100.61***	530.32***
Hausman Test	32.88***	
Standard errors in parentheses * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$; FE: Fixed effects; RE: Random effects		

4.3 Two-Stage Least Square (2SLS) and Generalized Method of Moments (GMM) Results

Table 7 presents the results of fixed effects, which incorporate country-specific factors, it does not account for time-invariant features of the countries. The 2SLS is used to combine these variables and it tackles endogeneity (Majeed and Ayub, 2018). Therefore, table 10 reports the results attained from the 2SLS and GMM. Renewable energy consumption plays an important role in enhancing human health which is directed by the positive and highly significant sign of the coefficient. Lagged values of independent variables have been incorporated as instruments. Sargan, Basmann, and Hansen tests are reported for the validity of the instruments. The p-value of both tests (Sargan, and Basmann) is greater than 5% authenticating the instruments used.

Table 10: 2SLS and GMM Results of Life Expectancy

Variables	2SLS	GMM
Dependent Variable: Health (Life expectancy)		
Renewable energy per capita	0.354***	0.359***
	(0.0589)	(0.0531)
GDP per capita	3.069***	3.034***
	(0.0936)	(0.103)
Trade	0.719***	0.729***
	(0.105)	(0.0901)
Urbanization	0.0130**	0.0148**
	(0.00626)	(0.00654)
South Asia	0.500	0.470
	(0.654)	(0.420)
Europe & Central Asia	0.173	0.156
	(0.538)	(0.202)
East Asia & Pacific	1.103*	1.110***
	(0.568)	(0.243)
Middle East & North Africa	1.349**	1.297***
	(0.604)	(0.292)
Sub-Saharan Africa	-11.97***	-12.06***
	(0.577)	(0.382)
Latin America & Caribbean	0.655	0.589**
	(0.561)	(0.265)
Constant	39.61***	39.77***
	(0.935)	(0.780)
Observations	2979	2979
R^2	0.827	0.827
Adjusted R^2	0.827	0.827
Wald chi^2	14271.72***	12726.12***
Hansen's score		3.492*
Sargan score	3.851*	
Basmann score	3.841*	
Standard errors in parentheses * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$		

Table 11 presents the results obtained from the 2SLS and GMM considering mortality rate as the dependent variable. Column 1 presents the result obtained from the 2SLS and reveals a 1% increase in renewable energy consumption (per capita) will lead to a decline in mortality rate by 0.661 infants per 1000 live births. This finding is consistent with Hanif (2018) who found a decline in mortality rate resulting from renewable energy consumption in Sub Saharan Africa. An increase in the consumption of renewables and decreasing reliance on fossil fuels for energy leads to a decrease in emissions and a decrease in premature mortality, and health care visits in urban areas (Dougherty et al., 2019). Khan et al. (2020) also documented the positive impact of renewable energy on health outcomes in

ASEAN economies. The substitution of conventional energy sources with green technologies improves environmental quality through emission reduction, therefore the loss of life and the spread of diseases can be avoided associated with poor air quality (Taghizadeh-Hesary et al., 2020). Similarly, results of GMM in column 2 support that a 1% increase in renewable energy consumption (per capita) will decrease infant mortality by 0.627. Renewable energy consumption has a negative and highly significant relationship with the mortality rate. Lagged values of independent variables have been incorporated as instruments. Hansen's, Sargan and Basmann score validate the instruments used.

Table 11: 2SLS and GMM Results of Mortality Rate

Variables	2SLS	GMM
Dependent Variable: Health (Mortality Rate)		
Renewable energy per capita	-0.661*	-0.627**
	(0.363)	(0.244)
GDP per capita	-2.813***	-3.015***
	(0.605)	(0.563)
Trade	-6.392***	-5.791***
	(1.074)	(1.044)
Urbanization	-0.171***	-0.138**
	(0.0552)	(0.0586)
Female education	-0.119***	-0.129***
	(0.0391)	(0.0492)
South Asia	-	-
	-	-
Europe & Central Asia	2.573	2.223*
	(2.076)	(1.273)
East Asia & Pacific	3.331	3.303**
	(2.302)	(1.664)
Middle East & North Africa	8.014*	7.526***
	(4.160)	(1.692)
Sub-Saharan Africa	28.69***	28.90***
	(2.430)	(1.491)
Latin America & Caribbean	6.261***	5.948***
	(2.235)	(1.431)
Constant	87.42***	85.29***
	(5.869)	(5.838)
Observations	232	232
R^2	0.818	0.817
Adjusted R^2	0.810	0.809
Wald chi^2	1041.91***	4053.14***
Hansen's Score		2.383
Sargan Score	1.468	
Basmann Score	1.394	
Standard errors in parentheses * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$		

Table 12 presents the results obtained from the 2SLS and GMM considering the incidence of tuberculosis as the dependent variable. Column 1 presents the result obtained from the 2SLS and reveals that a 1% increase in renewable energy consumption (per capita) will decrease the incidence of tuberculosis by 0.055 percent. Similarly, results of GMM in column 2 support that a 1% increase in renewable energy consumption (per capita) will decrease the incidence of tuberculosis by 0.055 percent. Renewable energy consumption leads to a decline in the incidence of tuberculosis. Lagged values of independent variables have been incorporated as instruments. Hansen's, Sargan and Basmann scores validate the instruments used.

Table 12: 2SLS and GMM Results of Tuberculosis

Variables	**2SLS**	**GMM**
Dependent Variable: Health (Tuberculosis)		
Renewable energy per capita	-0.0559***	-0.0558***
	(0.0171)	(0.0159)
GDP per capita	-0.755***	-0.755***
	(0.0269)	(0.0327)
Trade	0.0181	0.0181
	(0.0315)	(0.0238)
Urbanization	0.0109***	0.0109***
	(0.00177)	(0.00220)
South Asia	1.314***	1.314***
	(0.188)	(0.0826)
Europe & Central Asia	0.667***	0.667***
	(0.155)	(0.0512)
East Asia & Pacific	1.565***	1.565***
	(0.163)	(0.0793)
Middle East & North Africa	-0.265	-0.265***
	(0.174)	(0.0866)
Sub-Saharan Africa	1.677***	1.677***
	(0.166)	(0.108)
Latin America & Caribbean	0.267*	0.267***
	(0.161)	(0.0734)
Constant	9.179***	9.179***
	(0.272)	(0.225)
Observations	1977	1977
R^2	0.691	0.691
Adjusted R^2	0.690	0.690
Wald chi^2	4425.83***	11692.26***
Hansen's score		0.015
Sargan score	0.009	
Basmann score	0.009	
Standard errors in parentheses * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$		

Table 13 reports the impact of nuclear energy, fossil fuel energy, access to clean fuels, solid fuel emission, and electricity produced from coal, oil and gas on life expectancy using GMM. The results indicate that nuclear energy, fossil fuel energy, and access to clean fuel ensure high life expectancy while emissions caused by solid fuel consumption decrease life expectancy due to chronic diseases. The impact of electricity generated from oil coal and gas is insignificant.

Table 13: GMM Results of Life Expectancy

Variables	(1)	(2)	(3)	(4)	(5)
Dependent Variable: Health (Life expectancy)					
Renewable energy per capita	0.379***	0.400***	0.368***	0.371***	0.408***
	(0.0622)	(0.0599)	(0.0697)	(0.0542)	(0.0551)
GDP per capita	3.519***	3.028***	3.012***	3.048***	3.127***
	(0.148)	(0.0984)	(0.131)	(0.104)	(0.101)
Trade	1.206***	0.736***	0.374***	0.713***	0.791***
	(0.162)	(0.0893)	(0.109)	(0.0904)	(0.0925)
Urbanization	0.00327	0.00422	-0.00424	0.0150**	0.00684
	(0.00893)	(0.00670)	(0.00957)	(0.00670)	(0.00667)
Nuclear energy	0.242**				
	(0.102)				
Fossil fuel energy		0.722***			
		(0.210)			
Access to clean fuels			0.389*		
			(0.220)		
Solid fuel emissions				-0.00941***	
				(0.00363)	
Oil Coal Gas electricity					0.0200
					(0.0503)
South Asia	0.0128	0.503	0.911*	0.496	0.538
	(0.451)	(0.442)	(0.489)	(0.413)	(0.426)
Europe & Central Asia	-0.0536	0.205	0.188	0.190	0.170
	(0.261)	(0.211)	(0.263)	(0.196)	(0.204)
East Asia & Pacific	3.906***	1.114***	0.912***	1.177***	1.279***
	(0.263)	(0.252)	(0.311)	(0.239)	(0.241)
Middle East & North Africa	5.235***	1.272***	1.541***	1.189***	1.541***
	(0.447)	(0.300)	(0.386)	(0.297)	(0.288)
Sub-Saharan Africa	-13.31***	-11.65***	-11.69***	-12.10***	-12.16***
	(0.786)	(0.463)	(0.627)	(0.387)	(0.387)
Latin America & Caribbean	1.254***	0.749***	0.920***	0.445	0.788***
	(0.385)	(0.274)	(0.334)	(0.275)	(0.273)
Constant	32.90***	37.20***	41.52***	39.84***	38.77***
	(1.405)	(1.269)	(1.065)	(0.795)	(0.860)
Observations	718	2887	1915	2960	2888
R^2	0.881	0.836	0.832	0.828	0.834
Adjusted R^2	0.879	0.836	0.831	0.827	0.833
Wald chi^2	7178.79***	12413.06***	8301.04***	1287.48***	12384.90***
Hansen's score	0.775	7.637***	0.944	6.219**	4.442**
Standard errors in parentheses * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$					

Table 14 reports the impact of nuclear energy, fossil fuel energy, access to clean fuels, solid fuel emission, and electricity produced from coal, oil, and gas on mortality rate using GMM. Results suggest that access to clean fuel supports decline in infant mortality rate. Fossil fuel consumption, and electricity generated from oil, coal, and gas also support reduced mortality rate. The impact of nuclear energy and solid fuel emissions is insignificant.

Table 14: GMM Results of Mortality Rate

Variables	(1)	(2)	(3)	(4)	(5)
Dependent Variable: Health (Mortality Rate)					
Renewable energy per capita	-0.320***	-0.626**	-0.314**	-0.123	-0.549***
	(0.0913)	(0.264)	(0.153)	(0.175)	(0.207)
GDP per capita	-3.203***	-5.767***	-4.494***	-5.868***	-6.144***
	(0.213)	(0.394)	(0.414)	(0.469)	(0.446)
Trade	-1.912***	-1.376***	-1.528***	-1.654***	-1.448***
	(0.329)	(0.293)	(0.267)	(0.265)	(0.301)
Urbanization	0.0610***	0.113***	0.0603**	0.0978***	0.125***
	(0.0160)	(0.0243)	(0.0243)	(0.0283)	(0.0280)
Female education	-0.285***	-0.493***	-0.408***	-0.513***	-0.519***
	(0.0571)	(0.0239)	(0.0368)	(0.0285)	(0.0273)
Nuclear energy	-0.107				
	(0.174)				
Fossil fuel energy		-2.617**			
		(1.234)			
Access to clean fuels			-3.262***		
			(0.797)		
Solid fuel emissions				0.00799	
				(0.0134)	
Oil Coal Gas electricity					-0.682***
					(0.170)
South Asia	34.72***	3.794	4.771*	3.267	3.135
	(5.095)	(2.445)	(2.632)	(2.294)	(2.381)
Europe & Central Asia	-0.671*	-2.557***	-1.519***	-1.765***	-2.589***
	(0.363)	(0.545)	(0.393)	(0.385)	(0.450)
East Asia & Pacific	-2.039***	-2.672**	-2.324**	-2.226**	-2.688***
	(0.538)	(1.039)	(0.955)	(0.907)	(0.927)

Middle East & North Africa	-1.848*	-7.212***	-3.519***	-5.201***	-7.903***
	(0.988)	(1.365)	(0.960)	(1.252)	(1.385)
Sub-Saharan Africa	28.17***	4.728***	5.805***	6.318***	5.257***
	(1.625)	(1.630)	(1.934)	(1.572)	(1.631)
Latin America & Caribbean	0.786	-9.717***	-4.314***	-8.043***	-10.64***
	(0.964)	(1.015)	(0.948)	(1.104)	(1.111)
Constant	70.72***	124.3***	109.2***	114.4***	120.6***
	(6.048)	(7.094)	(3.290)	(3.484)	(3.973)
Observations	390	1210	998	1203	1189
R^2	0.974	0.866	0.887	0.857	0.862
Adjusted R^2	0.973	0.865	0.886	0.856	0.861
Wald chi^2	7768.77***	5154.98***	6508.11***	4889.22***	4141.97***
Hansen's score	1.662	3.394*	1.922	0.804	1.609
Standard errors in parentheses* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$					

Table 15 reports the impact of nuclear energy, fossil fuel energy, access to clean fuels, solid fuel emission, and electricity produced from coal, oil, and gas on incidences of tuberculosis using GMM. The results reveal that nuclear energy, fossil fuel energy, solid fuel emissions are associated with increased incidences of tuberculosis while the impact of electricity generated from oil, coal, and gas is insignificant.

Table 15: GMM Results of Tuberculosis

Variables	(1)	(2)	(3)	(4)	(5)
Dependent Variable: Health (Tuberculosis)					
Renewable energy per capita	-0.0947***	-0.0277	-0.0383**	-0.0690***	-0.0730***
	(0.0217)	(0.0192)	(0.0163)	(0.0162)	(0.0165)
GDP per capita	-0.832***	-0.753***	-0.834***	-0.755***	-0.720***
	(0.0355)	(0.0303)	(0.0308)	(0.0326)	(0.0331)
Trade	-0.387***	0.00848	-0.0569**	0.0163	0.0123
	(0.0575)	(0.0233)	(0.0230)	(0.0252)	(0.0215)
Urbanization	0.00577**	0.00719***	0.00760***	0.0105***	0.00777***
	(0.00244)	(0.00217)	(0.00241)	(0.00220)	(0.00216)
Nuclear energy	0.0550**				
	(0.0275)				
Fossil fuel energy		0.258***			
		(0.0513)			
Access to clean fuels			0.291***		
			(0.0455)		
Solid fuel emissions				0.00597***	
				(0.00104)	
Oil Coal Gas electricity					0.0135
					(0.0132)
South Asia	0.979***	1.313***	1.307***	1.300***	1.251***
	(0.158)	(0.0917)	(0.0795)	(0.0811)	(0.0848)
Europe & Central Asia	0.750***	0.685***	0.637***	0.644***	0.663***
	(0.0846)	(0.0523)	(0.0505)	(0.0542)	(0.0516)
East Asia & Pacific	1.371***	1.669***	1.608***	1.507***	1.643***
	(0.108)	(0.0832)	(0.0828)	(0.0815)	(0.0706)
Middle East & North Africa	-0.515***	-0.208**	-0.335***	-0.197**	-0.293***
	(0.137)	(0.0900)	(0.0885)	(0.0886)	(0.0845)
Sub-Saharan Africa	4.034***	1.907***	1.968***	1.724***	1.712***
	(0.104)	(0.135)	(0.134)	(0.110)	(0.112)
Latin America & Caribbean	0.357***	0.372***	0.224***	0.373***	0.326***
	(0.104)	(0.0757)	(0.0747)	(0.0802)	(0.0753)
Constant	12.05***	8.172***	9.117***	9.156***	9.141***
	(0.458)	(0.345)	(0.239)	(0.228)	(0.227)
Observations	466	1894	1916	1974	1885
R^2	0.891	0.710	0.708	0.697	0.706
Adjusted R^2	0.889	0.708	0.706	0.696	0.704
Wald chi^2	11086.34***	11325.10***	15720.85***	12700.44***	11289.57***
Hansen's score	0.166	0.022	0.247	0.013	1.516
Standard errors in parentheses * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$					

5. Conclusion

This study analyzed the renewable energy and health nexus by examining the data of 155 countries over the period 1990-2018. Life expectancy, mortality rate, and tuberculosis incidence were used to measure human health outcomes. The study also examined the impact of nuclear energy, fossil fuel energy, access to clean fuels, solid fuel emissions, and electricity generated from oil, coal, and gas on health. The study empirically explored the links between renewable energy and human health.

The findings support the positive effect of renewable energy on human health. Renewable energy increases life expectancy, decreases child mortality, and prevent tuberculosis cases by substituting conventional energy sources and, consequently, improving environmental quality. Moreover, it improves health outcomes by influencing the access, price, supply, and quality of food and nutrition. An increase in income is associated with an inline in life expectancy, decline in child mortality, and tuberculosis incidence because of better access to health facilities. Moreover, the findings also validate the positive effect of urbanization and trade on human health outcomes. Nuclear energy and access to clean fuels increase life expectancy and decrease child mortality. Solid fuel emissions decrease life expectancy.

5.1 Contribution of The Study

Renewable energy has the potential to improve health. The present study contributes to the literature in following follows: First, this study is the pioneering study that investigated the impact of green technologies on health. Second, the study used life expectancy, mortality rate, and incidence of tuberculosis to measure health. Third, the study used fixed and random effects to incorporate country-specific and time-invariant characteristics. Fourth, the study used 2SLS and GMM to account for endogeneity. Fifth, important determinants of health including urbanization and trade are incorporated in the model which has a determinantal impact on health. Sixth, the study provides results for 155 economies for which renewable energy health nexus is missing in the literature.

5.2 Theoretical/ Policy Implications

The substitution of renewable energy for conventional energy supports human health and also decreases costs associated with mining, transportation, and fuel refining. Renewable energy is sustainable as can be replenished naturally from ongoing flows of energy in our surroundings (Owusu and Asumadu-Sarkodie, 2016) and does not generate any negative externality. The use of renewable energy can help in controlling diseases such as respiratory issues, eye infections, lung cancer, and skin issues. Renewable energy improves health quality.

The results are consistent with the theory of sustainable development, as the use of renewable resources does not compromise the ability of future generations and does not degrade environmental assets. Renewable resources do not lead to the exploitation of scarce resources thus promoting sustainability and efficiency in resource use which supports health through an increase in life expectancy, reduction in child mortality, and decline in incidences of tuberculosis. Thus, our results support the theory of sustainable development. Furthermore, our results are consistent with the findings of Hanif (2018), Khan *et al*. (2020). They also suggested the positive impact of renewable energy on human health through a decline in infant mortality, and incidences of tuberculosis thereby enhancing life expectancy.

Global efforts in energy transformation by increasing the share of renewables in the energy the mix will not only contribute to emissions reduction and combat climate change but will lead to a decline in costs associated with health due to air pollution. Therefore, all countries should take initiatives including subsidizing renewable energy to promote its deployment and use along with implementing a carbon tax.

5.3 Study Limitations

The study is not able to incorporate country-specific or regional analysis and the effects of different sources of renewable energy on health. Renewable energy can be generated from different sources (solar, wind, thermal, hydropower, and biofuel), however, due to data unavailability, the study used renewable energy consumption.

5.4 Future Research Directions

Future studies can focus on a different source of renewable energy and its effects on human health. Best institutional practices offer better health results in this regard and as such role of institutions can be examined. Moreover, future studies can incorporate other indicators of human health as well as a different group of countries for comparative analysis. Instead of performing linear analysis future studies can account for asymmetries in the relationship between health and renewable energy.

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