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The role of renewable energy on life expectancy: evidence from method of moments quantile regression based on G-7 countries data

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Nooshin Karimi Alavijeh and Mohammad Taher Ahmadi Shadmehri
Department of Economics, Faculty of Economics and Administrative Sciences, Ferdowsi University of Mashhad, Mashhad, Iran

Fatemeh Dehdar
Faculty of Economics, University of Coimbra, Coimbra, Portugal

Samane Zangoei
Department of Economics, Faculty of Economics and Administrative Sciences, Ferdowsi University of Mashhad, Mashhad, Iran, and

Nazia Nazeer
FAST School of Management, National University of Computer and Emerging Sciences, Karachi, Pakistan

Abstract

Purpose – While science has researched the impact of air pollution on human health, the economic dimension of it has been less researched so far. Renewable energy consumption is an important factor in determining the level of life expectancy and reducing health expenditure. Thus, this study aims to investigate the impact of renewable energy, carbon emissions, health expenditure and urbanization on life expectancy in G-7 countries over the period of 2000–2019.

Design/methodology/approach – This study has adopted a novel Method of Moments Quantile Regression (MMQR). Furthermore, as a robustness check for MMQR, the fully modified ordinary least square, dynamic ordinary least squares and fixed effect ordinary least square estimators have been used.

Findings – The results indicated that renewable energy consumption, health expenditure and urbanization lead to an increase in life expectancy across all quantiles (5th to 95th), whereas higher carbon dioxide emissions reduce life expectancy at birth across all the quantiles (5th to 95th).

Practical implications – The empirical findings conclude that governments should recognize their potential in renewable energy sources and devise policies such as tax-related regulations, or relevant incentives to encourage further investments in this field.

Declarations:

Ethics approval and consent to participate: This paper does not contain any studies with human participants or animals performed by any of the authors.

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Originality/value – This paper in comparison to the other research studies used MMQR to investigate the impact of factors affecting life expectancy. Also, to the best of the authors' knowledge, so far no study has investigated the impact of renewable energy on life expectancy in G-7 countries.

Keywords Renewable energy, Life expectancy, Health expenditure, CO_2 emissions, MMQR

Paper type Research paper

1. Introduction

Human activities for the purpose of achieving economic growth have become a threat to people's health in both developed and developing countries (Bekun *et al.*, 2019). Despite policymakers' attempts, carbon emissions have been increasing so far (Acheampong, 2019; Ghosh, 2022). One of the most important factors contributing to premature mortality is air pollution, and it has a greater impact on low- and middle-income countries than on high-income nations (Cohen *et al.*, 2017; Landrigan *et al.*, 2018; Khan and Hou, 2021). According to the Second UN Environment Conference report, the casualties from air pollution is about 7 million every year (Han *et al.*, 2020), as air pollution causes several issues for human health and well-being (Yi *et al.*, 2020; Baloch *et al.*, 2020; Chen *et al.*, 2019). Air pollution affects cognitive performance and has significant economic expenditures (Zhang *et al.*, 2018). Over the past couple of decades, researchers have illustrated that the possibility of getting cerebrovascular and heart disease by many types of primary pollutants, such as carbon monoxide, particulate matter and ozone cause is relatively high (Mikati *et al.*, 2018; Knittel *et al.*, 2016).

Most of the air pollution is due to the fossil fuel combustion and many researchers have found and confirmed its side effects on human's health. For instance, Pablo-Romero *et al.* (2016) stated that reducing the burning of fossil fuels and increasing renewable energy consumption have positive impacts on human health. Treyer *et al.* (2014) showed that CO_2 emissions produced by fossil fuel combustion have the most significant impact on human health, whereas nuclear and renewables have lower impacts. While there is significant evidence of air pollution impacts on human health in epidemiology and toxicology research, the economic dimension has been less researched so far. Given that econometrics is a useful tool for causal inference, this can be considered as an interesting topic to economists (F.Chen and Chen, 2021). According to Kwakwa (2019), governments should not only focus on improving economic growth but also ensure the achievement of better health conditions for the people. Life expectancy is defined as how long a person can expect to live before death on average (Nkalu and Edeme, 2019), which is the major indicator of health, and has been used as one of the best measuring equipment for a country's economic development (Alam *et al.*, 2016). Many studies have shown that fossil energy consumption affects human health by degrading the environmental condition (Wang *et al.*, 2019; Matthew *et al.*, 2020).

The main energy source has been fossil fuels since the Industrial Revolution, and their use is expected to grow by 78% of total energy consumption by 2040 (Halkos and Gkampoura, 2020; Salehnia *et al.*, 2020). The positive relationship between fossil energy consumption and carbon emissions and the subsequent further degradation of the environment has been proven in a tremendous number of studies (Hanif *et al.*, 2019; Ibrahiem and Hanafy, 2020; Lawson, 2020; Kwakwa, 2020; Dehdar *et al.*, 2022). According to the U.S. Environmental Protection Agency, carbon dioxide emissions from the usage of fossil fuels and industries are 68% of total greenhouse gas (GHG) emissions [EPA (2020) reports]. To overcome environmental problems, the renewable energy transition has become an interesting topic among researchers. It refers to the change in the energy system from fossil fuel consumption (oil, coal and natural gas) to renewable energy consumption (wind, solar and hydroelectric) (Chen *et al.*, 2019; Banday and Aneja, 2019; Dogan *et al.*, 2022).

Diminishing the effects of climate change and minimizing CO_2 emissions by using alternative energy have positive impacts on the health of humans and have benefits for the surrounding ecosystem. As a result, shifting from fossil fuel consumption to renewable energy increases life expectancy and decreases the expenditure on the treatment of diseases (Anarbaev *et al.*, 2019). On the other, various studies have investigated that health expenditure can promote health indices, such as life expectancy. They revealed that health-care expenditure has a positive effect on life expectancy in nations due to "well-judged" spending, while it can have an insignificant effect in countries that only concentrate on quantity rather than quality of expenditure (Deshpande *et al.*, 2014; Duba *et al.*, 2018; Bousmah *et al.*, 2016; Becchetti *et al.*, 2017).

The process of increasing the population in urban areas is called urbanization. Currently, the global population that lives in the urban area consists of over 50% of total population. This percentage of the population is 3.9 billion and will grow to 5 billion by 2030 (Wang, 2018). Urbanization makes substantial progress in economic and social situations and has human welfare results, but its impact on human health is not clear. People who live in an urban area may benefit from appropriate infrastructure and sanitation and also access to health care, they, however, may have some other problems, such as environmental pollution in urban areas and unhealthy lifestyles. Many studies showed that urbanization leads to health improvement (Bandyopadhyay and Green, 2018; Otsu *et al.*, 2004), while, in other parts of the area where the majority of the population excessively concentrates, health development is not satisfactory (Santana *et al.*, 2015; Haines *et al.*, 2000).

Based on the explanations and arguments mentioned above, the purpose of this research is to appraise the impacts of renewable energy, carbon emissions, health expenditure and urbanization on life expectancy using the novel econometric method – Method of Moments Quantile Regression (MMQR) of Machado and Silva (2019) for the G-7 countries. Considering the previous arguments, this paper contributes to the literature in three paths. The first contribution is considering renewable energy consumption and urbanization as two less considered factors in determining the level of life expectancy for a period of 20 years (2000–2019). Second, to our knowledge, this is the first research to use the MMQR to investigate the impact of renewable energy consumption, carbon emissions, health expenditure and urbanization on life expectancy in G-7 countries. Third, this method gives a complete picture of the conditional distribution compared to traditional panel methods such as fixed effect ordinary least square (FE-OLS), fully modified OLS (FMOLS) and dynamic OLS (DOLS) methods. This method provides a nonlinear relationship between variables via various quantile distributions. So, it is thought that the findings obtained through this method in the present study will contribute significantly to the literature. For several reasons, this article focuses on G-7 countries. The G-7 countries include Canada, France, Germany, Italy, Japan, the UK and the USA, which are considered as highly developed economies. These countries consume 23.14% of the global total produced energy and are responsible for 44% of the global total CO_2 emissions (WDI, 2020; Qin *et al.*, 2021). In addition, renewable energy consumption has been growing over the past ten years in G-7 countries. These countries are also committed to achieving 60% of electricity from renewable energies by 2030 to achieve their net zero goals (Ahmed *et al.*, 2022). This interest in renewable energy is also being reflected in human health. Moreover, the average urbanization level of G-7 countries is 54% higher than the level of global urbanization (Ahmed *et al.*, 2020). This study is also in line with the Sustainable Development Goals, namely, Good Health and Welfare, which can assist governments in legislation.

This paper is organized as follows. To review and examine the aim of this study, Section 1 covers the introduction. Section 2 presents literature review. Variables, theoretical background and model are discussed in Section 3., The results and discussion are presented in Sections 4 and 5, respectively. The final part concludes this work with some policy recommendations in Section 6.

2. Literature review

2.1 Theoretical literature

One of the most important factors in determining the standard of living in modern civilizations is life expectancy. As a result, research into the variables that determine life expectancy is crucial for decision-makers (Salehnia *et al.*, 2022). The literature on energy and environmental protection has given considerable attention to the factors influencing life expectancy. Governments encourage the use of alternative energies due to the energy crisis, climate change, global warming and energy efficiency. Thus, research into renewable energy is expanding quickly. The use of renewable energy is crucial for countries that aspired to improve environmental quality and attain sustainable development (Adebayo *et al.*, 2022b). According to past studies, using renewable energy has a positive impact on the long-term environmental effects of emissions (Saqib *et al.*, 2022). Several research have found that using renewable energy can help prevent environmental deterioration (Adedoyin *et al.*, 2021; Cevik *et al.*, 2021; Cheng *et al.*, 2021; Mahalik *et al.*, 2021; Tufail *et al.*, 2021). According to Rodriguez's (2021) study, the health impacts caused by the pollutants have been determined as the most significant indicator of life expectancy. So, a country may reach its highest possible level of health by investing in a cleaner and more sustainable economy using renewable energy.

The effects of air pollution on public health are catastrophic. In the past 40 years, there has been an increase in the concentration of carbon dioxide in the atmosphere and high GHG (CO_2) emissions due to both natural and human activities. This has caused climate change as a result of global warming. A danger to average life expectancy is the negative impact of climate change on human habitat, food production, migration and health (Amuka *et.al.*, 2018). Studies conducted over the past two decades have revealed that air pollution rises the risk of numerous diseases (Hill *et al.*, 2019; Mikati *et al.*, 2018; Knittel *et al.*, 2016; Heutel and Ruhm, 2016; Greenstone and Hanna, 2014). Hence, it makes logical sense to associate a decrease in air pollution with an increase in life expectancy (Lelieveld *et al.*, 2020).

Health expenditures also have an impact on life expectancy. Nations that spend a considerable budget on health care are in fact investing on their human capital. It is possible to quantify this result in terms of additional years or prolonged life (Nkemgha *et al.*, 2021). Some research has shown that health spending has a positive impact on life expectancy (Osakede, 2021; Kofi Boachie *et al.*, 2018; Edeme *et al.*, 2017). This research has proven that advancing health care is a crucial prerequisite for raising human capital. Health is a crucial component of one's welfare, and access to health care might be seen as one of the prerequisites for attaining long-term, sustainable economic growth (Ojo Olusoji *et al.*, 2020).

Finally, scholars have given attention to the connection between urbanization and life expectancy. Economic growth in emerging nations depends on urbanization or the rising proportion of the population living in urban areas. This is because urbanization promotes economic growth, lowers poverty, rises living standards and increases life expectancy. It is believed that urbanization fuels industrialization and also transforms the living standards of people residing in cities (Mahalik *et al.*, 2022). Urbanization is a process in which the industrial layout shifts away from primary industries and toward secondary and tertiary sectors, as stated by Chaolin (2020). In this view, urbanization encompasses changes in the employment of the labor force, from agricultural to non-rural industrial and service occupations, as well as changes in lifestyle, behavior models, values and cultural practices. In terms of physical development, urbanization typically implies the construction of new public amenities and urban infrastructure to suit shifting economic and social conditions (Effiong *et al.*, 2021).

2.2 Empirical literature

Higher life expectancy indicates a better public health situation in society, which is considered a necessary factor for economics overall development. Life expectancy can be affected by various factors. Several papers have examined the factors affecting life expectancy. These studies can be classified into four groups.

The first group of papers investigates the relationship between life expectancy and renewable energy. For example, Gohlke *et al.* (2011) studied the impacts of coal consumption and electricity on infant mortality and life expectancy using data from 41 countries from 1965 to 2005. This study used an autoregressive model. The results revealed that coal consumption had significant harmful effects on human health, while increasing electricity consumption has not led to increased health benefits. Ertay *et al.* (2013) indicated that dependency on alternative energy is a way of solving sustainable development in health and economics. Because renewable energy is a clean source of energy and improves environmental quality, these energy sources reduce the harm caused by environmental pollution. Another study conducted by Hanif (2018) found that fossil fuel energy use harms life expectancy through increasing the mortality rate, however, the consumption of renewable energy lengthened life expectancy. They used a generalized method of moment (GMM) in 34 Sub-Saharan African countries covering the period 1995–2015. By using the geographically weighted regression estimation technique, Wang *et al.* (2019) found a significant impact between electricity consumption and life expectancy in China from 1990 to 2010. In another study, Adom *et al.* (2021) showed that improving renewable energy could make adequate capacity for tolerating energy shocks and so facilitate improvements in development outcomes; for example, GDP per capita, employment, human capital, environmental health and life expectancy. There are also similar papers with identified findings, such as Rodriguez (2021), Rahman and Alam (2022a, 2022b).

The second group are studies that evaluated the impact of air pollution on life expectancy. Fakhri *et al.* (2015) investigated the impacts of CO_2 emissions on economic growth, energy consumption, urbanization, welfare and life expectancy in MENA countries by using FMOLS model between 1999 and 2010. The results indicated that CO_2 emissions reduce life expectancy in the short and long term. The results of Ray *et al.*'s (2016) study indicated that quality energy use has effects on three aspects such as recusing CO_2 emissions, improving income and increasing infrastructure. They also showed that transfer to those energies brings opportunities for using clean fuel resources and making a significant contribution to human health and reducing health expenditure. Similarly, Amuka *et al.* (2018) investigated the relation between life expectancy and CO_2 emissions in Nigeria for 1995–2013 by using the OLS method. They found an insignificant positive relationship between variables. Nkalu and Edeme (2019) examined the relation between environmental problems and life expectancy in Nigeria, using the GARCH approach spanning from 1960 to 2017. The study results displayed the negative impacts between carbon emissions and life expectancy and the positive effects between population growth, income and human health. By applying the GARCH approach, Nkalu and Edeme (2019) examined the effects of environmental problems on life expectancy over the period 1960 to 2017. They used CO_2 emissions as an indicator for environmental hazards and showed that a reduction in CO_2 emissions can increase life expectancy. According to Gozgor *et al.* (2020), the rise in air pollution brings destructive effects on global warming, climate change and human health. This may also create a reduction in life expectancy. But there is a bright side that makes motivation in both consumers and producers to transfer their energy using from nonrenewable to renewable energy. This is a "win-win" situation because the use of renewable energy is a great solution to the energy crisis in OECD countries and promotes the environment quality. By using two stages least squares econometric method, Matthew *et al.* (2020) examined the relationship between the effects of CO_2 emissions on life expectancy from 2000 to 2018 in West Africa. The results showed a significantly positive relationship between carbon emissions and life expectancy. Nathaniel and Khan (2020) investigated the relationship between life expectancy and CO_2 emissions in Nigeria for the period from 1970 to 2014. The results showed the insignificant effect of CO_2 on life expectancy. Moreover, Urhie *et al.* (2020) studied the nexus between air pollution, economic growth and health outcomes by using a moderated mediation model in Nigeria. The findings revealed that government costs on health and air pollution have a negative impact on human health. By using VECM method, Nwani (2022) displayed that there is a negative relationship between carbon emissions and life expectancy in Nigeria from 1981 to 2019.

In the third group, the relationship between life expectancy and health expenditure is evaluated. For instance, with using the method of ordinary least squares (OLS), Duba *et al.* (2018) discovered that health-care expenditure has a positive impact on life expectancy in 210 countries over the period from 1995 to 2014. Becchetti *et al.* (2017) also proved that health expenditure reduces chronic illness. This study examined a large case of European countries covering the period from 2004 to 2012. On the other hand, some researchers revealed an unclear relationship between life expectancy and health expenditure (Rahman *et al.* 2018; Jiang *et al.*, 2018; Tran *et al.*, 2017). Rahman *et al.* (2018) demonstrated the positive effects of health expenditure on infant mortality rate, but it did not have a significant effect on life expectancy. They used the GMM method in ASEAN regions for the data period 1995–2014. Jiang *et al.* (2018) also discovered a different impact of health expenditure on human health because social development was heterogeneous across the 31 provinces of China. They used geographically weighted regression during 2000–2010.

Finally, the four group is a few studies that examined the relation life expectancy and urbanization. For example, Brady *et al.* (2007) investigated the nexus between life expectancy and urbanization. They found that urbanization improves life expectancy. They used an unbalanced panel analysis for less-developed countries over the period from 1980 to 2003. By applying ARDL approach, Shahbaz *et al.* (2016) analyzed the effect of urbanization on life expectancy in Pakistan from 1972 to 2012. This study illustrated that urbanization improves life expectancy. Miao and Wu (2016) studied the effect of urbanization on population health in China during 1991–2011. The results showed that living in the city enhances the risk of getting sick and decreases physical activity. Ali and Audi (2019) examined the impact of urbanization on life expectancy in MENA countries from 2001 to 2016 by using Panel ARDL method. The results showed that urbanization has a positive and significant impact on life expectancy.

According to the above four groups, different methods have been used to investigate the impact of renewable energy consumption, carbon emissions, health expenditure and urbanization on life expectancy. But in this research, the new MMQR has been used to investigate the impact of factors affecting life expectancy. In fact, this approach allows for a more understanding of the interrelationship of heterogeneity. Also in this paper, as a robustness check for MMQR, the FE-OLS, FMOLS and DOLS estimators have been used. In addition, according to our knowledge, so far no study has investigated the impact of renewable energy consumption, carbon emissions, health expenditure and urbanization on life expectancy in G-7 countries.

3. Models, data and methods

3.1 Models and data

In line with Rodriguez-Alvarez (2021), Rahman and Alam (2022a) and Alharthi *et al.* (2022), the following function is extended to investigate the relationship between renewable energy and life expectancy in G-7 Countries (Figure 1):

$$LE_{it} = f(REN_{it}, CO_{2it}, HEX_{it}, URB_{it}) \quad (1)$$

In equation (1), LE, REN, CO_2, HEX and URB represent life expectancy, renewable energy, carbon emissions, health expenditure and urbanization, respectively. The number of countries is represented by *i* (from 1 to 7) while *t* is indicated the time period. To create more stable results, all data are converted to a logarithmic form. Thus, equation (1) is set as follows:

$$\text{Ln}\,RE_{it} = \alpha_i + \beta_1 \text{Ln}\,REN_{it} + \beta_2 \text{Ln}\,CO_{2it} + \beta_3 \text{Ln}\,HEX_{it} + \beta_4 \text{Ln}\,URB_{it} + \xi_t, \quad (2)$$

In equation (2), α_i defines the constant term. β_1, β_2, β_3 and β_4 display the long-run elasticities which illustrate the effects of renewable energy, carbon emissions, health expenditure and urbanization on life expectancy. ξ_t shows the error terms. The definition of different variables, symbols and data source are given in Table 1.

3.2 Panel estimation techniques

The present study uses different estimation methods of FMOLS, DOLS and FE-OLS for comparative purpose and the novel MMQR as the main estimation technique. Phillips and Hansen (1990) introduced FMOLS regression. FMOLS method includes individual intercepts, which allow for heterogeneous serial-correlation, across different individuals in the panel (Pedroni, 2004; Anwar *et al.*, 2021). The DOLS method, which was introduced by Kao and Chiang (2001), makes an unbiased comparison between FMOLS and OLS

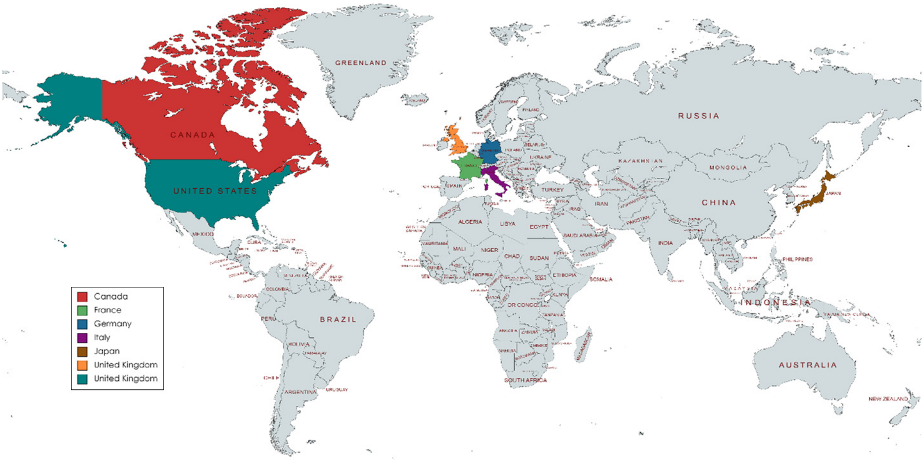

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Figure 1. Map of G-7 countries

estimations in a restricted sample. The basis of DOLS method is the Monte Carlo simulation, to control endogeneity through the augmented of lag differences. The FE-OLS method is an enhancement over standard errors of Driscoll and Kraay, which was initiated by Driscoll and Kraay (1998). This statistical method is robust with heterogeneity, cross-sectional dependence and autocorrelation.

The panel quantile regression technique was established by Koenker and Bassett (1978), estimating the conditional median or several quantiles of the response variables relevant to certain values of the exogenous variables. However, due to its drawbacks, the MMQR approach was established by Machado and Silva (2019), which takes fixed-effects into account, to measure the distributional and heterogeneous effects of multiple quantiles (Adebayo *et al.*, 2022a). The model of MMQR considers the estimation of location-scale conditional quantiles:

$$Y_{it} = \alpha_i + X_{it}^{'} \lambda + \left(\delta_i + Z_{it}^{'} \Phi \right) + U_{it} \quad (3)$$

In equation (3), the parameters (α, λ, δ, Φ) are to be evaluated and $P\left\{ \delta_i + Z_{it}^{'} \Phi > 0 \right\} = 1$. Z shows a k-vector of recognized parts of X. U_{it} is a random variable, and $X_{it}^{'}$ and U_{it} are independent. U_{it} is normalized to realization the conditions of moment ($E(|U|) = 1$ *and* $E(U) = 0$). Thus, equation (3) illustrates the following:

$$Q_Y\left(\Psi | X_{it} \right) = \left(\alpha_i + \delta_i q(\Psi) \right) + X_{it}^{'} \lambda + Z_{it}^{'} \Phi q(\Psi) \quad (4)$$

In equation (4), $\alpha_i + \delta_i q(\Psi) \equiv \alpha_i(\Psi)$ is the effect of distribution at quantile Ψ. The MMQR of equation (4) is performed by calculating two fixed effects regressions and using a univariate quantile.

The MMQR method has several advantages over the linear methods, such as FMOLS and DOLS, and even over the ordinary panel quantile regression. One of the drawbacks of linear estimation methods, which is covered by MMQR technique, is that linear methods do not condition the distribution of data, and they only address the averages. In addition, these methods fail to include unobserved heterogeneity across cross-sections in panel data. Moreover, the ordinary quantile regression suffers from lack of non-crossing estimates when calculating estimators for multiple percentiles leading to an invalid distribution for the responses (Adebayo *et al.*, 2022b). However, applying MMQR method, estimations do not encounter these issues. Also, Figure 2 exhibits the flow of analysis.

Table 1. Definition of variables

Variable	Symbol	Definition	Source
Life expectancy	LE	Life expectancy at birth, total (years)	WDI
Renewable energy	REN	Renewable energy consumption (% of total final energy consumption)	WDI
Carbon emissions	CO_2	Carbon emissions (metric tons per capita)	WDI
Health expenditure	HEX	Current health expenditure (% of GDP)	WDI
Urbanization	URB	Urban population (% of total population)	WDI

Notes: (1) The estimation period is 2000–2019. (2) WDI indicates World Development Indicators. (3) All variables are logarithmic
Source: Created by authors

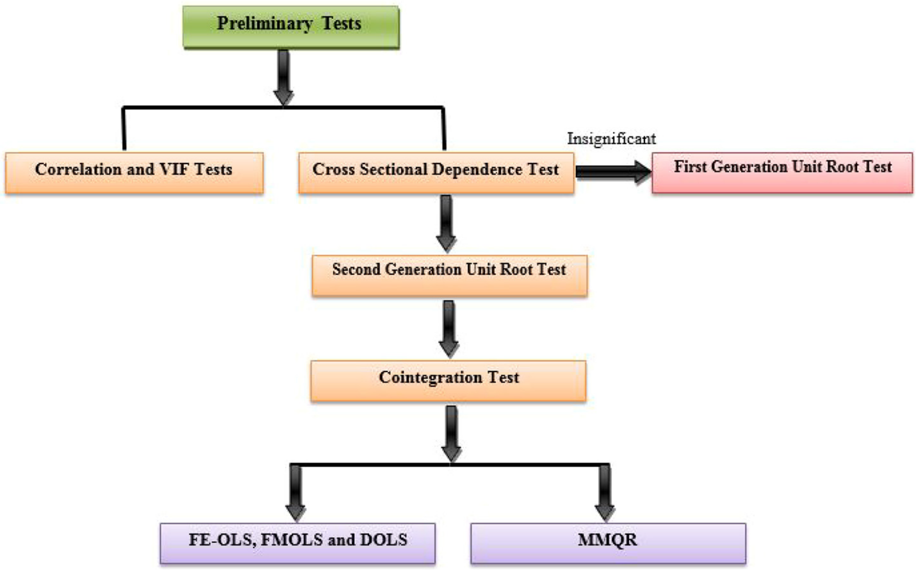

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Figure 2. Flow of analysis

4. Results

4.1. Descriptive of variables, correlation and variance inflation factor statistics

Initially, the descriptive statistics of the variables were investigated. Table 2 illustrates that the variables of life expectancy and urbanization conform the left-skewed distribution, while the variables renewable energy, carbon emissions and health expenditure follow the right-skewed distribution. According to Jarque–Bera test, all the variables have an asymmetric distribution. This finding therefore supports the use of quantile-based models.

Table 3 indicates the correlation matrix between the various variables as well as the results of variance inflation factor (VIF) statistics (VIF). All coefficients of the correlation matrix in absolute values are less than 0.8 (Awad, 2023; Karimi Alavijeh *et al.*, 2023). Thus, there is no evidence of multicollinearity, and the results of regression will be reliable. Also, the mean VIF value of 1.23 is less than 5. So, there is no intense multicollinearity problem.

Variables	LE	REN	CO_2	HEX	URB
Mean	80.6418	10.4156	10.3029	10.5114	79.1408
Median	80.6418	8.9932	9.0876	10.1816	79.9015
Minimum	76.6365	0.8528	4.4869	7.0345	67.2220
Maximum	84.3563	22.7699	20.4719	16.8443	91.6980
Skewness	−0.5542	0.6128	0.7008	1.2085	−0.0753
SD	1.7872	6.2388	4.4869	2.3745	5.7938
Jarque-Bera	6.1083**	11.2283***	15.2027***	40.0368***	10.0376**

Notes: ***Significance at 1% level; **significance at 5% level
Source: Created by authors

Table 2. Summary of descriptive statistics (before logarithm)

4.2 Cross-sectional dependence, unit root and panel cointegration test

Table 4 show the result of cross-sectional dependence (CD) test (Pesaren, 2004). The null hypothesis of this test demonstrates the absence of cross-sectional dependence. Based on *p*-values, the null hypothesis is rejected, so there is cross-sectional dependence in the model variables. Due to the problem of cross-sectional dependence, the second-generation unit root test is used to inspect the stationary of variables (Koengkan *et al.*, 2022). This study used panel unit root test introduced by Pesaran (2007), and the outcome is reported in Table 4. The results show all the series are stationary at the first difference, this means that all variables are I (1).

To investigation the cointegrating relation among the variables, the cointegration test of Westerlund (2007) is applied. The outcomes of in Table 5 confirm the long-term cointegrating relationship between the variables. Therefore, empirical findings have validity and stability.

Table 3.
Correlation matrix and VIF statistics

Variables	LE	REN	CO_2	HEX	URB	VIF	1/VIF
LE	1.0000					–	–
ENT	0.2994***	1.0000				1.36	0.7379
CO_2	−0.5238***	0.2205***	1.0000			1.25	0.7999
HEX	−0.3906***	0.0348	0.5146***	1.0000		1.18	0.8464
URB	0.2042**	−0.1477*	0.2356***	0.2345***	1.0000	1.13	0.8854
Mean	–	–	–	–	–	1.23	–

Notes: ***Significance at 1% level; **significance at 5% level; *significance at 10% level
Source: Created by authors

Table 4.
Results of CD and Pesaran CADF unit root test

Variables	CD test	CADF test Level	First difference
LE	19.89***	−1.985	−2.485**
REN	17.88***	−1.849	−2.626**
CO_2	15.43***	−1.856	−2.701***
HEX	18.94***	−1.924	−2.722***
URB	19.41***	0.539	−2.370**

Notes: (1) ***Significance at 1% level; **significance at 5% level. (2) The critical values for CADF test at 10, 5, 1% levels of significance are −2.210, −2.340, −2.600, respectively
Source: Created by authors

Table 5.
Results of Westerlund bootstrap panel cointegration

Statistic	Value	Z-value	*p*-value
Gt	−3.303	−3.003	0.001
Ga	−4.751	2.338	0.990
Pt	−7.258	−2.060	0.020
Pa	−4.174	1.326	0.908

Notes: The null hypothesis is no cointegration and the alternative hypothesis is at least one of the cross-sectional units has cointegration (Gt and Ga) or cointegration for the panel as a whole (Pt and Pa)
Source: Created by authors

4.3 Results of method of moments of quantile regression

Table 6 indicates the results of the MMQR. It is observed that the effect of renewable energy consumption (REN) on life expectancy is statistically significant and positive from 5th to 90th quantile, while at highest quantile that is 95th the effect of renewable energy is found insignificant, which represents the contribution of renewable energy consumption in enhancing life expectancy. Also, the results found a negative and significant relationship between carbon emissions (CO_2) and life expectancy in all the quantiles. This is much expected results and implies that an increase in carbon emissions decreases life expectancy in G-7 countries, indicating the deteriorating impact of carbon emissions on human life and well-being.

The results based on health expenditure (HEX) seems a positive and significant across all quantile starting from 0.071 in 5th quantile and 0.086 in the highest quantile. This implies that high health care expenditure could increase life expectancy. Finally, the effect of urbanization (URB) on life expectancy is significant across all quantiles but little disparate in 10th quantile that is 0.06%. In other words, increasing urbanization can increase life expectancy, due to better access to infrastructures and better earnings.

4.4 Results of the panel regression estimates

As a robustness check for MMQR, the FE-OLS, FMOLS and DOLS estimators have been used to examine the relationship between life expectancy and renewable energy, CO_2 emissions, health expenditure, urbanization. Table 7 presents the results from FE-OLS, FMOLS and DOLS estimation techniques. The results clearly show that coefficient estimates attained after analysis of all three measurements are different in terms of significance level but all are near to average. As expected, renewable energy and urbanization are the most robust across all three specifications in terms of coefficient size and statistical significance. A percentage increase in renewable energy consumption positively impacts on life expectancy by ~0.016% and 0.17% in FE-OLS and FMOLS estimator and ~0.013% in DOLS estimator. On the other hand, urbanization has a significantly positive impact on life expectancy by 0.1531%, 0.1651 and 0.1354, respectively in all three measurements. In observing carbon emissions, the results exert a significantly negative impact on life expectancy in FEOLS and FMOLS, and no statistical significant indication is found in the DOLS estimation. More so, health expenditure is observed to have appositive and significant effect on life expectancy in all three estimations by 0.0473, 0.0519 and 0.0514% which means percentage increase in life expectancy for a percentage increase in urbanization.

Figure 3 compares the results of all panel estimations, namely, FE-OLS, FMOLS, DOLS and MMQR. Based on Figure 3, it is obvious that the coefficients FE-OLS, FMOLS and DOLS regressions are constant. But, the MMQR coefficients are heterogeneous and illustrate a more complete picture in all quantiles. This result confirms the superiority of the MMQR model compared to traditional panel methods. Therefore, it can be found that MMR is a more efficient and comprehensive method to explain the relationships between variables.

5. Discussion

As results indicate, renewable energy consumption has a positive effect on life expectancy. One reason may be that renewable energy still needs significant improvement in most G-7 countries. Our result is with the line of Charfeddine and Mrabet (2017), Apergis *et al.* (2018), Alharthi and Hanif (2021), Oluoch *et al.* (2021); this show that renewable energy consumption will lead to better health care and hence increase life expectancy. Investment in technologies-related renewable energy could increase energy access, as well as elevate

Table 6.
Panel quantile regression results

			MMQR						
			Quantiles						
Variable	Location	Scale	Q5	Q10	Q25	Q50	Q75	Q90	Q95
REN	0.0090***	0.0022***	0.0085***	0.0131***	0.0111***	0.0085***	0.0071***	0.0052**	0.0047
CO_2	−0.0124***	−0.0001	−0.0118***	−0.0121***	−0.0133***	−0.0145***	−0.0157***	−0.0162***	−0.0170***
HEX	0.0678***	0.0100***	0.0701***	0.0505***	0.0589***	0.0701***	0.0761***	0.0845***	0.0865***
URB	0.0941***	0.0158**	0.0978***	0.0669***	0.0801***	0.0978***	0.1071***	0.1204***	0.1235***
Obs	140	140	140	140	140	140	140	140	140

Notes: ***Significance at 1% level; **significance at 5% level
Source: Created by authors

human development. The nations with high life expectancy rates indicate high readiness to invest in renewable energy sources and the environment.

On the contrary, carbon emissions found to have an adverse impact on life expectancy. This result echoes the work done by Murthy *et al.* (2021) on the relation between life expectancy and carbon emissions by considering a dataset from 2000 to 2016, which indicates that an increase in carbon emissions leads to decrease life expectancy in 54 selected countries. Also, our results confirm the study of the West *et al.* (2016), Steinberger *et al.* (2020), Landrigan *et al.* (2020), Poças *et al.* (2020), Nwani and Imhanzenobe (2022) and Salehnia *et al.* (2022). Also, Hill *et al.* (2019) confirm that carbon emissions is one the major environment factors that causes high mortality rates spread respiratory diseases and blood clotting within all fragments of society in the world. Hence, there is a severe need that organizations particularly industries must strictly implement air pollution control policies to minimize the effect of carbon emissions among people.

Health expenditure was found to have a positive contribution in improving life expectancy in study countries. This means that higher health expenditure increase life expectancy. Our result is in the line with Owumi and Eboh (2021) for Nigeria, Nkemgha *et al.* (2021) for Cameroon, Martín Cervantes *et al.* (2021) for Europe and Radmehr and Adebayo (2022) for Mediterranean countries, which show that rise in health-care expenditure increases life expectancy. However, our results contradict with Igbinedion (2019) for Nigeria and Rahman *et al.* (2018) which demonstrate that better health care does not boost life expectancy in case of SAARC and Nigeria.

Finally, the urbanization increases life expectancy in G-7 countries. In the other word, urbanization affects people's living, earning and socioeconomic infrastructure and their awareness of environmental issue have a positive effect on life expectancy. It can also be added that the impact of urbanization on life expectancy is the outcome of industrialization, which leads to income generation and hence life expectancy (Shahbaz *et al.*, 2016). Our result is in the line with Kalediene and Petrauskiene (2000), Thornton (2002) and Hassan *et al.* (2017), they showed that urbanization can affect life expectancy. Figure 4 indicates the summary of the results.

6. Conclusions and policy implications

This study investigates the impact of renewable energy, carbon emissions, health expenditure and urbanization on life expectancy for G-7 countries over the period of 2000 to 2019, using different panel estimation methods such as FE-OLS, FMOLS, DOLS and MMQR. According to the results obtained from MMQR method, as the most reliable and robust technique compared to the other three methods, renewable energy has a positive impact on life expectancy at birth, which implies the pivotal role of renewable energy utilization in human's life. Refining, burning and even transportation of fossil fuels generates air pollution and a variety of hazardous air toxics, including nitrous oxide, particulate matter, mercury and volatile organic compounds,

	FE-OLS		FMOLS		DOLS	
Variable	Coefficient	Prob.	Coefficient	Prob.	Coefficient	Prob.
REN	0.0169***	0.000	0.0172***	0.000	0.0137***	0.003
CO_2	−0.0269***	0.000	−0.0273***	0.000	−0.0245	0.120
HEX	0.0437***	0.000	0.0519***	0.000	0.0514***	0.002
URB	0.1531***	0.000	0.1651***	0.000	0.1354**	0.035

Notes: ***Significance at 1% level, **significance at 5% level
Source: Created by authors

Table 7. FE-OLS, FMOLS and DOLS results

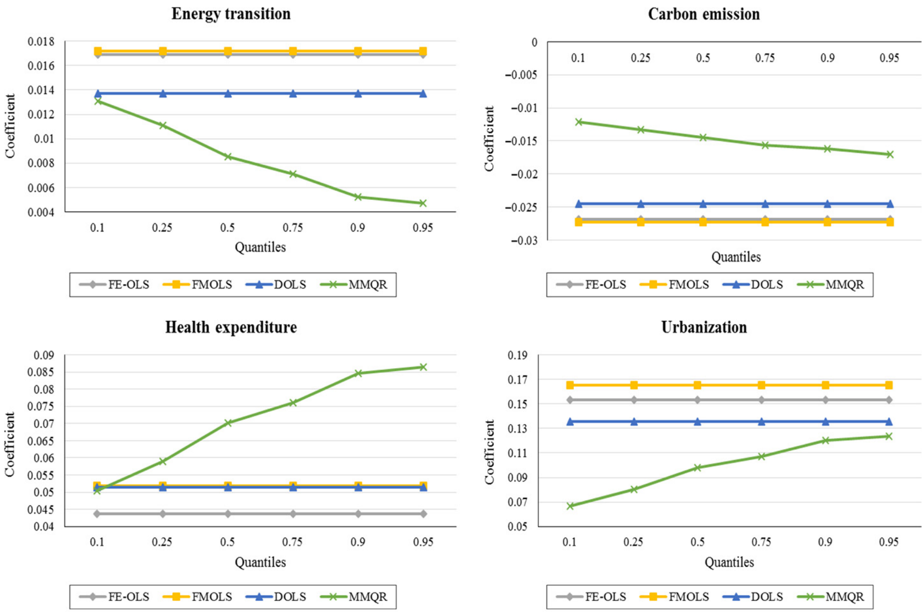

Figure 3. Comparing coefficients from FE-OLS, FMOLS, DOLS MMQR for variables of energy transition, carbon emission, health expenditure urbanization

Source: The authors created this figure

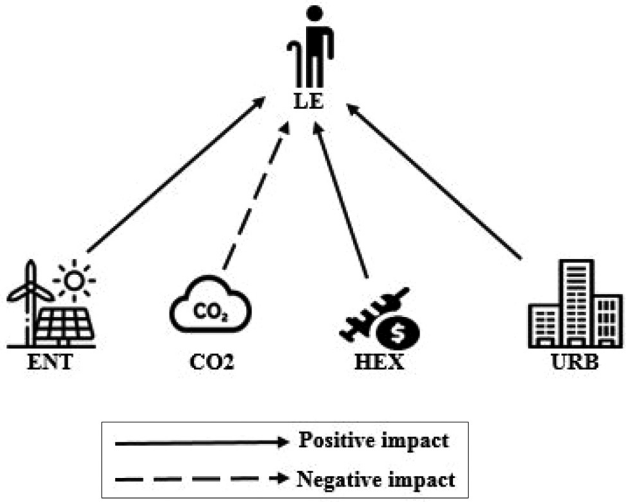

Figure 4. Empirical results from FE-OLS, FMOLS, DOLS and MMQR

Source: The authors created this figure

which all are harmful to human health, and will eventually affect life expectancy. Renewable energy, such as solar, geothermal and wind energy, is the most promising sources of clean and safe energy, which emit no GHGs or other hazardous and toxic pollutants. It is advisable that countries recognize their potential in renewable energy sources and devise policies such as tax-related regulations, or relevant incentives to encourage further investments in this field. G-7 nations are well placed to completely decarbonize their electricity generation by the year 2035, to stimulate the technological advancements and infrastructure enhancements, which is required to lead global energy market toward net zero emissions by 2050. Higher technologies that facilitate further implementation of renewable energy sources will eventually improve life expectancy. Coal power elimination can significantly reduce the carbon footprint of the studied nations and boost the health of their residences, which is expected to take place by the end of 2030.

In addition, health expenditure as a share of GDP enhances life expectancy, mainly due to lower mortality rates, especially among infants. Health expenditure will result in better provision of health opportunities, which not only will improve human capital but also increases productivity, and hence, to economic prosperity. It is recommended that G-7 countries priorities public health expenditure in their spending, to achieve higher life expectancy. Public spending on health systems is significantly different among G7 countries, and as a result the outcomes. More specifically, spending on health is higher in relation to the outcomes in France, Germany, the UK and the USA. However, spending in Italy and Japan is relatively more efficient. Hence, to achieve a higher efficiency in health expenditure, the focus should be given to countries with higher expenditure and lower outcome.

Urbanization also improves life expectancy, especially at the higher quantiles. Urbanization is associated with greater human longevity, as a result of better access to medical and health centers. In particular, urbanization affects people's earnings, living and socioeconomic infrastructure and plus built awareness of how environmental issues have an affirmative effect on life expectancy. However, higher carbon dioxide emissions will lead to lower life expectancy at birth. Air pollution, in which carbon dioxide is a major contributor, is the fourth significant overall risk factor for human health after high blood pressure, smoking and dietary risks globally and is associated with premature deaths worldwide. As fossil fuels, especially coal and oil, are responsible for almost half of these premature deaths, countries should move toward cleaner choices of energy such as natural gas or renewable sources of energy. Efficient and reliable public transport not only improves the quality of urban life but also attenuates the carbon emissions from private vehicles.

Finally, this study opens new paths for future research. The present study has examined the impacts of renewable energy consumption on life expectancy of G-7 countries, ignoring the effect of specific types of renewable energy. Researchers are advised to examine the relationship between any type of renewable energy (i.e. wind, geothermal and solar energy) and life expectancy. Future research can iterate this study for other groups of countries/regions such as BRICS, ASEAN countries, African nations and Middle East region. Other scholars can expand this study by adding other variables such as literacy rates, sanitation, income inequality, governance indicators, and achieve significant results.

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Further reading

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Corresponding author
Mohammad Taher Ahmadi Shadmehri can be contacted at: shadmhri@um.ac.ir