Investigating the Causal Relationship between Renewable Energy Consumption and Life Expectancy in Turkey: A Toda-Yamamoto Causality Test

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Submission Time: 14 March 2023 | **Acceptance Time:** 25 April 2023

ABSTRACT

This study examines the causal relationship between renewable energy consumption and life expectancy in Turkey using the Toda-Yamamoto causality test. By analyzing data from 1990 to 2019, the study explores the relationship between these variables. The results of the Toda-Yamamoto causality test indicate that there is no Granger causality relationship from renewable energy consumption to life expectancy, indicating that renewable energy consumption does not have a significant impact on life expectancy in Turkey. However, the study finds a Granger causality relationship from life expectancy to renewable energy consumption, suggesting that improving life expectancy could lead to an increase in renewable energy consumption in Turkey. This study is significant as it provides insights into the relationship between renewable energy consumption and life expectancy in Turkey. The results highlight the importance of considering factors other than renewable energy consumption when examining public health outcomes. The study's findings can inform policymakers in developing energy policies that prioritize public health outcomes and promote sustainable energy practices.

Keywords: *Life expectancy, Renewable energy consumption, Toda-Yamamoto causality test, Sustainable energy policies, public health*

JEL Codes: Q42, I12, O44, Q56, C22

1. INTRODUCTION

Deaton (2008) explains that life expectancy is a statistical measure of the average time that a person is expected to live, which is influenced by various factors such as genetics, lifestyle, healthcare, and environmental conditions. According to Deaton, the higher the life expectancy, the better the overall health and well-being of a population. On the other hand, Mukhopadhyay and Sarkar (2021) define renewable energy as the energy that is generated from natural resources that can be replenished over time, such as solar, wind, hydro, geothermal, and biomass. The authors argue that renewable energy is a key solution to reducing greenhouse gas emissions and mitigating the impacts of climate change.

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The relationship between life expectancy and renewable energy is complex and multifaceted. Life expectancy is influenced by numerous social, economic, and environmental factors, such as access to healthcare, education, sanitation, nutrition, and housing. Renewable energy, on the other hand, is influenced by factors such as technology, policy, finance, and public awareness. Despite these complexities, there are several ways in which renewable energy can positively impact life expectancy. Firstly, renewable energy can help reduce air pollution, which is a major

risk factor for a range of health problems, such as respiratory and cardiovascular diseases (Lelieveld et al., 2019; Yilmaz and Sensoy, 2022). Perera (2017) states that fossil fuels, such as coal, oil, and gas, are major sources of air pollution, which can cause premature deaths and chronic illnesses. On the other hand, Omer (2008) explains that renewable energy generates clean energy without emitting harmful pollutants, thereby improving air quality and reducing health risks. Secondly, Soto et al. (2022) state that renewable energy enhances access to healthcare, particularly in rural and remote areas that lack reliable electricity. The authors explain that renewable energy systems, such as solar panels and small wind turbines, can provide off-grid power to run medical equipment, refrigeration, and lighting, which can improve healthcare outcomes and reduce maternal and infant mortality rates. This is the second way in which renewable energy can positively impact life expectancy.

Thirdly, renewable energy creates new job opportunities and stimulate economic development, which can improve living standards and overall health outcomes. The renewable energy sector is a growing industry that requires a range of skills and expertise, from engineers and technicians to sales and marketing professionals. By promoting clean energy technologies and investing in renewable energy infrastructure, countries can create new jobs, reduce poverty, and improve access to education and healthcare, all of which can contribute to longer and healthier lives (IRENA and ILO 2022; Tutar and Atas 2022). Haines et al. (2006) explain that renewable energy reduces the risk of waterborne and vector-borne diseases, which are major health challenges in many parts of the world. The authors argue that access to clean water and sanitation is critical for preventing the spread of diseases, and renewable energy can power water treatment and distribution systems, as well as provide lighting to reduce the risk of mosquito-borne diseases, such as malaria and dengue fever.

Moreover, Arabska (2021) argues that renewable energy can promote sustainable and healthy food systems, which are essential for good health and well-being. The author explains that renewable energy can power irrigation systems, greenhouses, and food processing facilities, which can improve crop yields, reduce post-harvest losses, and increase access to nutritious foods. Additionally, Freeman and Hancock (2017) suggest that renewable energy can enhance resilience and reduce the impacts of natural disasters, which can cause significant harm to human health and well-being. The authors argue that by providing reliable and decentralized power, renewable energy can help communities cope with and recover from disasters, such as floods, hurricanes, and earthquakes, which can disrupt access to food, water, and healthcare.

The relationship between life expectancy and renewable energy is complex and multifaceted, and there are numerous ways in which renewable energy can positively impact health outcomes. By reducing air pollution, enhancing access to healthcare, creating new jobs and economic opportunities, reducing the risk of waterborne and vector-borne diseases, promoting sustainable and healthy food systems, and enhancing resilience to natural disasters, renewable energy can contribute to longer and healthier lives for people around the world.

It is possible to summarize the importance and motivation of this study in several ways. First and foremost, the global energy landscape is rapidly shifting towards renewable energy, and it is essential to understand how this transition can impact public health and well-being. By studying the relationship between life expectancy and renewable energy, we can identify the key drivers and mechanisms that can lead to positive health outcomes and inform policies and investments that can maximize the health benefits of renewable energy. Second, the health impacts of energy systems are often overlooked in policy and investment decisions, and by studying the relationship between life expectancy and renewable energy, we can raise awareness of the health implications of different energy choices and promote evidence-based decision-making. Finally, the relationship between life expectancy and renewable energy is a complex and multidisciplinary field that requires collaboration and integration of expertise from various fields, such as energy systems, public health, economics, and social sciences. By fostering interdisciplinary research and collaboration, we can generate new insights and approaches to addressing the global health and energy challenges of the 21st century.

In this study, the relationship between Life expectancy and Renewable energy consumption (% of total final energy consumption) was analyzed with the Toda-Yamamoto causality test. In the study, data for Turkey between the years 1990-2019 were used. The importance of this study was analyzed for the first time with this method, the relationship between Life expectancy and Renewable energy consumption (% of total final energy consumption).

2. LITERATURE REVIEW

The relationship between energy usage and health outcomes is a complex and important topic that has been the subject of extensive research in recent decades. With the growing concern about the negative effects of fossil fuels on the environment and human health, there has been an increasing interest in promoting sustainable energy practices as a means of improving health outcomes. In this literature review, we examine a selection of studies that investigate the relationship between energy usage and life expectancy, with a focus on the use of renewable energy sources. The studies range from analyses of the effects of emissions on mortality rates in California to examinations of the impact of energy consumption on health outcomes in Kuwait and Nigeria. We aim to provide insights into this complex relationship and highlight the need for further research to inform policy decisions aimed at promoting both sustainable energy practices and improved health outcomes.

Duncan (1993) examines the correlation between energy consumption and economic growth, while also considering energy efficiency and conservation as potential strategies for reducing carbon emissions. In a similar vein, Duncan (2001) argues that global energy production has reached its peak and that society must transition to renewable energy sources. de Grey (2005) discusses the potential for renewable energy to extend human life expectancy.

Notzon et al. (1998) examine the impact of energy consumption on life expectancy across different countries, finding that higher energy consumption is associated with increased life expectancy. This finding is echoed by Ebenstein et al. (2015), who find that the expansion of coal use in China has led to a decline in life expectancy. In contrast, Pasten and Santamarina (2012) argue that renewable energy policies can improve air quality and increase life expectancy.

Mariani et al. (2010) investigate the role of renewable energy in economic growth, arguing that investment in renewable energy can boost economic development and improve human welfare. Meanwhile, Rodriguez-Alvarez (2021) focuses on the potential health benefits of renewable energy, arguing that increased access to renewable energy can lead to improvements in respiratory health.

In terms of demographic factors, Manton et al. (1991) examine the impact of energy consumption on population aging, finding that increased energy use is associated with longer life expectancy and decreased population aging. Wen and Gu (2012) similarly find that increased income, education, and healthcare access are associated with longer life expectancy.

Finally, several studies explore the relationship between renewable energy and environmental sustainability. Mazur (2011) argues that renewable energy can reduce greenhouse gas emissions and mitigate the effects of climate change, while Salehnia et al. (2022) examine the potential for renewable energy to promote sustainable development. Rjoub et al. (2021) explore the impact of renewable energy policies on carbon emissions, while Polcyn et al. (2023) investigate the potential for renewable energy to reduce environmental pollution. Li et al. (2023) also explore the potential for renewable energy to improve environmental health.

Overall, the reviewed literature suggests that renewable energy policies can have positive impacts on life expectancy, economic growth, and environmental sustainability. Specifically, several studies find that increased energy consumption is associated with longer life expectancy, while others argue that renewable energy can improve air quality and reduce greenhouse gas emissions. These findings highlight the potential for renewable energy policies to improve both human health and environmental sustainability.

In conclusion, the studies reviewed in this literature review demonstrate the complex relationship between energy usage and health outcomes. However, a gap in the literature exists regarding the impact of energy usage on health outcomes in Turkey. Thus, further research is needed to fill this gap and provide insights into the specific relationship between energy usage and health outcomes in Turkey. This research can inform policy decisions aimed at promoting sustainable energy practices and improving health outcomes in the country.

3. DATASET, METHODOLOGY, AND APPLICATION

The study examined the relationship between Renewable energy consumption (% of total final energy consumption) and Life Expendancy per capita. For Turkey, annual data for the period 1990-2019 and two variables are used. The study has focused on the period between 1990 and 2019 for Turkey, as it represents the longest interval with available data and provides adequate coverage for sound data accessibility and quality. These variables are *LNRNW*, which expresses Renewable energy consumption (% of total final energy consumption) independent, and *LNLE*, which expresses Life Expendancy, is dependent variable. The natural logarithms of the variables were taken and analyzed. While the data for *LNRNW*, one of the variables, were compiled from the World Bank Database statistics, the data for the *LNLE* variable were obtained from the Sustainable Development Index (SDI) database. The model used in the analysis are as follows:

$$LNLE_t = \propto_0 + \beta_1 (LNRNW)_t + \mu_t \quad (1)$$

The datasets and their descriptions are shown in Table 3.1:

Varible	Descriptive	Source
LNLE	Life Expectancy (Natural logarithms are taken)	https://www.sustainabledevelopmentindex.org/
LNRNW	Renewable energy consumption (% of total final energy consumption) (Natural logarithms are taken)	World Bank, International Energy Agency, and the Energy Sector Management Assistance Program

Table 3.1 Descriptive Variables and Sources

Notes: Annual data between 1990 and 2019 were used for all variables.

In the study, first of all, unit root test is applied to study whether the series contain unit root or not. Boundary (ARDL) test was performed to determine whether there is a long-term cointegration relationship between the series after the unit root test. The Autoregressive Distributed Lag (ARDL) boundary test is a statistical method used to examine the existence of long-run relationships among variables in a time series data. It has several advantages over other methods, including its ability to handle small sample sizes and mixed-order of integration among the variables. Moreover, the ARDL model is flexible enough to allow for the inclusion of lagged dependent variables, exogenous variables, and deterministic trends in the model. Additionally, the ARDL approach can accommodate the presence of structural breaks in the data, making it a useful tool for analyzing economic and financial data over long-time horizons (Yilmaz and Sensoy, 2023). Overall, the ARDL boundary test is a powerful and versatile method for examining long-run relationships among variables in time series data. Model (2) was established for the ARDL Test.

$$\Delta(LNLE)_t = \propto_0 + \beta_1 (LNLE)_{t-1} + \beta_2 (LNRNW)_{t-1} + \sum_{i=1}^{m} \delta_{1i} + \Delta(LNLE)_{t-i} + \sum_{i=1}^{m} \delta_{2i} + \Delta(LNRNW)_{t-i} + \mu_t \quad (2)$$

Finally, Toda-Yamamoto causality test was performed to determine the direction of the causality relationship between the series. The Toda-Yamamoto causality test is a statistical test that can be used to assess the causality between two time series data. It is advantageous over other methods as it is able to detect nonlinear causal relationships, which are often present in real-world data. The test is also robust to the presence of autocorrelation and does not require the data to be normally distributed. Additionally, it can account for the possibility of feedback loops, which is a common occurrence in many economic and financial systems. Overall, the Toda-Yamamoto causality test is a powerful tool for examining causal relationships in time series data, especially in cases where linear models may not be appropriate.

Before starting the analysis, the stationarity of the series is checked to see if it contains a unit root. Therefore, the analysis starts with unit root tests. The stationarity of the related series was examined with ADF (Augmented Dickey-Fuller) and Philips-Perron (PP) unit root tests, and the results of the tests are shown in Table 3.2:

Variable	Test Equation	Level	Method	
			Aug. Dickey Fuller	Philips-Perron
LNLE	*Intercept*	*I(0)*	-8.738316[a] (0,0000)*	-6.043913[b] (0.0000)*
		I(1)	-0.167449[a] (0.9315)	-0.646765[b] (0.8442)
	Intercept and Trend	*I(0)*	1.064804[a] (0.9998)	0.503867[b] (0.9988)
		I(1)	-3.274660[a] (0.0912)**	-3.184247[b] (0.1079)
LNRNW	*Intercept*	*I(0)*	-1.468096[a] (0.5341)	-1.462564[b] (0.5379)
		I(1)	-5.755605[a] (0.0001)*	-5.946271[b] (0.0000)*
	Intercept and Trend	*I(0)*	-1.958200[a] (0.5897)	-1.856002[b] (0.6510)
		I(1)	-5.938951[a] (0.0002)*	-6.401593[b] (0.0001)*

Table 3.2 ADF and PP Unit Test Results
Notes: * and ** denote significance at 1% and 10% level, respectively. [a], denotes Aug. Dickey Fuller value and [b], denotes Philips-Perron adj. t-Stat value. **Source:** Research finding. (Authors' compilation from Eviews 11 (IHS Global Inc)).

According to the ADF and PP unit root test results in Table 3.2, it is seen that *LNRNW* is stationary at the level and *LNLE* variable is stationary at the first difference.

Boundary (ARDL) test applied to test the existence of cointegration among the related variables and the results are given in Table 3.3:

	Value	Signif.	I(0)	I(1)
F-statistic	3.229694	10%	3.303	3.797
		5%	4.5173	4.663
		1%	6.027	2.7912
ARDL Long Run Form and Bounds Test				
Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
LNRNW	0.029004	0.153960	0.188384	0.8522

Table 3.3 ARDL Boundary Test Results
Source: Research finding. (Authors' compilation from Eviews 11 (IHS Global Inc)).

According to the results of the bounds test, the F value was determined as 3.2296 and the null hypothesis (there is no cointegration between the variables) was accepted since the said value was not greater than the lower and upper limit values of Pesaran et al. (2001) 4.5173 and 4.663 According to this result, a long-term relationship between the variables could not be determined.

Cointegration is a statistical concept that implies a long-term relationship between two or more non-stationary time series variables. However, Toda-Yamamoto causality test does not rely on the assumption of cointegration. Instead, it uses vector autoregression (VAR) models to estimate the relationship between the variables (Ghosh and Kanjilal, 2014).

The Toda-Yamamoto test involves the estimation of two VAR models: one for the potential cause and one for the potential effect. The models are estimated using lagged values of the variables and any other relevant explanatory variables. The test then examines whether the residuals of the cause variable VAR model have a causal effect on the residuals of the effect variable VAR model. Therefore, the Toda-Yamamoto causality test can be used to test for causality between non-stationary time series variables, even when there is no cointegration relationship between them (Toda and Yamamoto 1995).

The Toda-Yamamoto causality test is based on the VAR (Vector Autoregression) model and allows estimation of the model with level values regardless of whether the series to be examined contain unit roots or not. In order to apply this test, the maximum degree of integration (dmax) of the VAR model and the optimal lag length (k) must be determined, and then a VAR model in the form of (k+dmax) must be estimated. Previously, the longest lag length was determined by ADF and PP unit root tests and was found to be k=1. The Toda-Yamamoto causality test is based on the VAR (Vector Autoregression) model and allows estimation of the model with level values regardless of whether the series to be examined contain unit roots or not. The model of the Toda-Yamamoto test is as follows:

$$LNRNW_t = \vartheta + \sum_{i=1}^{K+dmax} a_{1i}\, LNRNW_{t-1} + \sum_{i=1}^{K+dmax} a_{2i}\, LNLE_{t-1} + \mu_{1t} \quad (3)$$

$$LNLE_t = \vartheta + \sum_{i=1}^{K+dmax} \beta_{1i}\, LNLE_{t-1} + \sum_{i=1}^{K+dmax} \beta_{2i}\, LNRNW_{t-1} + \mu_{1t} \quad (4)$$

The hypotheses for the equation denoted as (3) are:

H_0 : LE is not Granger cause of RNW

H_1 : LE is Granger cause of RNW

The hypotheses for the equation denoted as (4) are:

H_0 : RNW is not Granger cause of LE

H_1 : RNW is Granger cause of LE

In order to apply this test, the maximum degree of integration (dmax) of the VAR model and the optimal lag length (k) must be determined, and then a VAR model in the form of (k+dmax) must be estimated. Previously, the longest lag length is determined by ADF and PP unit root tests and found to be dmax=1. There are various criteria for determining k and the results based on these criteria are given in Table 3.4:

Lag Length	LogL	LR	FPE	AIC	SC	HQ
0	71.05038	NA	1.69e-05	-5.311568	-5.214791	-5.283700
1	181.3793	**195.1973***	**4.75e-09***	**-13.49071***	**-13.20038***	**-13.40711***
2	184.1684	4.505477	5.26e-09	-13.39757	-12.91368	-13.25823
3	186.7031	3.704532	5.99e-09	-13.28485	-12.60741	-13.08977
4	189.9716	4.274276	6.54e-09	-13.22859	-12.35760	-12.97777

Table 3.4 Determining the Optimal Lag Length

Notes: LR indicates sequential modified LR test, FPE final prediction error, AIC Akaike information criterion, SIC Schwarz information criterion and HQ Hannan-Quinn information criterion**. Source:** Research finding. (Authors' compilation from Eviews 11 (IHS Global Inc)).

According to the analysis results in Table 3.4, k=1. k+dmax=2, that is, a 2-step Toda-Yamamoto equation will be solved.

Toda-Yamamoto causality test results are given in Table 3.5:

Hypothesis	Value Chi-square	df	Probability
There is a causal relationship from *LNLE* to *LNRNW*	5.933766	1	0,014853*
There is a causal relationship from *LNRNW* to *LNLE*	1.142.066		0,285216

Table 3.5 Toda-Yamamoto Causality Test Results
Notes: * denotes significance at 5% level. **Source:** Research finding. (Authors' compilation from Eviews 11 (IHS Global Inc)).

According to the results of the Toda-Yamamoto causality test in Table 3.5, there is no Granger causality relationship from *LNRNW* variable to *LNLE* variable. On the other hand, there is a Granger causality relationship from *LNLE* variable to *LNRNW* variable.

3.1 Results

The study analyzed the relationship between Renewable energy consumption (% of total final energy consumption) and Life Expectancy per capita for Turkey during the period of 1990-2019. Two variables were used, *LNRNW* as an independent variable and *LNLE* as a dependent variable. Unit root tests were performed to check the stationarity of the variables. ADF and PP unit root tests showed that *LNRNW* was stationary at the level while *LNLE* was stationary at the first difference. The ARDL boundary test was conducted to determine if there was a long-term cointegration relationship between the variables, and the null hypothesis was accepted. Thus, a long-term relationship between the variables could not be determined.

However, the Toda-Yamamoto causality test was performed to determine the direction of the causality relationship between the variables, regardless of the assumption of cointegration. The test involves the estimation of two VAR models: one for the potential cause and one for the potential effect. The residuals of the cause variable VAR model are then examined to see if they have a causal effect on the residuals of the effect variable VAR model. The results showed that there was no Granger causality relationship from *LNRNW* to *LNLE*, but there was a Granger causality relationship from *LNLE* to *LNRNW*.

4. CONCLUSION AND DISCUSSION

The findings of this study suggest that there is no direct causal relationship between renewable energy consumption and life expectancy in Turkey. Although renewable energy consumption has been promoted as a means to reduce environmental pollution and improve public health, the results of the Toda-Yamamoto causality test indicate that it does not have a significant impact on life expectancy in Turkey. This is consistent with previous research that has found mixed results regarding the impact of renewable energy consumption on health outcomes.

However, the study revealed that an improvement in public health outcomes in Turkey could be associated with an increase in renewable energy consumption, as evidenced by a Granger causality relationship from life expectancy to renewable energy consumption. This suggests that policymakers should consider promoting public health outcomes as a means to increase the adoption of sustainable energy practices.

In addition, the results highlight the importance of considering multiple factors when examining the relationship between renewable energy consumption and public health outcomes. While renewable energy consumption may not directly impact life expectancy in Turkey, it may have other environmental and economic benefits that should be considered when developing energy policies.

In conclusion, this study provides valuable insights into the relationship between renewable energy consumption and life expectancy in Turkey. The results suggest that promoting sustainable energy practices alone may not significantly impact public health outcomes. Instead, policymakers should consider promoting public health outcomes as a means to increase the adoption of sustainable energy practices. The findings of this study can inform the development of energy policies that prioritize both sustainable energy practices and public health outcomes in Turkey. By considering multiple factors, policymakers can develop more comprehensive energy policies that promote environmental sustainability and public health. Overall, this study underscores the need for continued research to better understand the relationship between renewable energy consumption and public health outcomes, and the importance of considering multiple factors when developing energy policies.

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