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Article

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The Nexus between Renewable Energy Consumption and Economic Growth: Empirical Evidence from Jordan

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ABSTRACT

Existing literature on the relationship between renewable energy and economic growth yields mixed outcomes, since the impact of renewable energy consumption on economic growth can be negative, positive or insignificant. Using the autoregressive distributed lag (ARDL) method, this paper examines the nexus between renewable energy and economic growth in Jordan from 2000 to 2020, utilizing renewable electricity output (REO), renewable energy consumption (REC), and gross domestic product (GDP). Utilizing the Dickey–Fuller (ADF) and Philips–Perron (PP) unit root tests, the levels or differences of the stationary variables were explored. The statistically robust findings reveal that renewable energy usage has a substantial positive economic effects. The results indicate that stakeholders (including energy planners, governments, and private sector organizations) must collaborate to increase investment in renewable energy to secure long-term economic growth.

Keywords: ARDL, Climate, Economic Growth, Greenhouse Gas
JEL Classifications: C24; O13; Q2; Q43

1. INTRODUCTION

Climate change and its significant detrimental effects on the environment are critical problems facing the modern world. In recent decades, human activity, particularly energy use, has been identified as one of the primary contributors to climate change (Pachauri and Meyer, 2014). Among other measures, a substantial change in the current technologies of energy production is required to tackle future environmental changes. Traditional fossil fuel combustion techniques for energy generation (e.g., coal, oil, and gas power stations) have negative consequences on the environment; consequently, nations worldwide are trying to shift to more eco-friendly generation methods from renewable sources, including wind and solar. The Energy Information Administration (EIA) indicates that renewable energy generation has been the fastest-growing energy source in recent years (IEA, 2020). Developed nations embrace renewable energy sources to lower greenhouse gas emissions and enhance energy supply security (Al-Kasasbeh et al., 2022).

In addition to contributing to increased modernization of the energy sector itself (Kaygusuz, 2007), investment in and promotion of renewable energies contributes to macro-economic development and the sustainability goals of many nations (Inglesi-Lotz, 2016). Achieving sustainability in energy consumption is likely to result in a cleaner environment, more access to electricity, enhanced energy efficiency with low-carbon renewables, and increased investment in cleaner technologies. In the global context, renewable energy deployment is increasing, which aids in combating climate change and expanding energy access to the billions of people currently living in poverty. In 2013, an estimated 19.1% of global final energy consumption was derived from renewable sources. Hydropower, solar PV, and wind have driven the sector's recent growth. The growth of heating capacity is proceeding at a consistent rate, while the production of biofuels for transportation has lately increased after a recession commensurate with the global economic downturn c. 2011–2012. According to the International Energy Agency's (IEA) most optimistic scenario, the renewable share of electricity generation will increase from 18.3%

in 2002 to 39.0% by 2050, with a commensurate 50% reduction in global CO_2 emissions.

In addition, studies on national energy policies are advancing in this direction. Countries' reliance on imports from potentially unreliable sources, as manifest in the current EU boycott of Russian gas, the uncertainty of fossil resources themselves (which are becoming relatively more expensive to extract), political instability, and the negative environmental impacts of fossil fuels are the major sources of concern motivating political interest in renewables. According to scientific studies, the positive benefits of renewable energy use on the economy and the environment are accumulating daily. Moreover, according to post-oil-crisis policies, mistrust of fossil fuel availability has elevated the issue of energy diversification, and dependence on fossil resources is seen as something to be avoided. The majority of proposed solutions tend to transition to renewable and less expensive energy sources.

According to Special Report of the IPCC on Climate Change Mitigation and Renewable Energy, historical increases in greenhouse gas emissions have been caused by the delivery of energy services, whereas boosts in renewable energy decrease the consequences of climate change (Edenhofer et al., 2011). There is a substantial body of literature studying the association between renewable energy consumption and economic growth as its use has increased, particularly studies investigating the correlation between renewable energy consumption and economic growth. There is a rivulet of literature probing the "neutrality hypothesis," which posits that there is no causal connection between energy consumption in general and economic growth (Menegaki, 2011; Chang et al., 2009; Omri et al., 2015; Bulut and Muratoglu, 2018; Al-Kasasbeh et al., 2023).

Some studies have provided empirical evidence that the consumption of renewable energy increases economic growth (Bilgili and Ozturk, 2009; Magnani and Vaona, 2013; Bilgili and Ozturk, 2015; Bhattacharya et al., 2017). Conversely, other studies have reported that increased use of renewable energy contributes to negative economic growth, which is mainly attributed to the high upfront costs of investing in renewable infrastructure (Marques and Fuinhas, 2012; Ocal and Aslan, 2013; Bhattacharya et al., 2016).

The aim of this study, is to examine the nexus between renewable energy and economic growth in Jordan (Jordan does not have large oil and gas reserves, unlike other countries in the region, therefore Jordan increased renewable energy use). Utilizing unique variables such as renewable electricity output (REO); renewable energy consumption (REC); and gross domestic product (GDP).

In addition, this study consists of five other sections. The second section gives an overview of Literature Review. The third one shows the methodology of the study, sample, data, and model used, and the fourth section discusses the results of the model. Finally, the fifth section highlights the findings and recommendations.

2. EMPIRICAL LITERATURE

Numerous developments in the global climate and environment, macroeconomic factors, globalization, energy technologies (particularly renewables), and market conditions have led to increasing research examining the relationship between energy consumption and economic growth. Economic growth is generally analyzed at the national level (e.g., in terms of GDP), but nations have different political systems, cultures, energy policies, and domestic and imported energy sources, making it highly problematic to make generalized inferences from the outcomes of particular studies. Studies of specific nations with different social, environmental, and economic profiles tend to lead to contradictory outcomes. However, certain economic fundamentals are universal, such as the anticipated effect of energy prices being instrumental in national economic growth; this has numerous potential implications, such as lower economic growth in nations lacking significant energy resources (who thus have to import more costly energy).

Within the framework of sustainable energy supply, the nexus between renewable energy and economic growth has been the subject of numerous streams of literature in various disciplines, including investigations of the relationship between energy and growth within the framework of sustainable energy supply. Since Kraft and Kraft's (1978) groundbreaking study, the literature on the link between energy consumption and economic development has grown. some major empirical studies examining the relationship between renewable energy consumption and economic growth (in terms of GDP) are summarized below.

Al-Mulali et al. (2013) examined the association between renewable energy use and economic growth using data from 1980 to 2009 for 108 countries. According to their findings, there was a two-way relationship between renewable energy usage and economic growth in 85 of the studied nations; in 21, there was no correlation between renewable energy and economic growth; and two nations exhibited a one-way relationship between growth and usage of renewable energy. In total, 79% of nations exhibited a positive, bidirectional, long-term link between the consumption of renewable energy and GDP growth. Shafiei and Salim (2014) evaluated the effects of renewable and nonrenewable energy use on economic development and CO_2 emissions for 29 OECD nations using data from 1980 to 2011. According to their findings, there was a two-way causal relationship between economic growth and use of both renewable and nonrenewable energy. Ohler and Fetters (2014) investigated the association between economic growth and electricity generation from renewable sources using data for 20 OECD nations from 1990 to 2008. The results imply that energy conservation policies could have a positive impact on GDP under certain conditions.

Bhattacharya et al. (2016) analyzed the association between renewable energy use and economic growth for 38 countries with high renewable energy consumption using data from 1991 to 2012. They claimed that renewable energy had a substantial effect on economic growth, and that governments and other relevant institutions and organizations should determine renewable energy policies collaboratively. The findings indicate that some countries have a unidirectional relationship between the consumption of renewable energy and economic growth, and the long- run boost in consumption of renewable energy has a major effect on economic production.

From 1980 to 2012, Hassine and Harrathi (2017) found a causal association between real GDP, trade, renewable energy consumption, and financial development for Gulf Cooperation Council (GCC) countries. It is estimated that private sector credit, exports, and renewable energy consumption have substantial effects on output. In addition, it is anticipated that the usage of renewable energy and exports may contribute to the economic growth of GCC nations. Conversely, Sasana and Ghozali (2017) studied the impact of fossil fuel and renewable energy consumption on economic growth for the five BRICS countries, using data from 1995 to 2014. The findings indicate that the consumption of fossil fuels had a favorable impact on economic growth, whereas the usage of renewable energy had a negative impact.

Benavides et al. (2017) examined the short- and long-term correlations between CH4 emissions, economic growth, power production from renewable sources, and trade openness for Austria using data from 1970 to 2012. Long-run Granger test revealed one-way causation between CH4 and associated variables.

Aydin (2019) analyzed the association between renewable and nonrenewable electricity use and economic growth for 26 OECD nations using data from 1980 to 2015. The link between the variables was analyzed using two distinct panel causality methods: Dumitrescu-Hurlin's (2012) panel causality test, and Croux and Reusens' (2013) causality test. The feedback hypothesis was supported for all studied countries, but Aydin (2019) noted that policies must be evaluated in terms of enhancing environmental quality and electricity energy supply security, in addition to economic growth.

Shao et al. (2020) analyzed the water-energy nexus for China during the period 2004–2014, in order to investigate the relationship between the synergetic conservation of water and energy resources. During the research period, China's industrial sector witnessed a minor reduction in its overall technical efficiency, as defined by the ratio of actual output to ideal output in the production frontier.

Based on yearly data collected from 30 cities in China, Yi et al. (2020) studied the effects of heterogeneous technical progress on haze pollution from 2003 to 2016. To empirically examine the consequences of neutral technical progress and biased technological growth, a systematic GMM method was utilized. Due to the cost-reduction and income effects, the results indicated that neutral technological advance and labor-saving technological progress are helpful for haze reduction, but capital-saving technological progress has no influence on haze pollution.

Rahman and Velayutham's (2020) examined the relationship between renewable and non-renewable energy use and economic growth for five South Asian nations from 1990 to 2014. The research employed the panel causality tests of Pedroni (2004), Kao (1999), and Dumitrescue-Hurlin (2012). The consumption of renewable and nonrenewable energy, as well as the formation of fixed capital, were found to have favorable effects on economic growth. A unidirectional causal link between economic growth and the consumption of renewable energy was also established.

Table 1: Variables description and data source

Variable	Abb.	Period	Source
Economic growth	GDP	2000-2020	WDI
Renewable energy consumption	REC	2000-2020	WDI
renewable electricity output	REO	2000-2020	WDI

WDI World bank development indicators

Therefore, there appears to be no consensus in the literature about the impact of renewable energy use on economic growth. Therefore, this study contributes to the existing literature by examining these unique variables mainly in Jordan. Where Jordan, has not been studied extensively before.

3. METHODOLOGY AND DATA

This study explores the connection between renewable energy and Jordan's economic growth, using data obtained from the World Bank from 2000 through 2020 concerning renewable electricity output (REO), renewable energy consumption (REC), and gross domestic product (GDP). Other variables were dependent on the proportion of REC to total final energy consumption and REO to total electricity output. Before studying the long-term relationship between series, it is essential to determine whether they are stationary. There are numerous unit root tests available for determining the stationarity of a series and the existence of regression issues. The augmented Dickey–Fuller (ADF) and Philips–Perron (PP) unit root tests were utilized in this study to investigate the levels or differences of the variables that are considered to be stationary. The ARDL bound test examined the existence of a long-term relationship between variables in the study. Some variables can be employed at level values *I*(0), while other variables are static in the first difference *I*(1). Moreover, further cointegration methods are sensitive to the periods of the sample. In this method, the duration of the sample periods are not an issue, even if they are brief (Harris and Sollis, 2003). In this regard, Pesaran et al. (2001) firstly evaluated the existence of a long-term association with the boundary test. We can compose an ARDL-constrained model for the purposes of this study as follows:

$$GDP_t = \beta_0 + \sum_{i=1}^{n}\alpha_1 \Delta GDP_{t-i} + \sum_{i=1}^{n}\alpha_2 \Delta REC_{t-i} + \sum_{i=1}^{n}\alpha_3 \Delta REO_{t-\mathrm{i}} \quad (1)$$
$$+\rho_1 GDP_{t-i} + \rho_2 REC_{t-i} + \rho_3 REO_{t-i} + \varepsilon_{t1}$$

Where *GDP* is economic growth; *REC* is renewable energy consumption; *REO* is renewable electricity output; α_1, α_2, and α_3 are coefficients that measure short-run relationships; ρ_1, ρ_2 and ρ_3 are coefficients that measure long run relationships; ε_t is an error term, denoting the lag length of the auto regressive process; and $_t$ is the time trend of the model.

The hypotheses from the above equations are:

$$H_0 : \rho_1 = \rho_2 = \rho_3 = 0$$

(indicating that there is no long run association between the independent and dependent variables).

Table 2: ADF and PP unit root tests

Variables	ADF		P.P	
	At level	At first different	At level	At the first different
GDP	−3.766* (0.006)	−4.795* (0.000)	−3.572* (0.010)	−4.719* (0.000)
REC	−2.011 (0.281)	−8.998* (0.000)	−2.449* (0.134)	−4.912* (0.000)
REO	−2.421 (0.141)	−7.745* (0.000)	−2.384 (0.151)	−7.711* (0.000)

Source: Author's calculation using EViews 11.0

$$H_1 : \rho_1 \neq \rho_2 \neq \rho_3 \neq 0$$

(indicating that there is a long run association between independent and dependent variables).

Table 1 shows the variables used in this analysis. In the Granger causality study, the optimal lag length is calculated using the Akaike information criterion (AIC) and the Schwatz information criterion (SCI) after the maximum integration level of the series has been identified by the ADF and PP unit root tests. To determine causality link and direction, the VAR model is calculated using the number of lags. In the causality relation, the null hypothesis states that independent variables equal zero, whereas the alternative hypothesis states that independent variables do not equal zero. The null hypothesis is rejected and the alternative hypothesis is accepted if the Granger statistic is statistically significant. Acceptance of the alternative hypothesis entails the existence of a causal link between the independent and dependent variables.

4. EMPIRICAL ANALYSIS RESULTS

In order to acquire reliable results, ADF and PP tests were utilized. The results of the unit root test are shown in Table 2, which displays the findings of the unit root analysis of the variable components for REC, REO, and GDP. Each series has a unit root, indicating that they are nonstationary at their levels, but stationary at their initial differences. According to the results of the ADF unit root test, REC, REO, and GDP are integrated in the same sequence, $I(1)$. However, identifying the appropriate lag length is crucial for examining long-term connections between variables; this is where the SCI and AIC come in. The results confirm that "2" is the optimal lag duration for this study. The ARDL bound model is used to examine the long-term relationship.

The ARDL method involves determining whether or not a model's variables have a long-term relationship. A "bounds testing" methodology was developed for this determination, and the ARDL model is specified to determine whether variables have a long-term association. Table 3 shows the critical values. Because the calculated F-statistic was greater than the upper critical value at the 1, 5, and 10% significance levels, it can be argued that there is a long-term association between the variables REC, REO, and GDP.

The short- and long-term results are shown in Table 4 The value of ECM (−1), which must be significant and negative according to the results reported in Table 4, must be both of these things. The "error correction" term suggests that the process of adjustment utilized to restore equilibrium is quite effective. The coefficient is 0.632, and it is significant at a level of 1%; this indicates that short-term shocks or deviations are corrected at the rate of 63.2% in the direction of the long-term equilibrium.

Table 3: Bounds test results

Critical value	Lower bound value	Upper bound value
1%	5.01	4.94
5%	3.82	4.28
10%	3.11	3.84

F-Statistic=8.42105, K=1, Source: Research finding

Table 4: Long run and short run estimates

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D (GDP)	0.015*	0.0076	2.2815	[0.000]
D (REO)	0.102**	0.0052	2.0450	[0.001]
D (REC)	−0.032**	0.0076	6.7563	[0.002]
ECM (−1)	−0.632**	0.02449	−6.5917	[0.000]
Long run coefficients				
GDP	0.628*	0.0459	3.3976	[0.000]
REO	−0.167**	0.0059	3.7332	[0.000]
REC	0.216**	0.0055	4.4425	[0.000]

Source: Research finding

Table 5: Granger causality wald test

Equation	Prob >Chi-square
GDP cause all	P<0.05
REO cause all	P<0.05
REC cause all	P<0.05

Source: Author's calculation

The results shown in Table 5 indicate that GDP is caused by REC and REO. This finding indicates that renewable energy and electricity output are anticipated to have a favorable effect on economic growth in Jordan. According to these findings, policymakers in Jordan must invest in renewable energy sources for the sake of the economy. It can be claimed that renewable energy policies play a crucial role in the nation's strategies, and that a significant portion of national investments should be made in this area. This conclusion is consistent with the findings of Jaradat and Al-Tamimi (2022) and Can and Korkmaz (2019).

5. CONCLUSION

Considering Jordan's dependence on fossil fuels and natural gas as a developing country with socio-economic preconditions antipathetic to renewables adoption (e.g., high unemployment etc.) (Sánchez and Subiela, 2007; Gharaybeh, 2014), it can be claimed that the contribution of renewable energy options in its power mix is relatively substantial. Positive economic advances are anticipated in the future if the cost of establishing renewable energy and its accessibility and cost are comparable with fossil energy sources.

According to the conclusions arising from this study, Jordan must expand its investments in renewable energy resources to enhance the long-term linkages between renewable electricity output, renewable energy consumption, and gross domestic product variables. In this context, it is possible to assert that the positive impacts of renewable energy consumption on economic growth will increase if the nation's strategy and investment incentives are maintained and expanded. Instead of relying on imported fossil fuels, the nation's energy supply should be increasingly geared toward renewable energy sources such as solar and wind.

The results of this study have important implications for legislative authorities; the results highlight the need for new strategies to increase the proportion of renewable energy investments in Jordan's energy production portfolio more quickly and efficiently. more steps must be done the government should invest in renewable infrastructure and support private sector partners via tax breaks for firms investing in renewables.

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