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How Does Renewable Electricity Affect the Environment? The Fresh Evidence from an OPEC Member Country

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Abstract

This study intends to measure the long- and short-run sensitivity of CO_2 emissions to renewable electricity in Iran over 1971-2014. It indicates the potential of renewable electricity in reducing environmental degradation. The results of the Autoregressive Distributed Lag and the Error Correction model confirmed the negative impact of the electricity generated from renewable sources on CO_2 emission. Moreover, the empirically obtained outcomes support the positive impact of energy consumption and GDP on CO_2 emissions in the short and long terms. Based on the growth-enhancing and environment-degrading effects of energy consumption and environment-quality effects of renewable electricity, switching from conventional energy to modern sources must be considered in designing the national energy policies.

Keywords: Renewable electricity; environmental degradation; ARDL; OPEC country

1 Introduction

Global warming caused by environmentally inconsistent manufacturing activities has been one of the most challenging concerns within recent decades. Therefore, it is needed that international organizations, researchers, and policymakers play a proactive role in overcoming the concern (Acheampong, 2018 and Acheampong, 2018). Precisely, two decades after the first Rio Summit, all countries encountered a double challenge: increasing economic opportunities for the growing population and dealing with environmental issues. In this regard, the concept of "green growth" has emerged as a core policy instrument to simultaneously use opportunities to realize the two objectives mentioned above (Hickel & Kallis, 2020).

As an energy-driven economy, Iran needs to integrate a "green economy" into the "energy sector" (Ardestani et al., 2017). However, based on the latest data available on the Statistical Center of Iran website, in 2017, 60.4% of manufacturing value-added belonged to energy-based industries, including the backbone of the manufacturing sectors, and cannot be considered the starting point to reduce energy consumption and control environmental issues. Chemical and petroleum products (38.5%) metals and non-metallic products (21.9%). However, these industries are the backbone of the manufacturing sectors and cannot be considered the starting point to reduce energy consumption and control environmental issues. Therefore, the other energy consumers and high emitting sectors must get more attention as a starting point to design and structure the green growth strategy. To this end, the energy consumption and CO_2 emissions by sectors are illustrated in Figures 1 and 2.

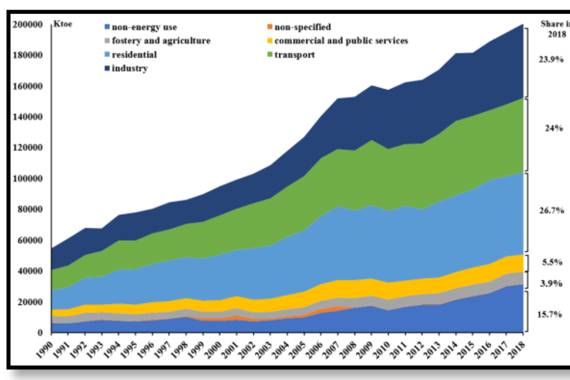

Figure 1: Final energy consumption by sector (1990-2018)
Source: (International Energy Agency, 2020)

As illustrated in Figure 1, between 1990 and 2018, the final energy consumption in Iran has increased at an annual average rate of 4.6% (from 54712 to 200299-kilo tones oil equivalent). Breaking down the final energy consumption by sector showed that in 2018, the residential sector (26.7%) is the largest energy consumer sector, followed by transportation (24%) and industry (23.9%).

As shown in Figure 2, total CO2 emissions have increased 3.4 times in the same period, from 171 to 579 million tons. Among energy consumer sectors, the electricity

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and heat producers (24.1%), followed by the transportation sector (23.9%), have emitted the highest amount of CO_2. This fact can be explained by the dominant share of fossil fuels in the electricity generation mix (Figure 3).

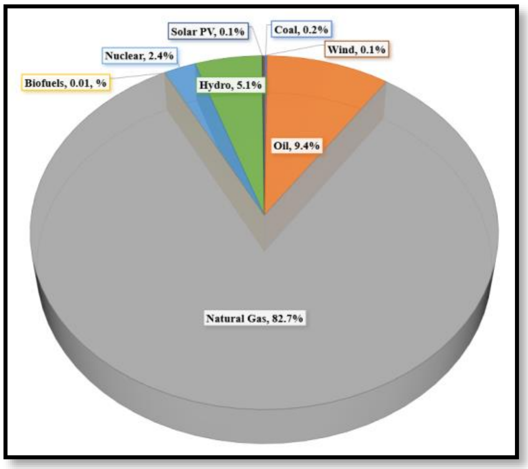

Figure 3. Electricity Generation by fuels, 2018 (%)
Source: (International Energy Agency, 2020).

Fossil fuels accounted for 92.3% of total electricity generation (285.9 TWh) in 2018. Furthermore, the hydro, nuclear, and RE share in electricity generation is 5.1%, 2.4%, and 0.21%, respectively.

Therefore, increasing energy security, controlling the environmental side effects of burning fossil fuels, and achieving sustainable economic growth could be reached through reshaping policies in the power sector. To this end, measuring the elasticity (sensitivity) of CO_2 emissions regarding this sector is required. Therefore, employing Autoregressive Distributed Lag (ARDL) and Error Correction Model (ECM), this paper intends to measure renewable electricity's long and short-run impact on CO_2 emissions in Iran over 1971-2014.

2 Literature review

The relationship between environmental quality and energy consumption as a production input has been widely investigated since the 1990s. Over the period, numerous studies have been conducted to evaluate this nexus using different specifications, methodologies, and variables. The related studies could be categorized into two groups. The first group is considered the renewable energies -CO_2 emissions nexus in a country or a panel of countries can be classified into two categories. The first strand discovered the negative and significant impacts of renewable energy sources on CO_2 emissions (Jebli & Youssef, 2015 for Tunisia; Ben Jebli et al., 2015 for 24 countries in the Sub-Saharan African region; Bölük & Mert, 2015 for Turkey; Dogan & Seker, 2016 for 15 countries in the European Union; Bilgili et al., 2016 for 17 countries of the Organization for Economic Co-operation and Development (OECD); Al-Mulali et al., 2016 for 25 countries of OECD; (Sugiawan & Managi, 2016; for Indonesia; Al-Mulali & Ozturk, 2016 for 27 advanced countries; Danish et al., 2017 for Pakistan; Liu et al., 2017 for four countries of the Association of South East Asian Nations (ASEAN); Zoundi, 2017 for 25 African countries; Dong et al., 2017 for Brazil, Russia, India, China, and South Africa (BRIC); Dong et al., 2018 for China; Zambrano-Monserrate et al., 2018 for Peru; Sinha & Shahbaz, 2018 for India; Gill et al., 2018 for Malaysia; Y. Chen et al., 2019 for China; Yao et al., 2019 for 17 developing & developed countries, six geo-economic regions; and (Lau et al., 2019) for 18 OECD. The second strand of studies concluded that renewable energy consumption has no impact on CO_2 emissions (Al-Mulali et al., 2015 for Vietnam; Al-Mulali et al., 2016 for Latin America and the Caribbean Countries (LACC); Pata, 2018 for Turkey).

The focus of the second strand is on the Energy-CO_2 Emissions Nexus in Iran or a group of countries, including Iran. Using different variables and model specifications, all investigated studies confirmed the positive impact of energy consumption on CO_2 emissions (Saboori & Soleymani, 2011; Safdari et al., 2013; Ozcan, 2013; Apergis & Ozturk, 2015; Amadeh & Kafi, 2015; Taghavee et al., 2016; Sarkodie & Strezov, 2019). Al-Mulali et al., 2016, investigated the existence of an environmental Kuznets Curve in seven regions regarding the role of RE. Their obtained outcomes confirmed the negative impact of RE on CO2 emissions for Central and Eastern Europe (CEE), Western Europe (WE), East Asia and Pacific (EAP), South Asia (SA), and the Americas. However, it cannot affect CO_2 emissions in the case of MENA and Sub-Saharan Africa. Finally, Sinha et al., 2017 employed the Generalized Method of Moments (GMM) to determine the impact of different forms of energy consumption on CO_2 emissions in the context of Next -11 countries. Their results supported the negative effect of RE on CO_2 emissions, whereas nonrenewable energy increases it.

The negative impact of switching from conventional fuels (oil, coal, and natural gas) to renewable electricity on CO_2 emissions was confirmed from the surveyed literature. It means that as a result of utilizing fewer fossil fuels, less CO_2 will be emitted. However, no research has been conducted to evaluate the environmental impact of the power sector in Iran, the country with numerous potentials in renewable sources, being the leading pollutant. Undoubtedly, knowing this sensitivity (elasticity) can help the government and policymakers design and structure the appropriate policies regarding the energy-intensive industry (electricity generation) to pursue green-growth strategies in Iran.

3 Data and Methodology

The yearly data was used over 1971–2014 to investigate the environmental impact of switching from fossil fuels to renewable sources to generate electricity in Iran. To reduce the data variability and to avoid the heteroscedasticity problem in the error terms, the data were converted to the logarithm form (Tiwari, 2010) (Eq.1)

$$\mathrm{L}\,CO2_t = \beta_1 + \beta_2\,\mathrm{L}\,GDP_t + \beta_3\,\mathrm{L}\,EC_t + \beta_4\,\mathrm{L}\,ER_t + \mu_i \quad (1)$$

Where, $\mathrm{L}\,CO_2$ is the logarithm of carbon dioxide emissions (metric tons Per Capita), $\mathrm{L}\,GDP$ is the logarithm of real GDP Per Capita (the constant 2010 US$), L$EC$ is the log of energy consumption (Mtoe) and LER is the logarithm of electricity generated from clean sources (kWh), and μ is the residual term.

The study proceeds to apply the Pesaran et al., 2001, ARDL bounds testing approach concerning this development. Several advantages of this approach can be compared to the Johansen co-integration techniques (Johansen & Juselius, 1990). Compared to the Johansen co-integration techniques, a smaller sample size is required (Oryani et al., 2021). Secondly, the ARDL bounds test does not require the variables to be integrated in the same order (Fatukasi et al., 2015). In other words, the ARDL can be applied whether the variables are purely I (0) or I (1) or mutually integrated. Equation 1 is transferred into the Unconditional Linear Correction Model (Equation 2) to implement the ARDL bounds testing:

$$\begin{aligned}\Delta \mathrm{L}CO2_t = c_o + \sum_{i=1}^{p} c_i \,\Delta \mathrm{L}CO2_{t-i} + \sum_{i=1}^{p} d_i \,\Delta \mathrm{L}GDP_{t-i} \\ + \sum_{i=1}^{p} \Delta \mathrm{L}EC_{t-i} + \sum_{i=1}^{p} \Delta \mathrm{L}ER_{t-i} \\ + \pi_1 \mathrm{L}CO2_{t-1} + \pi_2 \mathrm{L}GDP_{t-1} \\ + \pi_3 \mathrm{L}EC_{t-1} + \pi_4 \mathrm{L}ER_{t-1} + \mu_t\end{aligned} \quad (2)$$

Where: Δ indicates the first differential Operator; $c_0$and d_0 are drift components; p is the maximum lag length and μ_t is the usual white noise residuals. Implementing the ARDL bound test requires taking two steps. The F-test for the joint significance of the lagged level variables is determined in the first step. The null hypothesis for the non-existence of a long-run relation is denoted by $H_0 = \pi_1 = \pi_2 = \pi_3 = \pi_4 = 0$ against $H_a = \pi_1 \neq \pi_2 \neq \pi_3 \neq \pi_4 \neq 0$. Pesaran et al., 2001generate lower and upper critical bounds for F-test. The lower bound's critical values assume that all of the variables are I (0), while the upper bound's critical values assume that all of the variables are I (1). Depends on the F-statistic value, three possible outcomes are obtained. If the F- statistic exceeds the upper critical bound, then the null hypothesis of no-co-integration among the variables can be rejected. If the F-test falls below the lower bound, the null hypothesis of no long-run relation is accepted. If the F-test falls below the lower bound, the null hypothesis of no long-run relation is accepted. If the F-statistic lies between lower and upper bounds, a conclusive inference cannot be made without knowing the order of integration of the underlying regressors. If the results support the long-run relationship, the Error Correction Model (ECM), obtained from the above equation, is estimated as the second step of the ARDL procedure. This approach tests the speed of adjustment and how the variables converge towards equilibrium in the long run. The sign of the coefficient for the lagged error correction term (ECM_{t-1}) must be negative and statistically significant to ensure the convergence of dynamics to long-run equilibrium. Moreover, the diagnostic tests comprise the residual serial correlation, normality, heteroscedasticity, and functional form (B. Pesaran & Pesaran, 2010). Once the variables are co-integrated for the long-run relation, the long and short-run causality can be investigated (Rafindadi & Ozturk, 2017). If the results support the long-run relationship, the ECM obtained from the above equation is estimated as the second step of the ARDL procedure. It uses to test the speed of adjustment and how the variables converge towards equilibrium in the long run. The sign of the coefficient for the lagged error correction term (ECM_{t-1}) must be negative and statistically significant to ensure the convergence of dynamics to long-run equilibrium. Moreover, the diagnostic tests comprise the testing for the residual serial correlation, normality, heteroscedasticity and functional form (B. Pesaran & Pesaran, 2010). Once the variables are co-integrated for the long-run relation, then the long and short run causality can be investigated (Rafindadi & Ozturk, 2017).

4 Empirical Results and Discussion

The first step is to test the unit root properties of the variables to consider the co-integration relationship for the long run. Next, the Kwiatkowski-Phillips-Schmidt-Shin (KPSS) is employed to test the stationary. In this test, the null hypothesis indicates the stationary (Table 1).

Table 1: Unit Root Test Results (at 5% significance level)

Variable	KPSS	Stationary order
LCO_2	0.175	
$LGDP$	0.193	
LEC	0.060	I (0)
LER	0.097	I (0)
ΔLCO_2	0.072	I (1)
$\Delta LGDP$	0.068	I (1)

Note: The critical value at the significance 5% level included the trend and an intercept equal to 0.146

The results confirm that all variables are either I (0) or I (1) at a 5% significance level. In other words, no variable is integrated of order 2, and therefore ARDL approach is applied. The F-Bounds Test is used for examining the existence of co-integration among the respective variables. In this respect, the Akaike Information Criterion (AIC) is used for lag selection (Table 2).

Table 2: ARDL Long Run Form and Bounds Test

t-Statistic	Value	Signif.	I (0)	I (1)
F-Statistic	8.20	10%	2.6	3.5
k	3	5%	3.1	4.09
		1%	4.3	5.5

Critical values are retrieved from (Narayan & Smyth, 2005)

The Wald F-statistic value is greater than the critical value of the upper bound at a 5% significant level, meaning that the null hypothesis can be rejected. In other words, there is a long-run equilibrating (co-integrating) relationship among the respective variables. The long-run results are presented in Table 3.

Table 3: Long-run Result (Dependent Variable: Log CO_2)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LEC	0.504042	0.40614	12.41059	0.0000
LER	-0.208619	0.050863	-4.101614	0.0006
$LGDP$	0.617992	0.057086	10.82569	0.0000
$Constant$	-1.354133	1.161209	-1.166141	0.2580

According to Table 3, energy consumption has a positive and significant impact on CO_2 emission at a 5% level. Keeping other things constant, a 10% increase in energy consumption leads to an increase in CO_2 emission by 5%. This study discovered that the impact of real GDP on CO_2 emission is positive, and it is statistically significant at a 5% level. The results show that a 10% increase in real GDP leads to an increase in CO_2 emission by 6.2% if other things remain the same. The electricity generated by clean energy was negative and had a significant impact on CO_2 emission. By keeping other things constant, it was revealed in this study that a 2.1% decrease in CO_2 emission is due to a 10% increase in generating electricity from clean energy resources. The results of the short-run analysis are presented in Table 4.

Table 4: The Short-run Result (Dependent Variable: Log CO_2)

Variable	Coefficient	T-Statistic	P-value
ΔLEC	0.752639	4.443907	0.0003
ΔLER	-0.083137	-3.070841	0.0063
$\Delta LGDP$	0.602516	4.360612	0.0003
ECM_{t-1}	-0.886911	-5.173931	0.0001
R^2	0.845606		
$D.W$	1.876575		

The results show that renewable electricity has a negative and significant impact on CO_2 emission, confirming the role of clean energy generated on CO_2 emission reduction. Energy consumption is positively and significantly linked with CO2 emission. The impact of real GDP on CO_2 emission is positive and statistically significant. The value of the ECM is negative and statistically significant. The estimate of the lagged ECM is −0.89, meaning that short-run deviations towards the long-run would be corrected by 89% in each year. The results of diagnostic tests, including serial correlation, heteroscedasticity, functional form, and normality of residuals, are reported in table 5.

Table 5: Diagnostic Test Results

Null Hypothesis	F-Statistic	P-Value
There is no serial correlation among the residuals	0.053495	0.9481
The absence of ARCH components	0.029712	0.8641
The normality of residuals	--	0.204368
Appropriate functional form	3.124826	0.0941

ARCH: Autoregressive conditional heteroscedasticity

The findings confirm no evidence of serial correlation, heteroscedasticity, and normality of the residuals as well. The "Ramsey Regression Equation Specification Error Test (RESET) test" showed that the short-run model's functional form is well specified. The "Cumulative Sum of Recursive Residuals" (CUSUM) test and the "Cumulative Sum of Recursive Residuals of Square" test are implemented to examine the stability of coefficients (Figures 3 and 4).

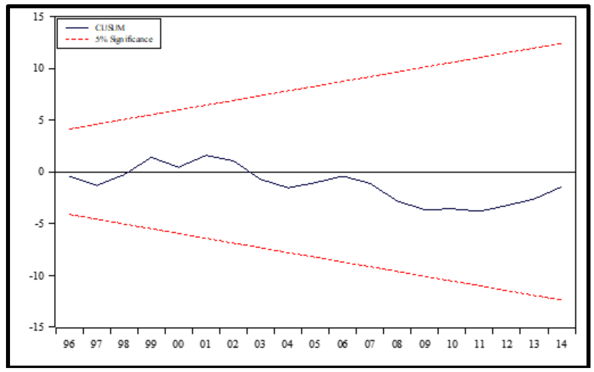

Figure 3: Plot of the Cumulative Sum of the Recursive Residuals

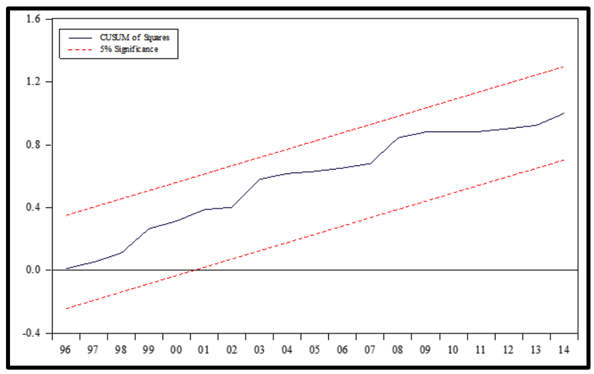

Figure 4: Plot of the Cumulative Sum of the Recursive Residuals of Square

The CUSUM and CUSUM squares (continuous line) did not exceed the dashed line (the upper and lower critical bounds). This statistic verified the consistency of the parameters over time and the absence of structural breaks in the model.

5 Concluding Remark

This study was conducted to evaluate the impact of the electricity generation mix on CO_2 emissions in Iran spanning the period 1971–2014. The ARDL and ECM models were applied. The results of unit root tests confirmed the possibility of applying the ARDL model. The CO2 emissions were identified at the first difference, and none of the independent variables were stationary at the second difference. The existence of long-run co-integration among investigated variables was confirmed by employing the bounds test. The estimation results verified the negative impact of renewable electricity on CO_2 emissions in the long- and short term. The opposite was true for GDP and energy consumption. The negative and significant coefficient of the error correction showed that full convergence to the long-run equilibrium takes 1.5 years. The residual diagnostic tests verified the perfectness of the results from the ARDL.

The results of this study provide some policy implications for the government and policymakers. First, the negative elasticity of CO_2 emissions to renewable electricity and the positive elasticity of CO_2 emissions to energy consumption confirmed that diversification of energy/electricity mix (shifting away from polluting energy towards clean and carbon-free energy) and enhancing energy efficiency is a good energy policy option. In this regard, the following measures must be taken by the government and policymakers:

- Granting subsidies on the factor prices of renewable energies;
- Setting a guaranteed price for renewable energy products;
- Gradual fossil fuel price liberalization to catch up at the international level;
- Providing investment incentives in renewable energies;
- Establishing/extending the required infrastructure.

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