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Do Oil Price, Renewable Energy, and Financial Development Matter for Environmental Quality in Oman? Novel Insights from Augmented ARDL Approach

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Abstract: As an oil-exporting country, Oman traditionally relies on oil sources to meet its energy demand. The country has not been able to safeguard its environment from carbon emissions (CO_2)-related adversities. In this context, this study evaluated the impacts of the price of oil, financial development, economic growth, and nonrenewable energy on the environmental quality in Oman. The research used the recently developed augmented autoregressive distributed lag (ARDL) approach to investigate annual data from 1980 to 2018. The outcomes revealed the following: (i) financial development negatively affected ecological quality in the short and long term; (ii) oil prices positively impact carbon emissions in the long term; however, the price of oil does not significantly influence CO_2 emissions in the short term; (iii) nonrenewable energy is harmful for ecological quality over both the short and long term; (iv) there is a causal link among financial development, nonrenewable energy, and carbon emissions. The current research outcomes present valuable findings for Oman's policymakers in heading toward sustainable financial and energy sectors.

Keywords: Oman; financial sector development; environmental degradation; Bayer and Hanck; bootstrap ARDL

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1. Introduction

Achieving ecological neutrality has become an important goal for Oman. The country is committed to alleviating its carbon emissions. Likewise, in line with its decision to ratify the global Paris 2015 agreement, the country aims to achieve carbon neutrality by 2040. Despite this fact, climate change is still a significant issue in the country [1]. In this context, 75% of the total energy utilization in 2019 was from natural gas and liquid fuels. Moreover, the annual rate of CO_2 emissions increased by approximately 70%, year-on-year, between 1980 and 2018 (see Figure 1). The majority of emissions occurred in the industrial section, transport, and power industry sectors (see Figure 2). On the other hand, the rate of gross domestic product (GDP) in the country has increased in the past few decades; the growth of the GDP increased from 11.2 billion USD in 1990 to 73.6 billion United States dollars (USD) in 2018. This is in line with the research objective, which is to study the impact of oil prices, nonrenewable energy, economic growth, and financial development on carbon emissions from 1980 to 2019.

The price of oil ultimately affects the economic development of both oil-importing and oil-exporting economies [2]. Households use energy in daily life for cooking, transportation, and heating purposes. Moreover, firms heavily depend on fossil fuels in production, communications services, banking, economics, transport, and other services. Therefore, any change in oil price has a significant effect on the economy. Research suggests that increasing oil prices as an external factor will mitigate fossil fuel utilization and encourage markets and individuals to switch to green energy sources such as solar energy. Several empirical studies affirmed that the price of oil has a considerable influence on ecological neutrality [3]; for example, in Pakistan [4], in the top 10 carbon-emitting countries [5], in 30 European countries [6], in the United Arab Emirates (UAE), in Gulf Cooperation Council (GCC) economies [2,7] and in Organization for Economic Co-operation and Development economies [8]. However, the prevailing study aimed to evaluate the link among oil prices and Oman's environmental neutrality. To the best of our research knowledge in the energy and environment literature, no empirical discussion has focused on Oman's economy to test the effects of oil prices on the country's ecological neutrality. Hence, this research aimed at studying the impact of external factors such as oil prices, and local factors such as energy, financial development, and economic growth on the environmental quality in the case of Oman.

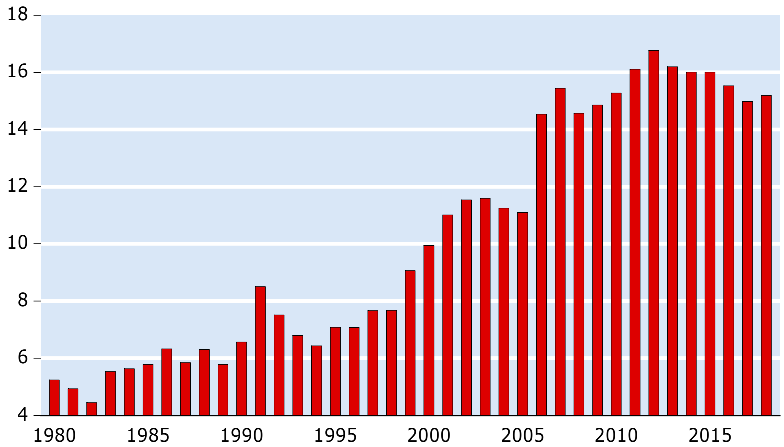

Figure 1. CO_2 emissions rates in Oman over the period from 1980 to 2019.

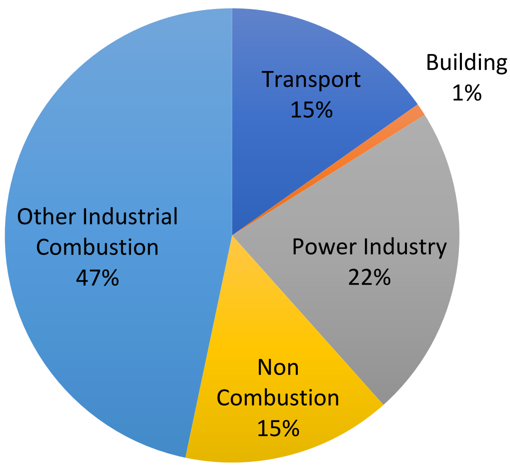

Figure 2. Fossil CO_2 emissions by sector in Oman in 2019.

The country is ranked among the top oil-producing Arab economies, with a production volume of 0.957 million barrels per day and 5306 million barrels of proven oil reserves. Furthermore, the country is ranked 21st globally, accounting for about 0.3% of global oil reserves. However, the country signed the Paris Climate Accord, and diminishing the level of CO_2 emissions has become a central agenda for policymakers in the country. However, the annual rate of CO_2 emissions has increased by approximately 70%, year-on-year, between 1980 and 2018. Thus, the ecological quality in Oman has continuously deteriorated in recent decades. The policymakers in the country have envisioned turning carbon emissions neutral by 2040; however, achieving this objective is likely to be difficult for the country given the fact that fossil fuels, especially oil, predominantly fuel its economic and financial activities. However, the financial stress due to oil price volatility and its impact on Oman's ecological quality is worth an in-depth study. Currently, there are no specific empirical studies for Oman on the link between the price of oil and ecological quality. Moreover, the prevailing research is the first to estimate the impact of focused variables on the rates of Oman's CO_2 emissions, using the recent approach of augmented autoregressive distributed lag (AARDL) as suggested by Sam et al. (2019) [9].

The financial sector in Oman has improved significantly over the last decades; credit from the financial sectors increased from 69% as a share of GDP in 2015 to 20% in 1990. When the financial sectors provide funds to the markets, this reinforces capital and investment, increasing the rate of energy utilization and carbon [10]. However, growth of the financial sector offers cheaper loans to producers that purchase in advance, which raises the consumption of energy. On the other hand, financial sector growth may affect energy consumption through other economic channels, such as economic growth and investments. For instance, this sector offers funds for people and firms, promoting economic development rates. Subsequently, it increases the utilization of energy and CO_2 emissions. This research suggests that the influence of financial sector growth on ecological pollution depends on how this variable affects economic growth. In this respect, any improvement in the financial sectors, such as an increase in the credit from banks to the markets, may lead to boosts in projects and investment, which in turn will enhance the level of energy use and ecological degradation.

The following sections of the study show the review of the literature (Section 2), the empirical model, the employed methodology (Section 3), the outcomes of the study (Section 4), and the conclusions of our research (Section 5).

2. Review of Empirical Literature

Researchers have shown great interest in the interconnection among economic growth (EG), nonrenewable energy consumption (NREC), and CO_2 emissions. For example, reference [11] s howed that GDP positively affected NREC in Brazil, Russia, India, China, and South Africa (BRICS). Reference [12] reported that there is a positive interrelation among the GDP and CO_2 emissions in low-income countries. Reference [13] employed the ARDL method to explore the interconnection among GDP and CO_2 emissions in the case of the UAE from 1975 to 2011. The authors affirmed that the GDP affected REC passively in the case of the UAE. Reference [14] suggested that the GDP positively affects ecological neutrality in the case of BRICS economies. Reference [15] affirmed a positive impact of economic expansion on ecological quality in some European economies from 1990 to 2017. Reference [16] used the augmented mean group, and ensured that economic growth positively influenced the ecological quality in seven emerging economies from 1994 to 2015. In the case of Oman, reference [17] suggested that economic growth positively affected environmental sustainability levels. Similarly, results were found by [7] who employed the same method and demonstrated that economic growth positively affected environmental sustainability in the case of Oman over the period from 1980 to 2019. Study [18] utilized the ARDL method, and showed that the GDP positively affected the carbon emissions rate in Turkey from 1960 to 2013, while the authors suggested that the GDP square has a negative impact on carbon emissions. Hence, the authors confirmed that the Environmental Kuznets Curve (EKC) hypothesis is valid in the case of Turkey. Reference [19] also found that the GDP positively impacts carbon emissions, while the GDP square has a negative impact. Therefore, economic growth increased carbon emissions in the first stage of economic expansion while later, economic expansion decreased carbon emissions. In contrast, reference [20] used cointegration and Ganger causality approaches, and suggested that there were no causal links amongst economic growth and CO_2 emissions in OECD economies. Study [21] used the ARDL approach and suggested that the GDP had a negative impact on CO_2 emissions in the case of the USA from 1972 to 2020. References [22,23] implied that the EKC hypothesis is invalid in Indonesia and in the top six hydropower energy-consuming countries. These studies suggested that as economic growth increased in the tested countries, ecological pollution continued to increase in the long term; therefore, economic expansion is not a solution to address ecological sustainability problems.

Studies based on environmental quality determinates have also examined the link between nonrenewable energy (NREC) and carbon emissions. For example, study [24] applied the same approach to assess the interconnection between energy and the rate of ecological neutrality in BRICS economies from 1990 to 2019. The obtained outcomes demonstrated that an upsurge in NREC may increase CO_2emissions rates in BRICS countries. Reference [25] investigated the link between NREC and CO_2 emissions in 107 countries during the period from 1990 to 2013. Using panel integration analysis, the outcomes showed that an upsurge in NREC led to an increase in the rates of CO_2 emissions. Study [26] utilized the ARDL method, and indicated there was a positive link between NREC and CO_2 emissions in China over the years 1991–2020.

On the other hand, several studies have proven that financial development is the primary driver of economic growth (e.g., [27,28]). Furthermore, other studies have addressed the interconnections between financial development and ecological quality. For example, reference [29] employed the ARDL model and suggested that a significant improvement in financial development (FD) positively affected the level of carbon emissions in the case of China. Study [30] explored the connection between financial growth and ecological emissions in 40 European economies, and found a positive link between financial expansion and environmental emissions. Reference [31] examined the influence of FD on carbon emissions in West African economies from 2003 to 2014. The outcomes demonstrated that financial growth has a powerful impact to decrease the rates of CO_2 emissions in West African economies. Study [32] examined the interconnection between carbon emissions and financial growth for the tested period of 1985–2015. The outcomes demonstrated that FD positively impacted Bangladesh's carbon emissions. Reference [27] examined the effect of financial growth on CO_2 emissions for the G7 nations during the period 1970–2014. The authors revealed that financial growth had a positive effect on the rate of CO_2 emissions in Canada, Japan, and the USA. On the other hand, study [33] used the generalized method of moment approach, and suggested that financial development adversely affected the level of CO2 emissions from some selected countries over the period 1980–2015. Reference [34] used a non-linear ARDL approach, and suggested that financial development was negatively linked with carbon emissions from 1991 to 2015. The authors suggested that more research and development in the financial sector would be helpful in mitigating the level of CO_2 emissions. Study [35] employed d fully modified (CUP-FM) methods, and showed that an improvement in the financial sector had an adverse impact on CO_2 emissions in Asia Pacific Economic Cooperation nations. Meanwhile, study [36] used panel vector autoregressive analysis, and suggested that financial development had no significant impact on carbon emissions in the Middle East and North Africa from 1980 to 2015.

Finally, scholars have focused on exploring the link between oil prices and ecological neutrality. Some studies affirmed that the price of oil considerably influences ecological neutrality. In this way, study [3] investigated the interconnection between oil prices and carbon emissions levels in Pakistan; the outcomes demonstrated a negative linkage between them. Reference [4] used the NARDL model, and reported that oil prices negatively affected environmental sustainability levels in the top ten carbon-emitting countries. Similarly, results were found by [5], who used the FMOLS approach and found there was a negative link between the price of oil and ecological quality in European countries. Reference [6] further suggested that there was a negative link between oil prices and ecological emissions in the case of the USA. Recently, study [37] proposed a negative interrelationship between oil prices and some European countries' carbon emissions. Study [7] examined the same relationship in GCC countries, and found that there was a positive interrelation between oil prices and carbon emissions.

In contrast, study [2] suggested that negative oil price changes are positively linked with ecological carbon. On the other hand, some papers showed a positive interrelation between oil prices and ecological neutrality. For example, reference [8] proposed that an increase in the oil price increases ecological neutrality in the case of OECD countries.

3. Model, Data, and Methodology

In the current research, economic growth (GDP), nonrenewable energy consumption (NREC), financial sector development (FD), and oil price (OP) were the main determinants of carbon emissions. Hence, the examined model was structured as in the following formula:

$$CO_2 = f(GDP, OP, FD, NREC) \quad (1)$$

where CO_2 represents the carbon dioxide emissions to measure environmental pollution, GDP is the economic growth in Oman, NREC represents the utilization of nonrenewable energy in Oman, and OP is the oil price. Thus, the examined model can be formulated as follows:

$$\ln CO_{2t} = \beta_0 + \beta_1 \ln GDP_t + \beta_2 \ln OP_t + \beta_3 \ln FD_t + \beta_4 \ln NREC_t + \varepsilon\ it \quad (2)$$

where $\ln CO_{2t}$ is the carbon emissions per capita; $\ln GDP_t$ is the GDP per capita in constant 2018 US dollars; $\beta_3 InFD_t$ is the financial sector development index measured and determined by credits from banks to markets as a % of GDP in Oman; $\ln NREC_t$ is the total consumption of nonrenewable energy (coal, oil, and gas); $InOP_t$ represents Brent crude oil. The examined data of the current research were obtained from the World Bank (World Bank), the IMF, and the Our World in Data websites. The data retrieved were yearly data, and ranged from 1980 to 2018.

Stationary and Cointegration Tests

To capture the cointegration amongst the selected variables, this research used unit root tests with dates of structure changes (DSC) such as the Zivot–Andrews (ZA) (2002 [38] and Perron–Vogelsang (PV) (1999) [39] tests with one date of structural change. To check the long-run link amongst the FD, GDP, OP, NREC, and CO_2 variables, the study used the recently developed augmented autoregressive distributed lag (ARDL) testing. Unlike other estimating approaches, this model evaluated if there was cointegration among the variables in three cases, I (1), I (0), or both. Recently, this model was updated and improved; the updated method combines an additional t-test $t_{dependent}$ or F-test $F_{independent}$ on the lagged studied variables. The H_0 of the $t_{dependent}$ test is $\sigma 1 = 0$. The H_1 of the $t_{dependent}$ test is $\sigma_1 \neq 0$, whereas the H_0 of the $F_{independent}$ test is H_0: $\sigma_2 = \sigma_3 = \sigma_3 = \sigma_4 = \sigma_5 = 0$. The H_1 of the $F_{independent}$ test is H_1: $\sigma_2 \neq \sigma_3 \neq \sigma_3 \neq \sigma_4 \neq \sigma_5 \neq 0$.

In the new model of the ARDL testing, the critical values (CV) were established on a particular level of integration for each studied variable, which will affirm the ARDL (2001) test findings. The CV, as presented by Pesaran et al. (2001) [40], allows only for one selected variable to be endogenous. In comparison, the CV of the new method of ARDL testing allows for all employed variables to be endogenous. Sam et al. (2019) [9] proposed that the CV of the f-statistics for the tested samples could be obtained from Narayan (2005) [41], while the values of the t− statistics value could be derived from the CV suggested by Pesaran et al. (2001). The proposed method is called the "Augmented" ARDL. This method is formulated using the following equation:

$$\begin{aligned}\Delta \ln CO_{2\ t} = {} & \beta_0 + \sum_{i=1}^{n} y_1 \Delta \ln CO_{2\ t-j} + \sum_{i=1}^{n} y_2 \Delta \ln GDP_{t-j} + \sum_{i=1}^{n} y_3 \Delta \ln OP_{t-j} + \sum_{i=1}^{n} y_4 \Delta \ln FD_{t-j} \\ & + \sum_{i=1}^{n} y_4 \Delta \ln NREC_{t-j} + \sigma_1 \ln CO_{2\ t-1} + \sigma_2 \ln GDP_{t-1} + \sigma_3 \ln OP_{t-1} + \sigma_4 \ln FD_{t-1} + \sigma_5 \ln NREC_{t-1} \\ & + \varepsilon_{1t}\end{aligned} \quad (3)$$

where Δ means the first difference operators; $\ln CO{-_2}$ is the logarithm of the dependent variable; lnGDP, lnOP lnFD, and lnNREC are the independent tested variables in log; n is the lags optimal; and ε_{1t} symbolizes the error term. The error correction model (ECM) was formulated by the following Equation (4) to estimate the speed level of adjustment:

$$\Delta lnCO_{2\ t} = \beta_0 + \sum_{i=1}^{n} \beta_1 \Delta lnCO_{2\ t-j} + \sum_{i=1}^{n} \beta_2 \Delta lnGDP_{t-j} + \sum_{i=1}^{n} \beta_3 \Delta lnOP_{t-j} + \sum_{i=1}^{n} \beta_4 \Delta lnFD_{t-j} + \sum_{i=1}^{n} B_5 \Delta lnNREC_{t-j} + ECT_{t-1} + u_t \tag{4}$$

where Δ is a change in $lnCO_2$, lnOP, lnFD, lnGDP, and lnNREC, and ECT_{t-1} is an error correction term. In addition, the Bayer and Hanck (2013) [42] method was utilized to reinforce the A-RDL of the cointegration method. The core advantage of this approach is that it combines (four) cointegration techniques, namely that of Boswijk (1994) [43], Banerjee et al. (1998) [44], Johansen (1988) [45], and Engle and Granger (1987) [46]. Furthermore, this method includes the Fisher F statistics to enhance the cointegration outcomes. This approach is structured in the following formulas:

$$EGt - JOHt = -2[IN(P_{EGt}) + (P_{JOHt})] \tag{5}$$

$$EGt - JOHt - BOt - BDMt = -2[IN(P_{EGt}) + (P_{JOt}) + (P_{BOt}) + (P_{BAt})] \tag{6}$$

Likewise, the present research employed the autoregressive conditional heteroskedasticity (ARCH) statistical test, and the Breusch–Pagan–Godfrey test to ensure the explored model was free from serial correlations. Moreover, the study employed the normality and Ramsey assessments to ensure that the current model was customarily distributed and stable. Furthermore, the study utilized the fully modified OLS (FM-OLS) statistical model as developed by Phillips and Hansen (1990) [47], the dynamic-OLS model (DOLS) statistical model as advanced by Stock and Watson (1993) [48], and the canonical cointegrating regression (CCR) statistical model as introduced by Par (1992) to affirm the findings of the ARDL method.

Finally, the Granger causality approach was employed to check the causal link among the GDP, OP, FD, and CO2 emissions variables. In this way, the causal association among GDP, OP, FD, and CO2 in a short time was captured based on the Wald testing approach. Furthermore, the error correction term (ECT) was used to assess the short-run deviations of the focused variables. However, the ECT can be formulated in the equations below:

$$\Delta lnCO_{2\ t} = \partial_0 + \sum_{i=1}^{p} y_1 \Delta lnCO_{2\ t-1} + \sum_{i=1}^{q} y_2 lnGDP_{t-1} + \sum_{i=1}^{q} y_3 \Delta lnOP_{t-1} + \sum_{i=1}^{q} y_4 \Delta lnFD_{t-1} + \sum_{i=.1}^{q} y_5 \Delta lnNREC_{t-1} + \partial_1\ ECT_{t-1} + u_{1t} \tag{7}$$

$$\Delta lnGDP_t = \partial_0 + \sum_{i=1}^{p} y_1 \Delta lnGDP_{t-1} + \sum_{i=1}^{q} y_2 lnCO_{2\ t-1} + \sum_{i=1}^{q} y_3 \Delta lnOP_{t-1} + \sum_{i=1}^{q} y_4 \Delta lnFD_{t-1} + \sum_{i=1}^{q} y_5 \Delta lnNREC_{t-1} + \partial_1\ ECT_{t-1} + u_{1t} \tag{8}$$

$$\Delta lnOP_t = \partial_0 + \sum_{i=1}^{p} y_1 \Delta lnOP_{t-1} + \sum_{i=1}^{q} y_2 lnCO_{2\ t-1} + \sum_{i=1}^{q} y_3 \Delta lnGDP_{t-1} + \sum_{i=1}^{q} y_4 \Delta lnFD_{t-1} + \sum_{i=1}^{q} y_5 \Delta lnNREC_{t-1} + \partial_1\ ECT_{t-1} + u_{1t} \tag{9}$$

$$\Delta lnFD_t = \partial_0 + \sum_{i=1}^{p} y_1 \Delta lnFD_{t-1} + \sum_{i=1}^{q} y_2 lnCO_{2\ t-1} + \sum_{i=1}^{q} y_3 \Delta lnGDP_{t-1} + \sum_{i=1}^{q} y_4 \Delta lnOP_{t-1} + \sum_{i=1}^{q} y_5 \Delta lnNREC_{t-1} + \partial_1\ ECT_{t-1} + u_{1t} \tag{10}$$

$$\Delta lnNREC_t = \partial_0 + \sum_{i=1}^{p} y_1 \Delta lnNREC_{t-1} + \sum_{i=1}^{q} y_2 lnCO_{2\ t-1} + \sum_{i=1}^{q} y_3 \Delta lnGDP_{t-1} + \sum_{i=1}^{q} y_4 \Delta lnOP_{t-1} + \sum_{i=1}^{q} y_5 \Delta lnFD_{t-1} + \partial_1\ ECT_{t-1} + u_{1t} \tag{11}$$

4. Results and Discussion

The estimated values of means, medians, maximum and minimum, skewness, and standard deviations of the examined variables are presented in Table 1. Besides, Figure 3 shows the tested variables in the plot.

Table 1. Descriptive statistics results.

	Mean	Median	Maximum	Minimum	Skewness	Std. Dev.
CO_2	2.235556	2.2039	2.819387	1.491885	−0.01802	0.429103
GDP	2.290906	2.300255	2.374008	2.172268	−0.23836	0.063824
OP	3.538542	3.36211	4.718231	2.543176	0.395784	0.659158
FD	−1.20022	−1.13943	−0.8675	−1.66073	−0.24588	0.240026
NREC	4.537074	4.412575	5.942233	2.836641	−0.11175	0.935294

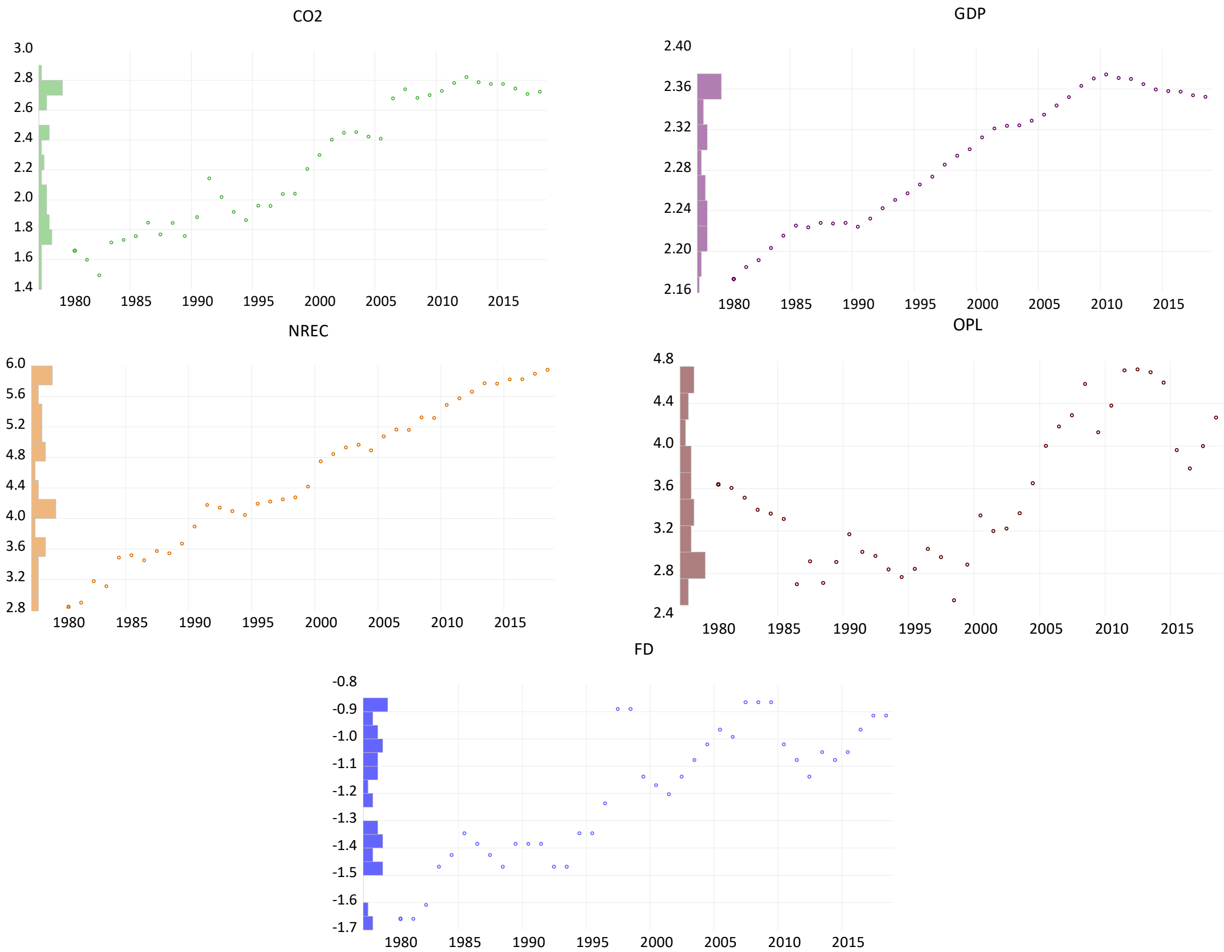

Figure 3. The tested variables in the plot.

The ZA and PV unit root tests with one DSC are illustrated in Tables 2 and 3. The employed assessments considered one and two DSCs in the explored variables. These employed assessments showed that all of the variables were found to be of order I (1). However, the results of the ZA and PV tests illustrated that the $\ln CO_2$, lnGDP, lnFD, lnNREC, and lnFD variables had order I (1). The outcomes of the ARDL method are displayed in Table 4. The results affirmed that the cointegration amongst $\ln CO_2$, lnGDP , lnFD, lnNREC, and lnOP is valid. Furthermore, the obtained outcomes of the BH testing, as shown in Table 5, illustrate that the values of *F*-statistics are higher than *F*-statistics in the four cointegration tests (Boswijk, Banerjee, Johansen, Engle, and Granger) at a 5% significant level. This finding proved that the focused variables have significance cointegration.

Table 2. The outcomes of ZA test.

	Level I (0)			Δ (1)	
Variables	***t*-stat**	**DSC**	**Variables**	***t*-stat**	**DSC**
CO_2	−3.676581	1999	CO_2	−6.691737 [a]	1995
GDP	−1.972157	2011	GDP	−5.035939 [a]	2011
OP	−3.516277	2004	OP	−6.333109 [a]	2009
FD	−3.207777	2008	FD	−5.291217 [a]	1999
NREC	−4.081156	2000	NREC	−6.869476 [a]	1999

[a] Symbolizes significance of variables at 1%. DSC means dates of structure changes.

Table 3. The outcomes of PV test.

	Level I (0)			Δ (1)	
Variables	***t*-Statist**	**DSC**	**Variables**	**S*t*-Stat**	**DSC**
CO_2	−2.946801	1998	CO_2	−7.098252 [a]	1991
GDP	−3.645669	1990	GDP	−8.542664 [a]	1986
OP	−3.644178	2003	OP	−6.144034 [a]	1986
FD	−1.506761	1999	FD	−6.512516 [a]	1997
NREC	−2.458311	1999	NREC	−7.768885 [a]	1991

[a] Symbolizes significance of variables at 1%. DSC means dates of structure changes.

Table 4. Augmented ARDL analysis.

			Test Stat				
F Overall			***t* Dependend**			**F Independent**	
6.769925			−4.580164			7.307154	
	(REC, GDP, FDI, OP, TR)				Lag length (1, 2, 1, 2, 4)		
CV		1%		5%	10%		
Statistics	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)	Reference
F overall	4.40	5.72	3.47	4.57	3.03	4.06	[41]
T dependent	−3.96	−4.96	−3.41	−4.36	−3.13	−4.04	[9]
F independent	3.40	5.68	2.40	4.31	1.97	3.62	[40]
	Diagnostic						
Tests	**F-statistics**	***p*-value**			**Tests**	**F-statistics**	***p*-value**
Ramsey	0.221749	0.6434			ARCH	1.276070	0.2659
Normality	0.485820	0.7843			Heteroskedasticity	1.162867	0.3728

Table 5. Results of BH test.

	Fisher−Statistics	
	EGT.JOT	EGT/JOT/BOT/BAT
	12.445 [a]	40.378 [a]
Significance level	10.576	20.143

[a] Symbolizes significance at 5% level.

The coefficients from the ARDL method are displayed in Table 6. The findings illustrate that the coefficient of the GDP variable is positive. These results demonstrate that a "1%" increase in GDP in the county would cause a 1% substantial increase in the rate of ecological pollution, with 1.32% and 1.52% in the short and long term; however, the coefficient of GDP in the short term is not significant. The DOLS, CCR, and FMOLS are displayed in Table 7. The coefficients of GDP in these models are positive and significant; however, the findings from the employed methods prove that a positive increase in the economic growth rate significantly increases the environmental pollution level. These empirical findings support the findings of [19,27,49], who illustrated that the GDP positively affected the CO2 rates.

Table 6. ARDL short- and long-run analysis.

Variable	Coefficient	Std. Error	$T_{Statistics}$	Prob.
Short run				
GDP	1.328479	1.220988	1.088036	0.2902
OP	0.052003	0.036100	1.440551	0.1660
FD	0.540404 [a]	0.188492	2.866984	0.0099
NREC	0.928644 [a]	0.288097	3.223377	0.0045
Long run				
GDP	1.526572 [a]	0.325791	4.685735	0.0002
OP	0.059758 [a]	0.009582	6.236370	0.0000
FD	0.620984 [a]	0.069116	8.984609	0.0000
NREC	1.067116 [a]	0.082851	12.87991	0.0000
ECT_{t-1}	−0.870237 [a]	0.135948	−6.401239	0.0000

[a] Indicates the significance of the explored variables at 1% levels.

Table 7. Findings of FMOLS, and CCR model.

Models		**FMOLS**			**CCR**	
Variables	**Coefficient**	***t.* Stat**	**PV**	**Coefficient**	***t.* Stat**	**PV**
GDP	0.264116 [a]	2.744030	0.0096	0.560915 [a]	5.785837	0.0000
FDI	0.111428 [a]	4.176536	0.0002	0.100201 [a]	4.013488	0.0003
OP	0.214798 [b]	2.496612	0.0175	0.385576 [a]	4.576984	0.0001
NREC	0.329302 [a]	10.03132	0.0000	0.249388 [a]	7.598924	0.0000

[a] and [b] indicate the significance of the explored variables at the 1% and 5% levels, respectively.

In addition, the findings from the ARDL method illustrate that the coefficient of NREC is positive and significant. These outcomes show that a one percent increase in NREC causes a considerable increase in environmental pollution in Oman, with 0.92% and 1.06% in the short and long run, respectively. The NREC coefficients in the FMOLS, DOLS, and CCR estimators are positive and significant. The outcomes from the employed methods affirm that a positive increase in the NREC level significantly reduces the environmental quality. These findings support the results of [50], who used the vector autoregressive model and found that NREC has a positive influence on the emissions levels in the case of France, and the researchers of [51–53], who affirmed that NREC affected emissions positively.

On the other hand, the obtained outcomes from the ARDL estimator, in the long run, illustrated that the coefficient of FD is positive and significant. These outputs illustrate that a one percent increase in FD causes substantial increases in the level of environmental pollution in Oman, with 0.551% and 0.160%. The estimated coefficients of BSD in the FMOLS, DOLS, and CCR models were positive and significant. However, the findings from the employed methods demonstrate that a positive increase in the level of FD significantly increases ecological pollution. These outcomes can be explained by the fact that growth in the financial sector means cheaper loans to producers, who then purchase advanced raised energy utilization. On the other hand, financial sector growth may affect energy utilization through other economic channels, such as through economic growth and investments. For instance, the financial sector funds projects and assets, which enhance GDP rates and fossil fuel consumption. However, this study suggests that financial development mitigates the rate of ecological pollution when the markets offer and introduce financial assistance to markets to obtain green technologies. In contrast, financial development promotes the rate of ecological pollution when the markets offer credits to increase investment and consumption in non-clean energy sources.

On the other hand, the findings from the ARDL estimator in the long run illustrated that the coefficient of oil price is positive and significant. These outputs demonstrated that a one percent increase in OP causes a substantial increase in the environmental pollution in Oman, with 0.05%. Moreover, the findings from the robust models show that oil price growth is positive and significant. However, the findings from the employed methods demonstrate that a positive increase in the price of oil significantly increases ecological pollution. This result is consistent with [2], which demonstrated that an increase in the price of oil mitigates environmental quality levels in the GCC countries. Figure 4 shows the summary of the linkages among the tested variables.

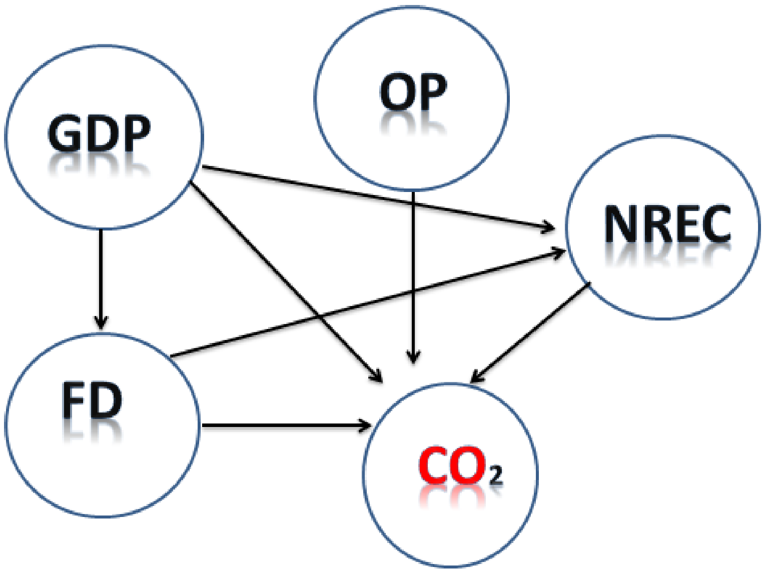

Figure 4. Summary of the linkages among the tested variables.

The ECM outcome is reported in Table 6. The ECM was −0.87, which is significant and negative. To reinforce that the tested model of the research was formulated correctly, the study employed the normality, Breusch–Pagan–Godfrey, ARCH, and Ramsey RESET tests. The outcomes of these tests verified that the studied model is statistically stable. Likewise, the results display that the model of the present research is typically distributed, and there is no auto-correlation. In addition, Figure 5 confirms that the examined model of the current research is stable.

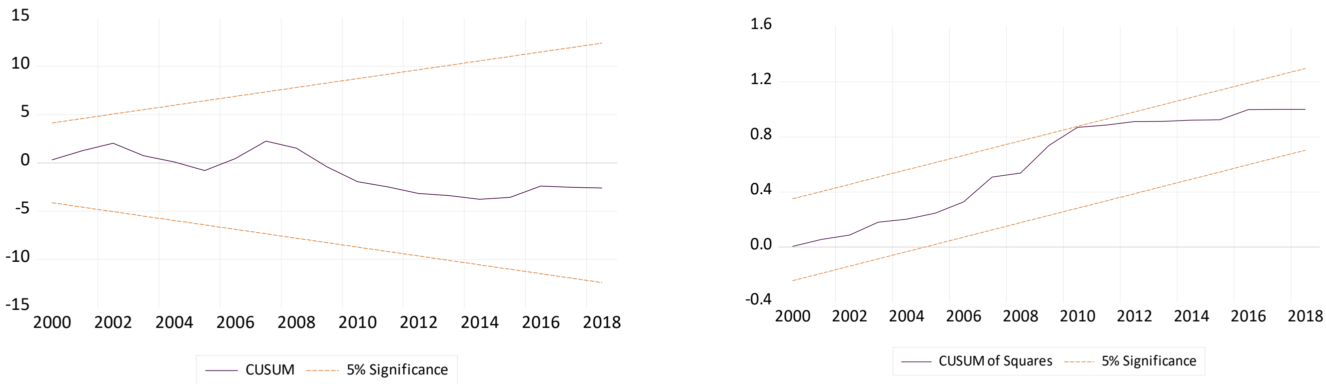

Figure 5. CUSUM and CUSUM squared assessments.

Finally, the findings from the Granger causality test (Table 8) show a causal link among financial development, nonrenewable energy, oil price, financial development, and carbon emissions, in both the short and long run. These findings affirm the findings of the ARDL approach.

Table 8. Findings of Granger causality test.

		Short−Run				**Long−Run**
(Y/X)	**CO_2**	**GDP**	**OP**	**FD**	**NREC**	**ECTt−1**
CO_2	-	14.75 [a]	3.06 [c]	3.94 [c]	6.11 [a]	−0.36 [a]
GDP	1.82	-	0.57	0.96	0.10	0.01
OP	1.36	0.57	-	1.49	2.15	−0.20
FD	2.03	4.56 [b]	1.49	-	1.83	0.45
NREC	2.19	2.60 [c]	0.95	6.22 [a]	-	−0.32 [c]

[a], [b] and [c] indicate significance of the explored variables at the 1, 5, and 10% levels, respectively.

5. Conclusions

5.1. Conclusions

Over the last decades, Oman's economy has been growing vastly. On the other hand, ecological degradation is still a significant challenge in Oman. However, the country is ranked among the top oil-producing Arab economies, with a production volume of 0.957 million barrels daily, and 5306 million barrels of proven oil reserves. Furthermore, the country is ranked 21st globally, accounting for about 0.3% of global oil reserves. Oman envisioned turning carbon emissions neutral by 2040. In this context, the country aims to increase the percentage of electricity generation capacities from renewable energy sources at least 30% by 2030. In the last years, the government has embarked on several projects in line with the 20,230 target, including 11 solar–diesel hybrid facilities; a wind power plant in Dhofar city; two solar independent power producers in Manah town; and the "Sahim" initiative to install small-scale solar panels on some buildings. Despite this fact, Oman, like all of the GCC economies, depends largely on conventional resources energy such as natural gas and oil, which accounted for 99% of the primary energy resources in Oman in 2018. Hence, the annual rate of CO_2 emissions has increased by approximately 70%, year-on-year, between 1980 and 2018. It is clear that achieving the 20,230 target is likely to be difficult for the country, given the fact that fossil fuels, especially oil, predominantly fuel the economic and financial activities in the country. This heavy economic reliance on fossil fuel consumption negatively affects the ecological sustainability. However, hydrocarbon revenues accounted for 79% of total government revenues in 2018. These revenues have a positive impact on economic development in the country. Therefore, sustaining hydrocarbons exports revenues, and thus maintaining the provision of energy subsidies to keep prices of electricity low, is an essential issue for the policymakers in the country. Hence, the main barriers to sustainable development in Oman are the lack of supporting renewable energy projects, competitiveness, and high oil and gas subsidies. Therefore, the current study aimed to evaluate the interactions between the price of oil, nonrenewable energy consumption, financial development, economic growth, and ecological quality in Oman. In the existing literature, few studies evaluated the impact of oil prices on environmental pollution in the case of GCC countries. However, the present research is the first to test the impact of oil prices on CO_2 emissions in the case of Oman, using the recently developed augmented approach as suggested by Sam et al. (2019). The findings from the AARDL, CCR, and FMOLS methods illustrated that economic growth positively affected the ecological pollution in Oman over the tested period. Furthermore, the findings affirmed that NREC positively affected the carbon emissions level. Furthermore, the findings affirmed that the financial sector positively influences the ecological degradation level. Likewise, the findings suggested that an increase in oil prices as an external shock led to increased carbon emissions in the country over the tested period. These outcomes can be attributed to the fact that any oil price change significantly affects the economic development of both oil-importing and oil-exporting countries. Hence, increases in oil prices presents good news for oil-exporting countries such as Oman to increase the country's revenues, which in turn will promote economic development. Subsequently, this leads to increases in the levels of carbon emissions.

5.2. Policy Implications

Based on the conclusions of this study, we propose several useful implications for policy.

Firstly, fossil fuel sources significantly affect economic and financial development. Simultaneously, the costs of power generated from green energy technologies are still higher than those generated from fossil fuels. Hence, renewable energy development requires essential changes that may not align with government interests to preserve the status quo on oil production. The vital changes can be oil and gas subsidy reform for electricity market liberalization. Likewise, the country must review hydrocarbons' pricing so that electricity prices reflect the production costs. This step will raise the competitiveness of renewable energy sources and reinforce the efficient use of energy. Likewise, this step will decrease pressure on the country's public budget. Hence, policymakers can use the public budget surplus to support renewable energy projects.

Secondly, promoting renewable energy resources is one of the most effective ways to promote environmental quality. Hence, the collective action of all actors involved in renewable energy development, including private companies, governments, scholars, and non-governmental organizations, is essential to enabling a systematic transition towards green energy sources. Likewise, policymakers must promote research and development in renewable energy, increase public awareness of new renewable energy technologies, and encourage people and firms to use renewable energy sources, for example, rooftop solar power systems can be promising for spreading small-scale clean energy projects. Hence, policymakers must design policies to support solar power system owners.

Thirdly, dedicated financial instruments and incentives are necessary to incentivize people and investors to engage in renewable energy development; the study suggests that financial incentives and fiscal tools are the main efficient tools that promote ecological sustainability by stimulating green projects [54]. Hence, financial and economic incentives such as low tax rates and low-interest rates on clean investment will help sustain the environment. However, financial incentives must be applied in the country to enhance ecological quality. In this context, the policymakers in Oman should adopt the environmental taxation instrument, which is considered one of the best practical tools to reduce ecological degradation. Likewise, governments in Oman must use the expansion of the financial sectors and taxation policies to mitigate CO_2 emissions by enhancing green investment utilization.

5.3. Limitations and Future Research

This study evaluated the impacts of the price of oil, financial development, economic growth, and nonrenewable energy on the environmental quality in Oman. Nevertheless, this study has some drawbacks. (i) The present research focused on only Oman; the country is ranked 21st globally, and accounts for about 0.3% of the global oil reserves. For this reason, future empirical studies can focus on other oil-exporting economies. (ii) The research considered only the price of oil, financial development, and nonrenewable energy; thus, new empirical studies can consider other factors, such as banking development. (iii) The research used annual data from 1980 to 2018, due to limitations in data availability. (iv) The research used the recently developed augmented ARDL method to investigate the connection among the selected variables; new empirical studies can employ other models and techniques.

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