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Abstract

This study examines the symmetric and asymmetric nexus between capital investment, economic growth, foreign direct investment, and CO₂ emissions in Oman during 1980- 2019. For this purpose, we applied ARDL Model for linear cointegration and NARDL model for nonlinear cointegration between capital investment, economic growth, foreign direct investment, and CO₂ emissions. The bound test shows the long-term equilibrium relationship among CO₂ emissions, capital investment, economic growth, and FDI in both models. The error correction mechanism demonstrates that CO₂ emissions congregate to their long-run equilibrium level at a 50.1 percent annual pace of adjustment by integrating capital investment, economic growth, and FDI under the symmetric model. The causality test results show that carbon emissions and FDI, economic growth, and CO₂ emissions exhibit bidirectional causal links. While, on the other hand, unidirectional causal links are running from capital investment to GDP. The asymmetric results show that positive shocks to FDI and economic growth have significant tumbling consequences on Oman's carbon dioxide emissions.

In contrast, negative shocks in FDI and economic growth substantially increase carbon dioxide emissions. The research findings also reveal that carbon dioxide emissions are more resilient to negative shocks in FDI and economic growth. Based on these results, this study accomplishes that abatement measures should consist of strategies to enhance the deepness of FDI and economic growth in the Oman economy.

Keywords: FDI Inflows, CO₂ emissions, Linear and Nonlinear ARDL, Oman

JEL Classification: F21, Q56, C22

1.Introduction

In present times, one of the utmost challenges faced worldwide is global warming and climate change. These challenges have become the most critical global issues in the face of the survival of humanity from the last several decades. Furthermore, no countries in the world are untouched by this issue, and the outcomes of global warming and climate change can have catastrophic effects on civilization as a whole and carbon dioxide (CO₂) emissions contributing as the major source of this global issue. Therefore, there is a need for sustainable development that could lead to the reduction of global warming. Ultimately these issues provide an opportunity to the academicians, researchers, and decision-makers to provide attention and careful study on the drivers of CO₂ emission for developing countries and chalk out the measures and policies to achieve sustainable development and improving the standard of environmental quality (Stern, 2015).

The Sultanate of Oman has significantly modified its attitude toward foreign investment since the early 1990s and has devised a new policy to attract Foreign Direct Investment (FDI) based on four essential elements. These include creating a new regulatory precedent, making it easier for foreign investors to do business, liberalizing the economy, and presenting the country as an excellent place to invest (Al. Azri, 2016). However, FDI plays an important role in the economic development of developing countries and capital financing that contributes to developing countries in enhancing their productivity through capital, skills, technology transfer, market access, and export promotion. FDI also generates employment opportunities and stimulates business and competition, which are treated as a key instrument for the swift development of these countries (Malampally and Soviet 1999); Heimes and Lensnic 2003; Beton and that. 2009; Reiter & Stensma 2010; Fernandes and Ponof 2012; Lee 2013).

According to the perception of Environmental Kuznets Curve (EKC), economic development and environmental pollution are related to N-shape. This means that pollution levels rise during the initial period of economic development and then descend as the economy develops and thrives (Ozturk and Acaravci 2010). The environmental Kuznets curve hypothesis further has been intensively investigated and evaluated in the provided literature of energy economics over the last decade to trace a link between the country's economic growth and environmental pollution (e.g., Alam et al., 2011). However, there is a paucity of research on EKC assessment for countries that have a different segment like global trade, capital investment, financial development, and foreign investment inclusive of FDI.

1 Foreign direct investment can affect the CO₂ emission that ultimately leads to environmental
2 degradation. There are contradictory discussions between the researchers; some advocate that FDI
3 provides efficient technology for products that contribute to reducing the air pollution of the
4 country (Stretesky and Lynch 2009; Pao and Tsai,2011; Wu and Liang 2016) advocate that FDI
5 could be treated as the contributor of the air pollution in the country. The logic behind this
6 argument is that FDI strengthens economic growth by increasing productivity which ultimately
7 increases the country's energy consumption. Moreover, high energy consumption usage ultimately
8 led to more CO₂ emissions and environmental pollution (Malik and Lan,2016; Shan et al.,2017).
9 Furthermore, polluting firms may decide to put resources into developing countries with fewer
10 environmental laws to reduce production costs, which also indicates an expansion of the country's
11 energy use limit (Acharya 2009); Lau, Chong, and England 2014; Hamid et al., 2020).

12 Consequently, lax environmental guidelines that permit firms to upsurge their degree of CO₂
13 emissions may entice foreign investors, increasing FDI inflow. The pollution haven hypothesis
14 formalizes this relationship. Given the importance of FDI impact on capital investment, CO₂
15 emissions, and economic growth, the impetus behind this investigation is to observe the long-
16 standing balanced relationship between investment, economic growth, CO₂ and FDI in Oman,
17 which is an energy-subordinate arising economy.

18 The carbon emission in Oman is rising from 7.3 million tonnes to 92.8 million tonnes from 1970
19 to 2019. The emission is growing at an average rate of 8.3% in Oman (Climate performance index
20 2021). The recent German watch report (2021) based on 2000 to 2019 data ranks Oman 95th of
21 180 countries in terms of global climate risk index, collected worldwide; it criticizes the
22 government for failing to implement national environmental policies. Conversely, Oman has been
23 a preferred FDI destination since 2008, inferable from its monetary steadiness and high profit rates
24 when contrasted with many developing nations. Thus, more FDI could drive up energy utilization
25 by boosting the Oman economy's development rate and accordingly add to CO₂ emissions. As a
26 result of these factors, Oman offers a fascinating contextual analysis for looking at the connections
27 between CO₂ emissions, capital speculation, economic growth, and FDI inflows, just as tending
28 to effective public environment strategy.

29 To the best of our knowledge, no research study has looked into the symmetric and asymmetric
30 impact of FDI inflows, capital investment, and economic growth on CO₂ emissions in Oman. In

order to fill this gap, this study uses advanced econometric approaches to examine the impact of economic growth, FDI inflows, and capital investment on CO₂ emissions. To begin, the symmetric short-run and long-run relationship between study variables were investigated using the linear ARDL (Autoregressive Distributed Lag). In contrast, the nonlinear ARDL (NARDL) of Shin et al. (2014) is applied to investigate this relationship asymmetrically, to analyze the implications of both positive and negative changes in FDI inflows, economic growth and capital investment on Oman's CO₂ emissions. Finally, we used the block exogeneity Wald test to examine the combined (long and short-run) direction of causality between carbon emissions and their determinants.

The rest of the research is structured as follows: The second section presents a review of literature. The third section discusses the model and methodology. Section four provides the estimated results and discussion part, and the last section concludes and provides some policy recommendations.

2. Literature Review

There is a large corpus of literature on carbon emissions and their determinants. We focus on some recent studies published since 2000 on CO₂ emissions, FDI, capital investment, and economic growth.

Keller and Levinson (2000) investigate the impact of varying environmental rules on global investment patterns. The contribution of this study in three ways. Firstly, to avoid making country comparisons, we will start with FDI into the U.S. and the cost of pollution abatement in different states. This is because the data on environmental costs in the United States is higher comparable than that of other countries, and the parameters that measure the conditions in the United States are more similar in some difficulty. Second, we consider disparities in state industrial alignments, identified as an issue in the past. Third, we use a panel of relative abatement costs spanning 18 years, allowing us to account for unobserved state features. This study's findings show that the cost of pollution has had a mild deterrent effect on international business.

Irandoost (2001) explores the impact of FDI on GDP and productivity growth expansion in the recipient country. A Vector Autoregressive (VAR) model applies to Denmark, Finland, Norway and Sweden to explore the FDI-led development hypothesis. Based on the new Granger non-causality technique established by Toda and Yamamoto (1995) and Yamada and Toda (1998), the findings demonstrate that FDI and GDP in Norway and Sweden are causally associated in the long term. Furthermore, in Sweden, the results show bi-directional causality but Uni-directional in

1 Norway, with higher FDI leading to economic growth. For Finland and Denmark, our findings
2 did not support the causation link. Two policy implications emerge from the proven bi-directional
3 causation between variables. First, recipient countries can stimulate FDI inflows by boosting
4 economic growth. Second, FDI has a significant impact on economic growth.

5 Xing and Kolstad (2002) demonstrate the validity of theoretical predictions and present a statistical
6 examination of the impact of environmental legislation on the capital flow of polluting enterprises.
7 The study looks at FDI in a spectrum of U.S. industries, including businesses that spend much
8 money on pollution control are listed and businesses with lower pollution control costs. Weak
9 environmental regulation has a negative influence on FDI. We propose two equations, one for FDI
10 assessment and one for pollution emissions, a variable significantly connected with the unobserved
11 variable because laxity is not immediately observable. As a pollutant, we use total national sulfur
12 emissions. The statistical results reveal that the laxity of environmental restrictions in a host nation
13 is a significant factor of FDI from the U.S. for substantially polluting businesses but is
14 inconsequential for less polluting industries when using instruments for the unobserved variable.
15 Jong Choe (2003) uses a panel VAR model to find a causal association between FDI and economic
16 growth and GDI in 80 countries from 1971 to 1995. The results mean that FDI Granger causes
17 economic growth and vice versa; however, when FDI causes growth FDI instead of growth, its
18 impact is more pronounced. Furthermore, GDI does not create economic growth; instead,
19 economic growth causes GDP. These results show that strong positive links between economic
20 growth and FDI inflow or GDI rates do not always mean that large FDI inflows or GDI rates mean
21 rapid economic expansion.

22 Martínez-Zarzoso, I., and Bengochea-Morancho, A., (2004) investigate the existence of the
23 Environmental Kuznets Curve for CO₂ in 22 OECD countries by using Pooled Mean Group
24 Estimator. The data covered from 1975 to 1998. The countries were selected based on quantified
25 emission limitations in the Kyoto Protocols. Results found that N-shaped EKC's existence means
26 that the Original EKC will not stand in the long run; instead, increasing the income level will lead
27 to a positive relationship between economic growth and environmental degradation.

28 Kholer (2005) investigated the relationship between energy consumption, income, foreign trade,
29 and CO₂ emission in France. This study applied the Johansen cointegration test and Vector Error
30 Correction Model to find the causal relationship. The study found the existence of the long-run

1 relationship between pollutant emission and energy consumption in France during the period 1960-
2 2000. Further, the result indicates that more usage for energy will be the reason for more Carbon
3 emission, and also, the relationship between output and Carbon emission has a long-run
4 relationship. Finally, the study concludes that output growth causes CO2 emission and energy
5 consumption in the long run.

6 Apergis et al. (2006) examine the dynamic relationship between FDI inflow and domestic
7 investment. This study uses panel cointegration and causality techniques. Based on the findings,
8 they found a bi-directional relationship between FDI inflow and domestic investment. While on
9 the other hand, the bivariate model assumption found a positive long-run relationship, and the
10 same result happened regarding the countries that have to employ the multivariate model.
11 Furthermore, the study concludes that FDI inflows increase the domestic investment benefits.

12 Changwen and Jiang (2007) looked at how FDI interacts with economic growth in the host country.
13 Toda and Phillips pioneered the vector autoregression (VAR) methodology, which we employ to
14 investigate the causation between FDI and growth in China. The empirical findings show that the
15 two-way causation between FDI and growth is not very strong in China. The fact that China's
16 economic growth draws FDI backs up the market-size argument; nonetheless, while FDI entry
17 boosts China's economic growth to some extent.

18 Ndikumana and Verick (2008) investigate the two-way linkage between FDI and domestic
19 investment in Sub-Saharan Africa. The data analysis found that FDI crowds domestic investment
20 and private investment are drivers of FDI and further explains that improving the domestic climate
21 will attract more FDI. This study illustrates that FDI enhances capital accumulation; thus, the
22 countries can positively impact growth and say that private investment significantly influences
23 FDI. Based on the findings, the study suggests that framing the right policy at the macro and
24 sectoral levels will benefit African countries' growth.

25 Acharyya, J., (2009) examines the GDP growth and environmental degradation in the framework
26 of FDI in the Indian context. Based on the cointegration analysis, the study found that FDI inflow
27 in India has a significantly positive impact on GDP growth in the long run. On the other hand, the
28 author argues that the pollution haven hypothesis is not applicable in 1990 because the FDI inflow
29 positively impacts carbon emission through output growth. However, the scenario changed in the
30 long run, and the government should consider the hypothesis and eliminate the chances of proving
31 the hypothesis.

1 Apergis and Payne (2010) examine the casual relationship between Carbon emission, energy
2 consumption, and actual output among eleven countries of the Commonwealth of Independent
3 States. In this study, the panel vector error correction model is used to analyze the data covered
4 from 1992 to 2004. The study found that energy consumption has a positive impact on carbon
5 emission in the long run, but in the EKC hypothesis, it was U-shaped. In the short-run effect,
6 unidirectional causality between energy consumption and actual output is found. This study
7 concludes that efficient energy conservation policies will reduce carbon emissions and enhance
8 the production and consumption of energy.

9 Apargis et al. (2011) carried out a study based on the environmental sustainability approach and
10 tried to explore the link between economic growth and pressure on nature. The study was gone
11 through a panel comprised of 213 countries and spans between 1970 to 2008. The study mainly
12 investigates the effects and pressures on nature due to economic growth, i.e. fixed impact and
13 definite impact-making variable (IV) regressions. The result and discussion find a positive
14 relationship between income and pressure on nature in a cross-country analysis. At the same time,
15 the effect is much more robust in middle-income countries than the low-income countries and does
16 not support the Environmental Kuznets Curve (EKC).

17 Danja (2012) scrutinizes the applicability of FDI and its Impact on the Nigerian Economy. The
18 theoretical evidence of the study indicates that Multinational corporations are highly adaptive to
19 the FDI but on the other hand policy choice of the host country influences the FDI. The study
20 applied both econometrics and statistical method to evaluate the relationship between FDI and
21 major economic indicators. The results find a positive association between FDI and GDP, GFCF,
22 and IIP, but on the other hand, the FDI has not given many contributions to the development of
23 the Nigerian economy. Based on the study conclusion, the researcher finds that FDI flow depends
24 on the policy framework and other factors such as strategic plans, better infrastructure facilities,
25 increasing labor skills, and capacity building.

26 Alkhathlan & Javid (2013) examined the interrelation between the different parameters such as the
27 country's economic growth, carbon emissions, and energy consumption for this study at the holistic
28 and at a contrasting extent. The study applied standard log-linear functional to inspect the
29 association among the different factors such as carbon emission per capita, total energy
30 consumption per capita, and real GDP per capita. The empirical findings indicate that any changes
31 in per capita income and energy consumption will affect the long-term equilibrium and is rectified

1 by a counterbalancing of carbon emission, which means that energy consumption ultimately leads
2 the country's economic growth in the long run. However, there is no causal relationship in the
3 short run. Overall, the study concludes that aggregate and disaggregate energy consumption could
4 be a major source in contributing towards rising carbon emissions in the country. Hence the
5 government should take necessary actions in their policy framework.

6 Belloumi (2014) studied the relationship between FDI, trade, and economic development in
7 Tunisia. ARDL model was used to analyze the data period from 1970 to 2008. The study's outcome
8 finds a cointegration among trade, FDI, and economic growth. Furthermore, in the short run, the
9 study explains that there is no significant Granger causality from FDI to economic growth and vice
10 versa. Finally, the study pinpointed the importance of trade openness and economic growth
11 because these two factors attract more FDI, and FDI positively impacts the country's economic
12 growth.

13 Neequaye and Oladi (2015) selected some emerging countries by using a panel approach to
14 evaluates the impact of foreign direct investment inflows and ecological aid spending on
15 environmental deterioration. According to our findings based on a fixed-effects model,
16 environmental Kuznets curve for CO₂ and total greenhouse gas emissions from the energy and
17 manufacturing sectors; however, nitrous oxide emissions from the waste industry and overall
18 greenhouse gas emissions are not included. We also find a clue of a technique impact, which we
19 analyze further by examining capital and labor responses to FDI in various developing nations.

20 Zhang and Zhou (2016) used province panel data from 1995 to 2010 to assess the impact of FDI
21 on China's CO₂ emissions at the national and provincial levels. This study uses Stochastic Impacts
22 by Regression on Population. According to the findings, FDI helps China in reducing CO₂
23 emissions. CO₂ emissions are lowered when foreign direct investment (FDI) flows from the west
24 to the east and central regions. Our findings are back to the pollution halo idea, which claims that
25 multinational companies can transfer renewable energy from advanced countries to deprived
26 countries and conduct business more environmentally friendly. Abduli and Hamami (2017)
27 studied the impact of strategic consumption, economic growth, FDI flows, trade openness on
28 environmental degradation in 17 MENA countries. The study was gone through the static and
29 dynamic panel data approach. They found that increase in economic growth in the inflow of FDI
30 leads to the degradation of the environment in 17 MENA countries, i.e., emission of CO₂ was
31 increased due to industrialization through FDI inflow. Based on the findings, the study suggests

1 improving the policy framework of the MENA countries to protect their environment and decrease
2 carbon emissions.

3 Rafindadi et al. (2018) This study uses Pooled Mean Group (PMG) Methodology to scrutinize the
4 impact of FDI inflows and energy consumption on pollution in the Gulf Cooperation Council. The
5 period of the study is 1990 to 2014. The findings show that FDI inflows have a negative
6 environmental impact. In contrast, energy consumption has a positive stimulus, and that both
7 factors are statistically significant in explaining the region's carbon emissions. More discretionary
8 income, local investment, and FDI all substantially impacted energy consumption in the Gulf
9 Cooperation Council. The study also showed how higher disposable income and FDI help the Gulf
10 Cooperation Council enhance environmental quality. Domestic investment, on the other hand,
11 reduces energy use. Furthermore, FDI harms the environment as a result of relative affluence. Our
12 findings disproved the misconception that the GCC countries are pollution-free havens.

13 Hussein and Ahmed (2019) premeditated the relationship between FDI and the economic growth
14 of the Sultanate of Oman. This study applies the Multiple Regression model to find out the
15 evidence regarding the impact of FDI on Oman's economic growth. The empirical result indicates
16 that there is a positive relationship between FDI and the GDP of Oman. Result also explains that
17 FDI is helping to find essential elements which are helpful to the domestic economy, i.e., skilled
18 labor, entrepreneurship, technological know-how, and direct flow of foreign resources, including
19 foreign exchange. Therefore, promoting these factors with the help of FDI will significantly impact
20 existing domestic resources. The study findings suggested framing and applying better investment
21 rules and regulations on FDI in Oman.

22 Li et al. (2020) investigate how environmental diplomacy affects a nation's greenhouse gases. We
23 examine whether the signing of environmental treaties resulted in a reduction in CO₂ emissions.
24 For almost 35 years, we use common correlated effects mean group models on panel data from 76
25 industrialized and developing nations. In the short term, environmental diplomacy appears to cut
26 CO₂ emissions for developing countries, according to our findings. However, the long-run
27 projections of FMOLS show that rich and developing countries do not comply with treaty
28 requirements as CO₂ emissions rise as the number of treaties increases. Overall, our findings
29 suggest that signing environmental treaties is more likely to constitute international diplomacy
30 than climate change mitigation. We suggest that governments carry out their treaty obligations
31 rather than indulging in periodic treaty signing rituals.

3. Methodology

3.1 Data and empirical model

The study uses annual data of 40 years from 1980 to 2019 to draw inferences. The study variables are CO₂ emissions as measured in metric tons per capita, Economic growth, Foreign Direct Investment, and Capital Investment as measured in billions of U.S. dollars. In addition, the data was collected from the Global Economic and World Development Indicator of the World Bank (2021) for empirical analysis.

The below equation depicts the functional relationship between CO₂ emissions, economic growth, capital investment, and FDI, which are as follows:

$$\ln CO_{2,t} = \beta_0 + \beta_1 \ln GDP_t + \beta_2 \ln CI_t + \beta_3 \ln FDI_t + \varepsilon_t \quad (1)$$

$\ln CO_{2,t}$, $\ln GDP_t$, $\ln CI_t$ and $\ln FDI_t$ are the logarithmic forms of CO₂ emission, capital investment, economic growth, and FDI.

3.2 Unit root test

In the series, the Zivot and Andrews (2002) unit root tests are applied under an endogenous structural division. This study applies three Zivot–Andrews unit root test specifications. Model Y denotes a break in the intercept only, model Q signifies a break in the trend, and model W represents a break in both the intercept and the trend. The following three models are as follows:

$$\text{Model Y: } \Delta Y_t = \beta_1 + \beta_2 t + \delta Y_{t-1} + \theta PU_t + \sum_{i=1}^r \alpha_i \Delta Y_{t-1} + \varepsilon_t \quad (2)$$

$$\text{Model Q: } \Delta Y_t = \beta_1 + \beta_2 t + \delta Y_{t-1} + \gamma PQ_t + \sum_{i=1}^r \alpha_i \Delta Y_{t-1} + \varepsilon_t \quad (3)$$

$$\text{Model W: } \Delta Y_t = \beta_1 + \beta_2 t + \theta PU_t + \gamma PQ_t + \sum_{i=1}^r \alpha_i \Delta Y_{t-1} + \varepsilon_t \quad (4)$$

Where $PU_t = 1$ and $PQ_t = t - T_b$ if $t > T_b$ and 0 otherwise. T_b stances for a possible breakpoint.

3.3 The bounds test for a level relationship.

In the ARDL process, the bounds test is used to examine the long-term level relationship between the given variables. The ARDL method was proposed by Pesaran et al. (2001), and can be used

irrespective of the integration order of the regressors or whether (0) or I (1) are in independent variables, or are in jointly cointegrated. The ARDL method propose the following error correction model (ECM);

$$\begin{aligned}\Delta \ln CO_{2t} = & P_{0Y} + \sum_{i=0}^s q_{iY} \Delta \ln CO_{2t-i} + \sum_{i=0}^s r_{iY} \Delta \ln CI_{t-i} + \sum_{i=0}^s s_{iY} \Delta \ln GDP_{t-i} \\ & + \sum_{i=0}^s t_{iY} \Delta \ln FDI_{t-i} + \varphi_{1Y} \ln CO_{2t-1} + \varphi_{2Y} \ln CI_{t-1} + \varphi_{3Y} \ln GDP_{t-1} \\ & + \varphi_{4Y} \ln FDI_{t-1} + \varepsilon_t\end{aligned}\quad (5)$$

Where P_{0Y} and ε_t are the intercepts and residual term. The dynamics of error correction and long-run relationship are shown in the first and second part of the equation, correspondingly. The bounds test in this study is based on two hypotheses. For example, the hypothesis of no cointegration between the variables in Eq (5) is $H_0 \varphi_{1Y} = \varphi_{2Y} = \varphi_{3Y} = \varphi_{4Y} = 0$, which indicates the long-run relationship of the variables. The hypothesis of cointegration is $H_1 \varphi_{1Y} \neq \varphi_{2Y} \neq \varphi_{3Y} \neq \varphi_{4Y} \neq 0$. The calculation of F statistics compares with the critical values of Shahbaz et al (2103). After finding the long-run association between variables, an error correction mechanism is applied to estimate the short-run coefficients and error correction terms. The ECM is interpreted in the following way:

$$\begin{aligned}\Delta \ln CO_{2t} = & P_{0Y} + \sum_{i=0}^s q_{iY} \Delta \ln CO_{2t-i} + \sum_{i=0}^s r_{iY} \Delta \ln CI_{t-i} + \sum_{i=0}^s s_{iY} \Delta \ln GDP_{t-i} \\ & + \sum_{i=0}^s t_{iY} \Delta \ln FDI_{t-i} + \alpha ECT_{t-1} + \varepsilon_t\end{aligned}\quad (6)$$

Where ECT_{t-1} is an error correction term that signifies the speed of adjustment to the long-run equilibrium level? Diagnostic and stability tests determine the model's fit. In a model confirms a series of correlations, functional form, normality and heteroscedasticity are verified and using diagnostic tests. Pesaran and Pesaran (1997) suggest the cumulative sum (CUSUM) and cumulative sum of squares (CUSUMSQ) model stability measures proposed by Brown, Durbin, and Evans (1975).

3.4 Causality test

To assess the direction of causality between the variables, the Toda-Yamamoto (1995) causality test is used. The most significant advantage of this test is that it can be used regardless of whether the variables are integrated or the models have cointegration properties. The Modified Wald statistic (MWALD) is recommended by Toda and Yamamoto (1995) for determining whether variables have a causal relationship. In this technique, this form is used to measure VAR ($k + d_{max}$), where k signifies the optimal order of the VAR model and d_{max} is the maximum integration order. This study used the Hacker and Hatemi-J (2012) bootstrap test with endogenous lag order and bootstrapped critical values are premeditated using 4000 simulations. The optimal lag in the model is chosen using the information criteria of Hacker and Hatemi-J (2012).

The VAR ($k + d_{max}$) model can be calculated using the following formula:

$$\begin{aligned} \ln CO_2 = & \alpha_0 + \sum_{i=1}^k \alpha_{1i} \ln CO_{2,t-i} + \sum_{j=k+1}^{d_{max}} \alpha_{2j} \ln CO_{2,t-j} + \sum_{i=1}^k \beta_{1i} \ln CI_{t-i} + \sum_{j=k+1}^{d_{max}} \beta_{2j} \ln CI_{t-j} \\ & + \sum_{i=1}^k \delta_{1i} \ln GDP_{t-i} + \sum_{j=k+1}^{d_{max}} \delta_{2j} \ln GDP_{t-j} + \sum_{i=1}^k \gamma_{1i} \ln FDI_{t-i} + \sum_{j=k+1}^{d_{max}} \gamma_{2j} \ln FDI_{t-j} \\ & + \varepsilon_{1t} \end{aligned} \quad (7)$$

$$\begin{aligned} \ln CI = & \beta_0 + \sum_{i=1}^k \beta_{1i} \ln CI_{t-i} + \sum_{j=k+1}^{d_{max}} \beta_{2j} \ln CI_{t-j} + \sum_{i=1}^k \varphi_{1i} \ln CO_{2,t-i} + \sum_{j=k+1}^{d_{max}} \varphi_{2j} \ln CO_{2,t-j} \\ & + \sum_{i=1}^k \delta_{1i} \ln GDP_{t-i} + \sum_{j=k+1}^{d_{max}} \delta_{2j} \ln GDP_{t-j} + \sum_{i=1}^k \gamma_{1i} \ln FDI_{t-i} + \sum_{j=k+1}^{d_{max}} \gamma_{2j} \ln FDI_{t-j} \\ & + \varepsilon_{2t} \end{aligned} \quad (8)$$

$$\begin{aligned} \ln GDP = & \delta_0 + \sum_{i=1}^k \delta_{1i} \ln GDP_{t-i} + \sum_{j=k+1}^{d_{max}} \delta_{2j} \ln GDP_{t-j} + \sum_{i=1}^k \beta_{1i} \ln CI_{t-i} + \sum_{j=k+1}^{d_{max}} \beta_{2j} \ln CI_{t-j} \\ & + \sum_{i=1}^k \varphi_{1i} \ln CO_{2,t-i} + \sum_{j=k+1}^{d_{max}} \varphi_{2j} \ln CO_{2,t-j} + \sum_{i=1}^k \gamma_{1i} \ln FDI_{t-i} + \sum_{j=k+1}^{d_{max}} \gamma_{2j} \ln FDI_{t-j} \\ & + \varepsilon_{3t} \end{aligned} \quad (9)$$

$$\begin{aligned}
\ln FDI = & \gamma_0 + \sum_{i=1}^k \gamma_{1i} \ln FDI_{t-i} + \sum_{j=k+1}^{d_{max}} \gamma_{2j} \ln FDI_{t-j} + \sum_{i=1}^k \delta_{1i} \ln GDP_{t-i} + \\
& \sum_{j=k+1}^{d_{max}} \delta_{2j} \ln GDP_{t-j} + \sum_{i=1}^k \beta_{1i} \ln CI_{t-i} + \sum_{j=k+1}^{d_{max}} \beta_{2j} \ln CI_{t-j} + \sum_{i=1}^k \varphi_{1i} \ln CO_{2,t-i} + \\
& \sum_{j=k+1}^{d_{max}} \varphi_{2j} \ln CO_{2,t-j} + \\
& \varepsilon_{4t}
\end{aligned} \tag{10}$$

3.5 The asymmetric analysis

To find out the asymmetric relation between CO₂ and other explanatory variables, we used the NARDL methodology of Shin et al. (2014) to capture a non-linear relationship. However, the linear ARDL model ignores the possible asymmetric link. Thus, according to Shin et al. (2014), equation five can be rewritten as follows:

$$\begin{aligned}
\Delta \ln CO_{2t} = & \delta_0 + \delta_1 \ln CO_{2,t-1} + \delta_2 \ln CI_{t-1}^+ + \delta_3 \ln CI_{t-1}^- + \delta_3 \ln GDP_{t-1}^+ + \delta_4 \ln GDP_{t-1}^- \\
& + \delta_5 \ln FDI_{t-1}^+ + \delta_6 \ln FDI_{t-1}^- + \sum_{i=1}^p \tau_i \Delta \ln CO_{2,t-i} + \sum_{i=0}^q (\tau_i^+ \Delta \ln CI_{t-i}^+ \\
& + \tau_i^- \Delta \ln CI_{t-i}^-) + \sum_{i=0}^q (\tau_i^+ \Delta \ln GDP_{t-i}^+ + \tau_i^- \Delta \ln GDP_{t-i}^-) + \sum_{i=0}^q (\tau_i^+ \Delta \ln FDI_{t-i}^+ \\
& + \tau_i^- \Delta \ln FDI_{t-i}^-) + \varepsilon_t
\end{aligned} \tag{11}$$

From Equation 11, $\delta_i^+ (\sum_{i=1}^q \tau_i^+)$ and $\delta_i^- (\sum_{i=1}^q \tau_i^-)$ signifies the long (short)-run positive and negative effects of GDP, CI, and FDI on CO₂. In the ARDL model, the bound test is performed to see if the variables are co-integrated asymmetrically or not. However, the wald test is also used to determine whether GDP, CI, and FDI have a long (short)-run symmetric relationship $\delta = \delta^+ = \delta^- (\tau = \tau^+ = \tau^-)$. The short-term asymmetric association can be established utilizing the dynamic multiplier effect after the nonlinear relationship has been validated. The dynamic multiplier effect can be applied in this study by using the following formula:

$$\begin{aligned}
W_q^+ &= \sum_{j=0}^r \frac{\partial \ln CO_{2,t-j}}{\partial \ln CI_{t-i}^+}, W_q^- = \sum_{j=0}^r \frac{\partial \ln CO_{2,t-j}}{\partial \ln CI_{t-i}^-} \\
W_q^+ &= \sum_{j=0}^r \frac{\partial \ln CO_{2,t-j}}{\partial \ln GDP_{t-i}^+}, W_q^- = \sum_{j=0}^r \frac{\partial \ln CO_{2,t-j}}{\partial \ln GDP_{t-i}^-}
\end{aligned}$$

$$W_q^+ = \sum_{j=0}^r \frac{\partial \ln CO_{2,t-j}}{\partial \ln FDI_{t-i}^+}, W_q^- = \sum_{j=0}^r \frac{\partial \ln CO_{2,t-j}}{\partial \ln FDI_{t-i}^-}$$

$$q = 0, 1, 2, 3, \dots \quad (12)$$

Where $q \rightarrow \infty$, then $W_q^+ \rightarrow \delta^+$ and $W_q^- \rightarrow \delta^-$.

4. Results and their discussions

The Zivot and Andrews' (2002) unit root test for one structural break in the series is shown in Table 1. The empirical results of unit route test indicate that the unit roots of the level of $\ln CO_2$ and $\ln CI$ are under a structural break, it shows that they are not stationary at their levels. Once the first difference is taken, they become stationary. On the contrary, we can reject the null hypothesis of a unit root under one structural break of $\ln FDI$ and $\ln GDP$, implying that $\ln CO_2$ and $\ln CI$ are stationary at their level forms. Our empirical evidence of Zivot and Andrews (2002) discloses that the independent variables $\ln CO_2$ and $\ln CI$ are integrated of order one, or $I(1)$. In contrast, $\ln FDI$ and $\ln GDP$ are integrated of order zero, or $I(0)$.

Table 1. Zivot Andrews Unit Root test

Statistics (Level)				Statistics (First Difference)			Conclusion
	ZA_B	ZA_T	ZA_I	ZA_B	ZA_T	ZA_I	
$\ln CO_2$	-4.176	-2.812	-3.610	-3.656*	-3.645	-3.069*	1(1)
Break Year	2005	2012	2001	2005	2012	2013	
Lag-length	0	0	0	0	1	0	
$\ln FDI$	-4.284***	-4.021**	-3.918	-4.808**	-5.604**	-5.110**	1(0)
Break Year	2004	2000	2004	2007	2012	2007	
Lag-length	0	0	0	1	1	1	
$\ln GDP$	-3.071	-2.833	-3.609	-3.434**	-3.366**	-2.129	1(0)
Break Year	2005	1998	2006	2013	2014	2013	
Lag length	0	0	0	4	4	0	
$\ln CI$	-4.422*	-3.200	-5.136	-5.370*	-5.240*	-4.261**	1(1)
Break Year	2005	1995	2005	2011	2013	2013	
Lag length	0	0	0	0	4	0	

Source: Authors own calculation using Eviews 12.

The model with a break in both the trend and the intercept is designated by ZA_B ; the model with a break in the trend is designated by ZA_T ; and the model with a break in the intercept is designated by ZA_I . *, **, and *** represent the null hypothesis rejection at the 1%, 5%, and 10% levels, correspondingly.

The unit root test revealed that the variables have a mixed order of integration. The next step is to apply the ARDL bounds test to determine the long-run association between CO₂ emissions, capital investment, GDP, and foreign direct investment (Pesaran, Shin, and Smith 2001). The outcome of the bound test is shown in Table 2, which demonstrates that the value of F-statistics is more than the upper critical bound at the 5% and 1% levels; as a result, the null hypothesis of no cointegration is rejected. This stipulates that the variables are cointegrated for a long-run relationship between capital investment, foreign direct investment, gross domestic product, and CO₂ emission in Oman.

Table 2. Bound Test for Level relationship

F-Bounds Test				
Test Statistic	Value	Sign in.	1(0)	1(1)
			Asymptotic: n=1000	
F-statistic	11.78917	10%	2.97	3.74
k	3	5%	3.38	4.23
		2.5%	3.8	4.68
		1%	4.3	5.23

Source: Author's calculation using Eviews 12.

The bound test reveals that the variables have a long-term equilibrium relationship. To estimate long-run and short-run coefficients, the ARDL model should be applied. The diagnostic test results for the ARDL model are reported in Table 3. The findings support the cogency of the ARDL model. Because our model is reliable and free from any econometric problem, the ARDL model's stability should be assessed through CUSUM and CUSUMSQ, shown in Figures 1, respectively. The graph plot of both stability tests indicates that the ARDL model is stable and consistent in the short and long run.

Table 3. Diagnostic Test Results

Diagnostic Test	Test statistics	P-value
Serial Correlation	0.9923	0.3924
Functional Form	0.1611	0.2641
Normality	1.7973	0.4071
Heteroscedasticity	0.4482	0.9492

Source: Author's calculation using Eviews 12.

Figure-1: Plots of CUSUM and CUSUMSQ tests for model stability

Note: At the 5% significance level, the straight lines signify critical bounds.

The empirical evidence of long-term coefficients of the ARDL model is shown in Table 4. The findings reveal that $\ln \text{FDI}$ and $\ln \text{GDP}$ have a positive, inelastic, and statistically significant impact on CO_2 emission in the long run. Whereas $\ln \text{CI}$ has a statistically significant, elastic, and adverse effect on CO_2 emissions. However, increased economic growth and foreign direct investment raise pollution levels in Oman, whereas capital investment reduces CO_2 emissions in the long -run.

Table 4. Level coefficients in the long-term model through the ARDL approach

Dependent variable $\ln \text{CO}_2$	Regressors			
	$\ln \text{FDI}$	$\ln \text{GDP}$	$\ln \text{CI}$	Intercept
$\ln \text{CO}_2$	0.134*	0.297*	-0.684**	1.984*
Coefficient	(0.000)	(0.000)	(0.000)	(0.000)

Source: Author's calculation using Eviews 12.

Note: In each model, the numbers in parentheses are the prob. values of the t-statistics. *, **, and *** indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

The findings of the conditional ECM using the ARDL technique are shown in Table 5. The coefficient of the ECM model is (-0.501), which signifies that CO_2 emissions in Oman converged to their long-run equilibrium level by a 50.1% speed of adjustment every year due to the involvement of FDI, economic growth, and capital investment. At varied lag lengths, all independent variables have a statistically significant short-term impact on CO_2 emissions. Furthermore, when GDP rises by 1%, CO_2 emissions in the country rise by 0.308 percent at the second lag. At different lag levels, the short-term coefficients of capital investment and FDI positively associate with air pollution.

Table 5. Conditional error correction model through the ARDL approach

Dependent variable: $\ln \text{CO}_2$ (3,3,4,4) *			
Regressor	Coefficient	Standard Error	p-value
Ect (-1)	-0.501	0.059	0.000

$\Delta \ln \text{CO}_2 t_{-1}$	-0.531	0.208	0.027
$\Delta \ln \text{CO}_2 t_{-2}$	-0.286	0.194	0.158
$\Delta \ln \text{CO}_2 t_{-3}$	-0.493	0.149	0.004
$\Delta \ln \text{FDI}$	-1.566	0.552	0.110
$\Delta \ln \text{FDI } t_{-1}$	0.256	0.305	0.000
$\Delta \ln \text{FDI } t_{-2}$	0.134	0.584	0.001
$\Delta \ln \text{GDP}$	-0.112	0.038	0.008
$\Delta \ln \text{GDP } t_{-1}$	0.360	0.069	0.000
$\Delta \ln \text{GDP } t_{-2}$	0.308	0.063	0.000
$\Delta \ln \text{GDP } t_{-3}$	0.297	0.056	0.000
$\Delta \ln \text{CI}$	0.070	0.081	0.397
$\Delta \ln \text{CI } t_{-1}$	0.104	0.246	0.003
$\Delta \ln \text{CI } t_{-2}$	-0.559	0.136	0.007
$\Delta \ln \text{CI } t_{-3}$	-0.684	0.125	0.000
Intercept	1.984	0.236	1.000
Adj. R^2	0.862	S.E. of Regression	0.519
AIC	1.109	SBC	2.428
F. Stat	10.587	F. prob	0.000
D.W. stat	2.543		

Source: Author's calculation using Eviews 12.

Note: * "p-lag structure in the model."

To evaluate the existence and direction of relationships between variables, the Toda–Yamamoto (1995) causality test is used. Table 6 shows a bidirectional relationship between carbon emissions and FDI in Oman, implying that FDI causes CO₂ emission and CO₂ emission causes FDI. Furthermore, there is a bidirectional relationship between economic growth and CO₂ emission, meaning that changes in economic growth lead to changes in CO₂ emission and vice versa. Capital investment and CO₂ emission, on the other hand, have a one-way causal relationship. Hence the capital investment growth hypothesis is irrelevant in Oman. Mutafoğlu (2012) similarly confirms the unidirectional causality of capital investment to GDP, concluding that there is no evidence of the capital investment-led growth hypothesis in the Oman economy. Furthermore, there are bidirectional causal links between FDI to GDP and capital investment to FDI. There was no evidence of a causal relationship between CO₂ and capital investment in Oman or GDP to capital investment. These results are relevant to the studies of (Chandran and Tang, 2013 and Shahbaz, 2013).

Table 6. Toda Yamamoto Causality Test

Hypothesis	Chi-square	P-value	Decision
$\ln \text{FDI}$ does not cause $\ln \text{CO}_2$	16.99762	0.0043	Reject
$\ln \text{CI}$ does not cause $\ln \text{CO}_2$	12.93827	0.0440	Reject
$\ln \text{GDP}$ does not cause $\ln \text{CO}_2$	23.88876	0.0005	Reject
$\ln \text{CO}_2$ does not cause $\ln \text{FDI}$	24.03150	0.0005	Reject
$\ln \text{CI}$ does not cause $\ln \text{FDI}$	17.29254	0.0033	Reject

lnGDP does not cause lnFDI	25.37930	0.0003	Reject
lnCO ₂ does not cause lnCI	8.841954	0.1827	Fail to Reject
lnFDI does not cause lnCI	16.24845	0.0125	Reject
lnGDP does not cause lnCI	1.958783	0.9235	Fail to Reject
lnCO ₂ does not cause lnGDP	65.00015	0.0000	Reject
lnFDI does not cause lnGDP	38.64454	0.0000	Reject
lnCI does not cause lnGDP	14.85320	0.0214	Reject

Source: Author's calculation using Eviews 12.

Note: 4000 simulations are run to establish the bootstrapped critical value criterion for the optimal lag length selection.

The outcome of the nonlinear bound test is shown in Table 7, which demonstrates that the value of F-statistics is 11.785, which is more than the upper critical bound at the 5% and 1% levels; as a result, the null hypothesis of no cointegration is rejected. This stipulates that the variables are cointegrated for a long-run relationship among the CO₂, $lnFDI_{pos}$, $lnFDI_{neg}$, $lnGDP_{pos}$, $lnGDP_{neg}$, $lnCI_{pos}$, and $lnCI_{neg}$.

Table 7. Bound Test for nonlinear cointegration

F-Bounds Test		Null Hypothesis: No levels relationship		
Test Statistic	Value	Sign in.	I (0)	I (1)
			Asymptotic: n=1000	
F-statistic	11.78519	10%	2.33	3.25
k	6	5%	2.63	3.62
		2.5%	2.9	3.94
		1%	3.27	4.39

Source: Author's calculation using Eviews 12.

The empirical findings for the diagnostic tests are shown in Table 8. We used the Jarque–Bera test to determine data normality, where the Chi-square test critical value is greater than 5%, demonstrating statistical insignificance and failure to reject the null hypothesis of the normal distribution, showing that the data is normally distributed. In heteroscedasticity, we used the Breusch–Pagan (B.P.) test in conjunction with the ARCH test. We discovered that the resulting probability value of the Chi-square test was statistically insignificant, indicating that the null hypothesis of homoscedasticity was not rejected. In addition, we checked the stability of the model incorporating the cumulative sum of recursive residuals (CUSUM) and cumulative sum of recursive residual square (CUSUMSQ). The graph plots for CUSUM and CUSUMSQ are shown in Figure 2, demonstrating that all models are dynamically stable.

Table 8. Diagnostic test for NARDL

Test	F-statistics	P-value
Normality	0.865	0.648
Serial Correlation	0.324	0.726
ARCH	0.082	0.775

Heteroscedasticity	0.853	0.617
CUSTOM	Stable	
CUSUM-SQ		

Source: Author's calculation using Eviews 12.

Figure 2. Plots of CUSUM and CUSUMSQ for Model Stability

Note: The straight lines signify critical bounds at the 5% significance level.

We used the Wald test for both long-run (W_{LR}) and short-run (W_{SR}) symmetries to ensure that an asymmetric model was adequate. The results in the lower part of Table 9 for the long-run time horizon show that the null hypothesis of long-run symmetry between the positive and negative components of each of the analyzed variables is rejected. More explicitly, the Wald test for the long run shows that all the three explanatory variables are significant, which means an asymmetry. Before looking at the magnitude of these long-run asymmetric repercussions, we first look at the short-run dynamics. In the short term, the Wald statistic is used to compare the null hypothesis of symmetry against the alternative of asymmetry: $\delta_i^+(\sum_{i=1}^q \tau_i^+)$ and $\delta_i^-(\sum_{i=1}^q \tau_i^-)$ respectively. The results show that the null hypothesis of a weak form of symmetric adjustment (W_{SR}) is rejected for all included variables. More specifically, the Wald test for FDI components is 43.196 (p-value=0.000), whereas the Wald test for GDP components is 8.827 (p-value=0.006), and the Wald test for CI components is 11.053 (p-value=0.002).

The findings of the NARDL model for long-run and short-run estimations are reported in Table 9. The long-run results report that FDI is significant for both positive (L_{FDI}^+) and negative (L_{FDI}^-) shocks. It suggests that FDI will bring positive effects on the CO₂ emission of Oman in the long run. The estimated results for long-run coefficients of (L_{FDI}^+) and (L_{FDI}^-) are found 1.52 and 0.73, respectively, revealing a 1% rise in FDI rises 1.52% of CO₂ emission in Oman. Similarly, a 1%

1 fall in FDI will reduce CO₂ by 0.73%. This demonstrates that Oman's foreign direct investment is
2 CO₂ efficient.

3 Meanwhile, improving living standards needs a higher quality of life and rigorous environmental
4 rules, and FDI brings more advanced technology that minimizes the country's pollution level.
5 These outcomes are reliable with Shahbaz et al. (2017). Regarding GDP, GDP results are
6 significant for both positive (L_{GDP}^+) and negative (L_{GDP}^-) shocks. The estimated long-run
7 coefficients of (L_{GDP}^+) and (L_{GDP}^-) are reported as 0.02 and 0.10, respectively. Hence, we conclude
8 that a 1% rise in GDP leads to CO₂ emission by 0.02%.

9 Similarly, the negative shock of GDP is also significant with a positive sign. As a result, our
10 findings show that negative changes have a more significant impact. GDP and CO₂ emissions have
11 a positive connotation, suggesting that as GDP rises, production upsurges, increased production
12 escalations the demand of labor and per capita income in the country, so does the usage of CO₂
13 emission increases. Consequently, GDP is a source to increase CO₂ emissions in Oman. These
14 results are consistent with Aqeel et al. (2001) and Shahbaz et al. (2017). In the long run, positive
15 shocks to capital investment have a significant impact on CO₂ emission. It is in line with recent
16 studies like Luqman et al. (2019) for Pakistan and Ghazouani (2021) for Tunisia, where they have
17 found a positive effect of capital formation on CO₂ emission. On the other hand, a negative shock
18 to capital investment is insignificant and has a negative impact on CO₂ emission (a coefficient of
19 0.39).

20 In the short run, the decomposed factors with positive and negative shocks have similar effects as
21 they do in the long run. On the other hand, the degrees of elasticity differ slightly, but the relations
22 are nearly identical. The ECM reflects the change in disequilibrium inaccuracy over time in the
23 short term. The estimated methodology maps the progressive adjustment towards the new
24 equilibrium after the shocks from the initial equilibrium. The error correction term (ECT) is
25 negative and statistically significant at a level of 1%. According to ECT, roughly 53% of the path
26 to long-run equilibrium is completed a year following an economic shock. The adjusted R-square
27 of the model is 0.93, indicating that independent factors account for 93.60 percent of the dependent
28 variable. The adjusted R-Square confirms the model's specification. The Durbin-Watson test
29 suggests no autocorrelation problem in the series, with a value of 2.05. The D.W. test has a decision
30 criterion of 1.5 to 2.5. The series does not have an autocorrelation if the value is between these
31 boundaries.

Table 9. NARDL estimation of long-run and short-run

Dependent variable: $\ln \text{CO}_2$ Long run estimation			
Variable	Coefficient	t-Statistic	Prob.
$\ln \text{FDI_POS}$	1.528	4.574	0.0002**
$\ln \text{FDI_NEG}$	-0.732	-4.182	0.0004**
$\ln \text{GDP_POS}$	0.021	1.345	0.0114**
$\ln \text{GDP_NEG}$	0.102	8.171	0.0401**
$\ln \text{CI_POS}$	0.328	5.072	0.0001*
$\ln \text{CI_NEG}$	0.039	1.253	0.2238
Constant	-0.029	-2.636	0.0208**
Short run estimation			
Variable	Coefficient	t-Statistic	Prob.
$\Delta \ln \text{FDI_POS}$	0.067	1.278	0.0105**
$\Delta \ln \text{FDI_NEG}$	-0.140	-4.519	0.0002**
$\Delta \ln \text{GDP_POS}$	4.886	7.994	0.0000*
$\Delta \ln \text{GDP_NEG}$	2.341	4.548	0.0232**
$\Delta \ln \text{CI_POS}$	1.050	5.137	0.0000*
$\Delta \ln \text{CI_NEG}$	0.124	1.231	0.2318
Count Eq	-0.104	-7.772	0.0000*
R-squared	0.962705	Mean dep var	-0.149459
Adjusted R-squared	0.936066	S.D. dep var	2.609201
S.E. of regression	0.659742	AIC	2.304532
Sum squared resid	9.140437	SC	3.001145
Log-likelihood	-26.63385	HC	2.550121
F-statistic	36.13864	DW	2.055801
Prob(F-statistic)	0.000000		
Wald test results			
	F-stat	Prob	
FDI_{WLR}	11.152	0.002**	
F_{EWER}	43.196	0.000*	
GDP_{WLR}	0.498	0.027**	
GDP_{WSR}	8.827	0.006***	
CI_{WLR}	14.770	0.000*	
$VIEW_{SR}$	11.053	0.002**	

2 Note: *, ** and *** represents significance level at 1%, 5% and 10%. W_{LR} and W_{SR} signify the Wald test for the
3 null of long-run and short-run asymmetries for the given variables.

4 The asymmetric cumulative dynamic multiplier for capital investment, economic growth, and
5 foreign direct investment are depicted in [Figure 3](#). The positive and negative unitary shocks in
6 every explanatory variable follow the adjustment pattern of capital investment, economic growth,
7 and foreign direct investment to the new state of balance. The dynamic multipliers reflect this. As
8 indicated in Table 9, the best-fit NARDL model estimates this dynamic multiplier. The modulated
9 pattern of the dependent variable (CO_2) to positive and negative shocks of the independent
10 variables (capital investment, economic growth, and foreign direct investment) is captured by the
11 solid black line (positive) and the dotted black line (negative) with breaks. The red dotted line

shows the asymmetry, which indicates the change in dynamic multipliers linked to each explanatory variable's shocks, i.e. $(w_q^+ - w_q^-)$. This curve is displayed in its entirety, with the bottom and top bands at a 95 percent confidence interval to provide a statistically meaningful estimate of asymmetry at any q-defined horizon. If the zero lines are found in the middle of the two bands, then the explanatory variable in consideration has insignificant asymmetric effects (see Fig. 4).

Figure 3: NARDL Dynamic Multiplier Effect Graphs

Source: Author's calculation using Eviews 12.

The shocks in CI, GDP, and FDI after a positive change in CI, GDP, and FDI are represented by the solid black line in figure 3. The shock in CI, GDP, and FDI after a negative shift in CI, GDP, and FDI is captured by the black short dashed line. The asymmetry curve, which depicts the difference between positive and negative changes in CI, GDP, and FDI, with its accompanying 95 percent confidence interval for statistical inferences, is represented by the red short dashed line. The zero lines are inside the upper and lower bands of the 95 percent confidence interval in Fig. 4 (a, b, and c), indicating that the asymmetric effect of CI, GDP, and FDI is statistically significant at the 5% level. The insignificant asymmetry curve shows that shocks in CI, GDP, and FDI hurt a short time but then turn positive in the long run, supporting the positive impact of symmetric CI, GDP, and FDI on access to CI, GDP, and FDI.

5. Policy Implications

We can infer some policy implications about environmental quality in Oman based on empirical results: Policymakers should work to increase energy efficiency by building a solid infrastructure that allows businesses and individuals to generate renewable energy from fossil fuels. To improve the environment and promote societal change, Oman must upgrade their high-cost/low-efficiency energy technology to produce more efficient and less energy-dependent commodities. To facilitate renewable energy generation, Oman must invest in renewable energy and promote technology transfers.

More complex rules and standards can help international investors spread environmentally friendly technologies, encouraging domestic polluting companies to embrace such technology in Oman. These findings should serve as a caution to policymakers that lax environmental rules in their country may hasten environmental degradation. Oman should pursue a dual approach of growing energy infrastructure investment while also passing energy conservation measures to promote energy efficiency and minimize waste to cut CO₂ emissions and avoid a negative impact on economic growth. More stringent laws requiring the adoption of energy-efficient technologies should reduce CO₂ emissions to pursue economic expansion.

6. Concluding Remarks

This study examines the symmetric and asymmetric nexus between capital investment, economic growth, foreign direct investment, and CO₂ emissions in Oman during 1980–2019. For this purpose, we applied Pesaran et al. (2001)'s Autoregressive Distributed Lag (ARDL) for linear cointegration and the Nonlinear Autoregressive Distributed Lag (NARDL) model of Shin et al. (2014)'s for nonlinear cointegration between capital investment, economic growth, foreign direct investment, and CO₂ emissions. The coefficient of the ECM model is (-0.501), which signifies that CO₂ emissions in Oman converged to their long-run equilibrium level by a 50.1% speed of adjustment each year due to joining FDI, economic growth, and capital investment. The concept of EKC can be tested by comparing long-term and short-term coefficients in assessing the impact of economic growth on CO₂ emissions. The existence of the EKC hypothesis is confirmed if the estimated long-run coefficient of GDP is smaller than the estimated short-run coefficient (Narayan and Narayan 2010). According to the findings of this study, a one percent rise in GDP reduces CO₂ emissions by 0.297 percent in the long run, but a one percent rise in GDP increases CO₂ emissions by 0.360 percent in the short term in Oman. This evidence shows that the EKC hypothesis is influential in Oman, but it contradicts Ozturk and Acaravci's investigation (2010). Ozturk and Acaravci, (2010) sample, which covers the years 1968–2005, could be the source of this discrepancy. In recent years, policymakers in Oman have sought alternative energy sources to prevent environmental deterioration and have increased investment in renewable energy projects such as solar and wind energy. Environmental deterioration has also been decreased as a result of increased public awareness and technological advancements. To evaluate the existence and direction of relationships between variables, the Toda–Yamamoto (1995) causality test is used. This test shows that FDI and CO₂ emissions have a feedback

connection in the case of Oman. The scale effect, which states that foreign direct investment increases a country's CO₂ emissions by boosting industrial output, can explain the causal relationship between FDI and CO₂ emissions (Zarsky 1999). Our results support the pollution haven hypothesis, revealing a causal association between CO₂ emissions and FDI in Oman. Countries with low environmental standards attract more FDI as polluting industries choose to invest in these countries to reduce production costs (Ching 2014).

Moreover, there is a two-directional relationship between economic growth and CO₂ emissions, which means that changes in economic growth lead to changes in CO₂ emissions and vice versa. Capital investment and CO₂ emission, on the other hand, have a one-way causal relationship. Hence the capital investment growth hypothesis is irrelevant in Oman. Mutafoğlu (2012) similarly confirms a directional reason for capital investment in GDP and has concluded that there is no evidence of investment-led growth assumptions in Oman's economy. Furthermore, there are bidirectional causal links between FDI to GDP and capital investment to FDI. There was no evidence of a causal relationship between CO₂ and capital investment in Oman or GDP to capital investment. These results are relevant to the studies of (Chandran and Tand, 2013 and Shahbaz, 2015).

The findings of the NARDL model for long-run and short-run estimations are reported in Table 9. Long-run results reported that FDI is a significant for both positive (L_{FDI}^+) and negative (L_{FDI}^-) shocks. It shows that FDI will have a positive impact on Oman's CO₂ emissions in the long run. The estimated results of long-run Coefficient (L_{FDI}^+) and (L_{FDI}^-) have been found to be 1.52 and 0.73 respectively, showing a 1% increase in FDI, which has increased CO₂ emissions in Oman by 1.52%. Similarly, a 1% fall in FDI will reduce CO₂ by 0.73%. This demonstrates that Oman's foreign direct investment is CO₂ efficient.

Meanwhile, improving living standards needs a higher quality of life and rigorous environmental rules, and FDI brings more advanced technology that minimizes the country's pollution level. These outcomes are reliable with Chima (2007) and Shahbaz (2014). Regarding GDP, the GDP results are important for both positive (L_{GDP}^+) and negative (L_{GDP}^-) shocks. Estimates are reported as long-run coefficients (L_{GDP}^+) and (L_{GDP}^-) 0.02 and 0.10, respectively. We therefore conclude that a 1% increase in GDP increases CO₂ emissions by 0.02%.

Similarly, the negative shock of GDP is also significant with a positive sign. As a result, our findings show that negative changes have a more significant impact. GDP and CO₂ emissions have

a positive connotation, suggesting that as GDP rises, production upsurges, increased production escalations the demand of labor and per capita income in the country, so does the usage of CO₂ emission increases. Consequently, GDP is a source to increase CO₂ emissions in Oman. These results are consistent with Aqeel et al. (2001) and Shahbaz et al. (2014). In the long run, positive shocks to capital investment have a significant impact on CO₂ emission. This is in accordance with recent studies such as Luqman et al. (2019) for Pakistan and Ghazouani (2021) for Tunisia, where they have had a positive impact on co2 emissions from capital formation. On the other hand, capital investment is not a negative blow and has a negative impact on CO₂ emissions (0.39 coefficient).

In the short term, positive and negative shocks have similar effects as they are disintegrated factors in the long run. On the other hand, the degrees of elasticity differ slightly, but the relations are nearly identical. The ECM reflects the change in disequilibrium inaccuracy over time in the short term. The estimated methodology maps the progressive adjustment towards the new equilibrium after the shocks from the initial equilibrium. The error correction term (ECT) is negative and statistically significant at a level of 1%. According to ECT, roughly 53% of the path to long-run equilibrium is completed a year following an economic shock.

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