The Correlation among Industrial Economic Growth, Renewable Energy Provision and CO_2 Emissions in Saudi Arabia

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Abstract: - The industrial sector remains crucial to the Saudi Arabian economy, as the country's industrial exports continue to grow, allowing for the emergence of a thriving international market. However, the effects of global warming caused by humans have become stronger due to higher emissions of gasses that contribute to global warming, carbon dioxide (CO2). These emissions hurt both industrial productivity and the economy. Given the projected population growth and the focus on environmental remediation efforts, it is important to consider the future energy resource requirements for industrial productivity. The question that arises is: what will be the impact of having a clean energy supply on the industry's economy and the environment, even though the industry itself has the potential to greatly contribute to renewable energy production? This study investigates the effect of Saudi Arabia's renewable energy supply, CO2 emissions, and trade openness on the economic growth of the industrial sector, covering the period from 1990 to 2022. The nexus offers valuable insights for policies aimed at promoting renewable energy in the industrial sector by identifying areas of priority. An autoregressive distributed lag (ARDL) analysis was used to estimate the nexus. The findings indicated that the growth of the industry sector contributes to environmental degradation, whereas international trade benefits the sector. The industrial economy experienced a slowdown due to the reduced growth of renewable energy supply. In the short-run, an increase of one unit in the industry sector is associated with a decrease of 0.88 in CO2 emissions, while in the long-run an increase of one unit industry sector, is associated with a decrease of 0.55 in CO2 emissions. The study provides new empirical evidence for the links between renewable energy supply and the industrial sector, which can influence policy regarding the use of renewable energy in Saudi Arabia's industrial sector.

Key-Word: - CO2 emissions, ARDL, Saudi Arabia, industrial sector, renewable energy, international trade.

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1 Introduction

Energy is a necessary component in the manufacturing of products and the provision of services, and it is crucial for driving economic growth. Economic and technological advancements are associated with changes in energy sources. The Industrial Revolution during the 18th century utilized non-renewable resources such as coal on a large scale, resulting in significant environmental consequences. The 21st century is marked by significant transitions in energy sources, moving progressively from coal to oil and ultimately to natural gas. Until now, fossil fuels have remained the dominant energy resource, and the extensive industrial usage of fossil fuels has resulted in emissions and environmental pollution. The world requires renewable and clean energy sources such as solar power as a substitute for fossil fuels to reduce emissions. However, the price of clean energy is excessively high and not within reach for the majority of emerging and underdeveloped nations across the globe. The entire world's objective is to attain economic growth. Therefore, it is necessary to thoroughly examine the structure of the connection between the expansion of the economy and the improvement of the ecosystem. With the rise of industrialization in particular, energy serves as a crucial factor in the production process. The demand for global energy keeps increasing because of the rapid growth in population and global Gross Domestic Product (GDP). As a result, the increase in energy demand and the corresponding rise in the utilization of fossil fuels for production purposes have caused a rise in the atmospheric concentration of greenhouse gaseous substances on Earth. In light of this, climate change and global warming have long been significant challenges for human existence worldwide. Carbon dioxide (CO2), which is an essential component of greenhouse gases, is widely regarded as one of the primary causes of this issue, [1]. Of course, various climate conditions, like glaciers that have recently melted, rising sea levels, and fluctuations in temperature and rainfall, are worth mentioning.

Table 1. 2020 Ranking of the top 18 countries based on per capita emissions

Ranking	Country	CO2 emissions (metric tons per capita)
1	Qatar	31.72684
2	Bahrain	21.97691
3	Brunei Darussalam	21.70581
4	Kuwait	21.16961
5	United Arab Emirates	20.25227
6	Oman	15.6362
7	Australia	14.77614
8	Saudi Arabia	14.26659
9	Canada	13.59937
10	North America	13.08884
11	United States	13.03283
12	Luxembourg	12.45695
13	Kazakhstan	11.29774
14	Russian Federation	11.23229
15	Korea, Rep.	10.99003
16	Turkmenistan	10.18409
17	Trinidad and Tobago	10.15712
18	Palau	8.802582

Table 1 presents the top 18 countries emitting the highest levels of CO2 in 2020, [2], encompassing a mix of developed and large developing nations. These countries hold significant roles in global CO2 emissions, as outlined in the Kyoto Protocol. Notably, Qatar exhibits the greatest per capita emissions at 31.7 tons, despite its relatively small population. Similarly, Bahrain (21.9 tons), Brunei Darussalam (21.7 tons), and Kuwait (21.1 tons) are small, populated countries with high per capita emissions, indicating a strong correlation between income and CO2 emissions per person. Conversely, China and India, despite having low per capita emissions in 2020 due to their large populations, wield substantial influence in the overall emission rankings. The main sectors contributing to emissions encompass energy-based emissions, industrial activities and product usage, industrial practices, the management of trash, as well as land use, land use change, and forestry, are all included. Aside from that, Australia, Saudi Arabia, and Canada exhibit the highest per capita emissions, standing at 14.7 tons, 14.2 tons, and 13.5 tons respectively. Crucially, these nations are also among the most densely populated. It is important to recognize that the release of CO2 is a complex problem that is affected by several variables, such as income, population, and industrial activity. Understanding the relationship between wealth, population, and CO2 emissions is crucial for devising efficient methods to tackle climate change and reduce world CO2 emissions.

Saudi Arabia had the greatest growth rate among the G20 economies in 2022. The overall growth reached 8.7 percent, which can be attributed to the combined effect of increased oil production and a 4.8 percent growth in the non-oil sector. This non-oil growth was primarily driven by strong private consumption and private investment, including notable projects of significant scale. Economic growth and high levels of energy consumption, coupled with a road-dominated transportation system, have resulted in significant increases in greenhouse gas (GHG) and air pollutant emissions. The increasing energy demand is predominantly fulfilled by fossil fuels, which make up 98% of the energy combination. This leads to an increase in the overall amount of emissions. Saudi Arabia is one of the largest emitters and was responsible for emitting 338.8 million metric tons of CO2 in 2022, as shown in Table 1. A ratification of the Kyoto Protocol was carried out by the Kingdom of Saudi Arabia on January 31, 2005. The first commitment period of the Protocol began in 2008 and concluded in 2012. C. Saudi Arabia became a member of the United Nations Framework Convention on Climate Change (UNFCCC) in 1994. Furthermore, in 2016, they officially approved the Paris Climate Agreement, a global accord that had been adopted in 2015. For a country that has not made a significant contribution to the historical accumulation of greenhouse gas (GHG) emissions, but at the same time has an economy supported by the unexpected profits from exporting hydrocarbon resources. However, according to an independent analysis that is aligned with government predictions, current policies are not sufficient to meet Saudi Arabia's Intended Nationally Determined

Contributions (INDC) and the country continues to invest in expanding its oil power production.

1.1 The Objective

The objective of our study is to fill the existing lack of understanding by employing environmental and growth functions to illustrate the efficacy of renewable energy provision in fostering economic growth and mitigating carbon emissions within the Saudi Arabian economy. As far as we know, no previous research has investigated this subject. Furthermore, this research makes a valuable contribution to the academic domain by examining the causal connection between renewable energy, economic development, and carbon emissions in both the immediate and extended periods, employing the Autoregressive Distributed Lag (ARDL) methodology. The subsequent sections of the article are organized in the following manner: Section 2 provides an overview of the extant scholarly works about the correlation between renewable energies, economic growth, and carbon dioxide (CO2) emissions. The data and econometric model utilized in this investigation are presented in Section 3. In Section 4, the empirical technique utilized is outlined. Section 5 examines and deliberates on the collected results. Section 6 provides a concise overview of the results and recommendations.

2 Review of Existing Literature

A multitude of empirical investigations have been undertaken to examine the relationship between the provision of renewable energy, environmental consequences in the form of carbon dioxide emissions, and the advancement of economic growth. Among the various types of academic literature, these investigations may be divided into two distinct groups. Investigating the effect that renewable energy sources have on the expansion of the economy is the primary emphasis of the first category. Coal, natural gas, and crude oil are the three primary components that make up the foundation of the global commerce system. Furthermore, there has been an increase in the costs related to the production of oil. In response to the increased costs of energy and raw materials, the economy has made necessary adjustments by implementing price increases for products. The difficulty is that, even though renewable energy sources have been extensively acknowledged in theory as well as in economic and social practice for a considerable amount of time, they are still considered to be a problem that will arise in the future, [3]. It is a matter of worry that, despite extensive deliberations on decarbonization strategies throughout the years, a consensus about the means to attain this objective has yet to be attained, [4]. Developed nations have enthusiastically adopted the renewable energy industry, but poorer countries continue to encounter challenges in its implementation due to technical and economic barriers, [5].

The global surge in emissions has propelled the idea of renewable energy as a viable solution to acquire significant traction worldwide. The investigation conducted by [6], revealed that greenhouse gas emissions by various businesses between 1990 and 2018 were influenced by specific patterns and variables. The study found that activities in Africa were the main driver behind the increasing emissions, and this upward trend is ongoing. Based on this discovery, it appears that it is particularly important for nations to prioritize investments in renewable energy sources, [7], performed research which yielded the finding that nations might mitigate their reliance on imported fuels, characterized by volatile and escalating costs, by the augmentation of renewable energy consumption. The efficient management of volatility in the future, particularly in the case of further shocks, is a significant problem when considering the current changes in fossil fuel prices resulting from geopolitical challenges. The most impoverished nations will experience the whole magnitude of these effects, and the adverse repercussions will also be evident in the industrial sector. The present predicament lies in the fact that much emphasis has been placed on investments in wind and solar energy, while the latent potential of contemporary biomass remains unexplored.

Saudi Arabia has predominantly allocated its recent investments towards renewable energy, specifically solar and wind power, facilitated by the Saudi Industrial Development Fund (SIDF), [8]. If one were to investigate the unexplored possibilities of contemporary biomass, the industrial sector stands to gain significant advantages through enhanced energy generation and, consequently, expanded production capacity. This has the potential to significantly decrease energy expenses, and any surplus energy produced might be sold to the national power grid, [9]. The research included [10], pan-African investigations of renewable energy generation, with South Africa, Nigeria, Ghana and Cameroon identified. The research proposed that providing tax incentives for renewable energy would facilitate the advancement of energy generation. The primary concern with tax incentives for renewable energy utilization is the insufficient supply, resulting in inflated costs and impeding the widespread adoption of such energy sources. Therefore, governments must give precedence to the provision of incentives to producers. This method has the potential to generate substantial economic advantages in the future. In a study done by [11], an examination was undertaken to assess the advancement of renewable energy in Africa, with particular emphasis on South Africa, Egypt, and Nigeria. Their ideas focused on emphasizing technology, raising awareness, and enhancing skills for the development of renewable energy. Due to the nascent nature of the renewable energy industry, a significant obstacle lies in the scarcity of proficient personnel. The resolution of this matter requires the implementation of a grassroots strategy, which entails the creation of a renewable energy curriculum within vocational institutions of higher education. These endeavors have the potential to enhance collaboration with technology training initiatives, hence enabling the dissemination of technology throughout the energy industry. Moreover, it is important to comprehend the interconnectedness among the industrial sector, trade, clean energy supply, and the environment to facilitate efficient policy formulation within the clean energy sphere.

Emissions of carbon dioxide in Saudi Arabia are the focus of the second category. Multiple studies that lock over the factors that contribute to carbon emissions in the context of Saudi Arabia have been reported in the scientific literature that is now available. The causal link between energy consumption, energy costs, carbon dioxide emissions, and economic development from 1971 to 2010 is examined by [12], in their study conducted in 2015. The results of the study indicate that the influence of energy consumption on the economic growth of Saudi Arabia is negligible, [13], conducted research examining the impact of overall oil consumption and oil consumption in the transportation sector on the environmental state of Saudi Arabia during the period spanning from 1971 to 2013. Based on their findings, it was determined that the pattern of carbon emissions in both models is non-linear and stochastic. Furthermore, they discovered a positive and considerable elasticity for carbon emissions in both total oil consumption and transport oil consumption.

In the context of Saudi Arabia's Vision 2030, the implications of transitioning towards manufacturing on the environment are also discussed throughout the period 1971-2021 was the subject of a study that was recently carried out by [14]. There is no evidence to support the validity of the inverted U-shaped Kuznets function in Saudi Arabia throughout the investigation, according to the findings of the study. In addition, the results of the short-term study do not provide evidence that an increase in manufacturing produces an increase in CO2 emissions. Throughout a recent study that was carried out by [15], the researchers investigated the subject of whether environmental innovation and green energy are crucial for improving environmental sustainability. Although there is some evidence of a beneficial effect, the extent of this benefit is restricted. The study primarily examined Saudi Arabia and found a robust and enduring correlation between the adoption of green energy and environmental innovation, as well as other indicators of CO2 emissions. Nevertheless, it is important to acknowledge that this correlation does not apply to CO2 emissions caused by the utilization of liquid fuels in the context of green energy utilization, and to CO2 intensity in the context of environmental innovation. The research findings indicate that the adoption of renewable energy and technology linked to environmental patents may present a feasible resolution if they do not engender environmental contamination. In their study, [16], sought to evaluate the disparate effects of the oil industry on carbon dioxide (CO2) emissions. The results of their study indicate that there is a positive but inelastic relationship between GDP per capita and carbon dioxide emissions. The concept of the inelastic effect posits that the rate of rise in per capita CO2 emissions is comparatively lower than the rate of income development. Nevertheless, this phenomenon plays a role in environmental degradation by exacerbating CO2 emissions.

3 Methodology

The process used in the research methodology is depicted in Figure 1, The time frame encompasses the years spanning from 1990 to 2022. All data used for the variables of this study are secondary based on information the data was acquired from the "World

Development Indicators (WDI) database" which is diligently managed by the World Bank, The Kingdom of Saudi Arabia's statistical annual yearbook reports various years.

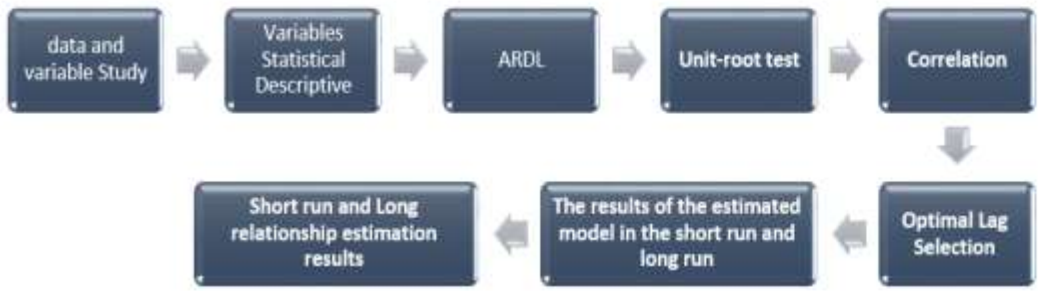

Fig. 1: Steps of Applied Study

Table 2. Variable definition

Variable	Description	Sources
NI	Industrial gross domestic value added	Data world bank
RE	Renewable energy production	Stats.gov.sa
CO_2	Carbon Emission	Data world bank
Ex	Export	Data world bank
Im	Import	Data world bank

Table 3. Statistics Description

	LNI	LRE	LCO_2	LEx	LIm
Mean	18.545	2.577	6.493	4.1082	4.003
Median	18.466	2.682	6.651	4.4961	4.151
Maximum	19.037	3.413	6.989	4.8321	4.724
Minimum	18.153	2.065	5.455	4.095	3.863
Std. Dev.	0.235	0.335	0.782	0.2321	0.295

Regarding the stands for the digital adoption index of the Kingdom of Saudi Arabia, reports for digitalization various years, [17]. Table 1 presents the description of the variables.

Equation 1 outlines the relationship between Industrial gross domestic value-added, Renewable energy production, Carbon Emission, export, and import can be defined. All the variable definition in this research are present in Table 2.

$$NI = f\ (RE, CO_2, Ex, Im\ ) \qquad (1)$$

The statistical description of the variable is presented in Table 3. The author used the logarithm to evaluate the similarity of the values of the variables *LNI*, *LRE*, *LEx*, and *LIm*. The remaining variables were mainly computed using percentages or per capita, as discussed in [18]. All the variables have standard deviations close to zero, indicating the data points exhibit a high degree of clustering around the means.

When analyzing time-series data, it is advisable to transform Equation 1 into logarithms. This conversion helps analyze the impact of a change in renewable energy on the percentage of environmental degradation. Furthermore, a logarithmic transformation at the national level is implemented to address any possible non-linear associations amidst the variables that are influenced by other factors. Consequently, the new equation can be written in the following manner.

$$LNI = \alpha_0 + \beta_1 LRE + \beta_2 LCO_2 + \beta_3 LEx + \beta_4 LIm + \varepsilon_t \qquad (2)$$

Where by *LNI* act is the national logarithm of industrial gross domestic value added, the *LRE* act is the national logarithm of renewable energy production, the *LCO2* act is the national logarithm of Carbon Emission, the *LEx* act is the national logarithm of the export,the *Lim* act is the national logarithm of Import. The expected signs for β_1, β_3, and β_4 will exhibit a positive relationship with the industrial gross domestic product, For the β_2, the expected result will show the pollution haven theory can have either a bad consequence or a good outcome, while the halo effect hypothesis can have a positive outcome. In this research, we used the Autoregressive Distributed-Lag (ARDL) model, [19], and [20], which has become popular as a dynamic approach that includes the element of time. The goal was to analyze the relationship between variables in the short and long term and determine how quickly the system reaches equilibrium. This study aims to analyze the relationship structure between renewable energy, CO2 emissions, economic growth, and industrial production growth in Saudi Arabia from 1990 to 2022, I using ARDL for analyses. The ARDL model comprises two components. Firstly, the Autoregressive (AR) component, relies on lagged values of the dependent variable, incorporating it as a lagged independent variable. Secondly, the distributed lagged (DL) component, indicates that the dependent variable is influenced by changes in the independent variables and their lagged values.

$$\begin{aligned}\mathrm{dLN}I_{t} = {} & \alpha_0 + \beta_1\,\mathrm{LR}E_{t-1} + \beta_2\,\mathrm{LC}O_{2t-1} \\ & + \beta_3\,\mathrm{LE}x_{t-1} + \beta_4\,\mathrm{LI}m_{t-1} + \sum_{j=1}^{p}\alpha_{1j}\Delta\mathrm{LR}E_{t-j} \\ & + \sum_{j=0}^{q}\alpha_{2j}\Delta\mathrm{LCO}_{2\,t-j} + \sum_{j=0}^{n}\alpha_{3j}\Delta\mathrm{L}Ex_{t-j} \\ & + \sum_{j=0}^{m}\alpha_{4j}\Delta\mathrm{LI}m_{t-j} \\ & + \varepsilon_{it} \qquad (3)\end{aligned}$$

Where (d) refers to the first difference operator, p, q, n, and m indicate lags, $(\alpha_1\ to\ \alpha_4)$ refers to long – run parameters, ($\beta_1$to 4) refers to short-run parameters, (α_0) refers to the intercept, and (μ) refers to the error term. (see equation 3)

4 Results

For our analysis in this study, we are using secondary data on macroeconomic variables. Thus, it is crucial to conduct a unit root test to ascertain the stability of the data. For this analysis, I am using the augmented Dickey-Fuller approach, which has been extensively utilized and demonstrated as effective in previous research. Economic analysis techniques are commonly used to examine whether there are periodic fluctuations in the average and variability of time-series information. The unit root test allows us to evaluate the null hypothesis, which suggests that the data is not stable, as opposed to the alternative hypothesis which suggests that the data is stable. Table 4 displays the results of conducting the unit root test using the, [21], method to assess the stability of all variables. All variables become stable when they go through differencing once. When an intercept and trend are included, all variables show stationarity when the differences are calculated. In conclusion, the variables used in this study have different levels of integration—some are integrated of order 1 (I (1)), while others are integrated of order 0 (I(0))—indicating that the ARDL technique can be applied, [22].

Table 4. Unit root test

Variables	Intercept		Intercept with Trend	
	Level	First Difference	Level	First Difference
$\boldsymbol{NI}$	3.4281	2.6463	0.8236	0.0001***
$\boldsymbol{RE}$	-0.9556	-0.0932	0.0620**	0.0000***
$\boldsymbol{CO_2}$	-5.5902	-4.7660	0.3065	0.0006***
$\boldsymbol{Ex}$	1.3632	0.9962	0.6502	0.0000***
$\boldsymbol{Im}$	0.7514	0.0845	0.0091**	0.0000***

Table 5. Bound test result

F-Statistic		7.5844***
Critical Value	Lower Bound	Upper Bound
10%	3.02	4.25
5%	3.65	4.84
1%	4.08	5.21

*Note: ***denotes significance at 1%*

Table 6. Short–run estimation results

Variables	Coefficient	Std. Error	T-Statistic	Prob
LNI	4.7242	1.7734	3.2138	0.0018
LRE	0.5691	0.3581	2.5487	0.0000
LCO_2	-0.8835	0.2021	8.6887	0.0000
LEx	12.806	3.1395	1.5984	0.0000
LIm	9.2540	1.2462	0.2659	0.0000
α_0	-2.9287**	0.0854	-10.9135	0.0000
ε_t	-0.2275	0.0419	-5.1084	0.0000

Table 7. Long–run estimation results

Variables	Coefficient	Std. Error	T-Statistic	Prob
LNI	0.5795	0.0164	35.1697	0.0000
LRE	0.2552	0.0092	27.736	0.0000
LCO_2	0.558	0.0126	4.4202	0.0000
LEx	0.2423	0.0384	6.30007	0.0000
LIm	01584	0.00562	3.2551	0.0000
α_0	-0.0025	0.0007	-3.2960	0.0017

Table 8. Diagnostic Test Results

F-Statistic = 6.2236		
Statistical Test	F-Statistic	Probability
Jarque-Bera	0.0925	0.542
Breusch-Godfrey series correlation test	0.163	0.701
Heteroskedasticity	1.852	0.209
Ramsey's stability test	1.864	0.156

We conducted the ARDL bounds testing technique, and the outcomes are presented in Table 5. The F-statistic of 7.5844 exceeds the critical value of 5.21, indicating that we reject the null hypothesis that there is no co-integration. This discovery implies that we can proceed with estimating the long-run and short-run effects. Moreover, we utilized the Akaike Information Criterion (AIC) to automatically select the optimal lag for our analysis.

a. *Short–run estimation results*

The data analyzed from Table 6 and Table 7 reveal the findings related to the relationship in the short term and the long term. Table 6 shows that the variables LRE, LCO2, LEx, and LIm have a significant impact on LNI in Saudi Arabia in the short term. Additionally, the results from the error correction model ($\boldsymbol{\alpha}$) in the table demonstrate that the error correction term ($\boldsymbol{\alpha}$) is highly significant at a significance level of 5%. It has a negative sign as expected. This suggests that there is a short-term equilibrium relationship, or cointegration, among the variables in the model, with a value of 2.9. Furthermore, this implies that approximately 2.9 within one year, the system returns towards the short-term equilibrium, correcting deviations from the equilibrium. Lastly, the coefficient for ECT is -0.2257 and significant, confirming the presence of short-term relationships between, CO2 emissions export, import, Renewable energy production, and Industrial gross domestic value added.

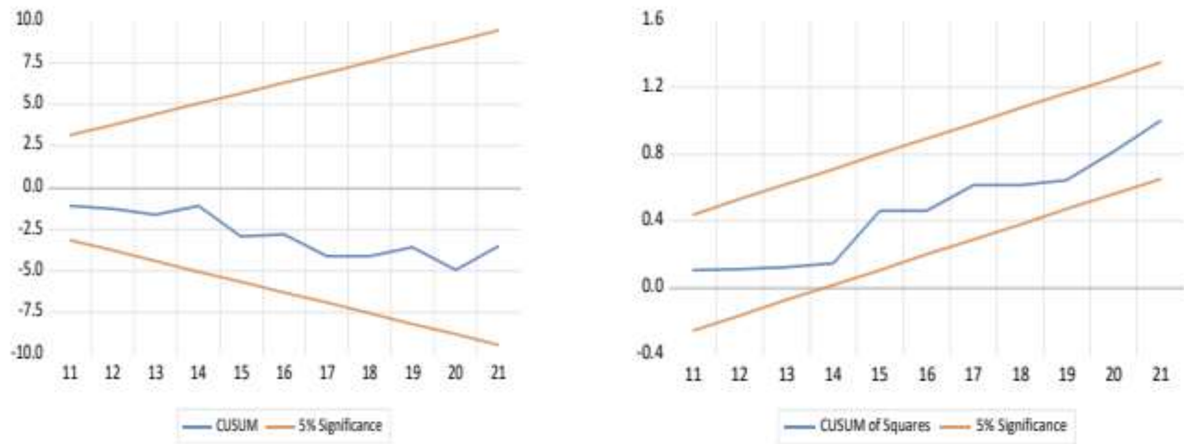

Fig. 2: CUSUM and CUSUMSQ plots

b. *Long-run estimation results*

The analysis of long-term data indicates that there is a significant and positive economic connection between CO2 levels and industry. This means that there is a positive correlation over the long term. To be more precise, for each additional unit of industry, CO2 levels increase by 0.558 units (Table 7).

An ideal ARDL model should be free from issues such as serial correlation, heteroscedasticity, specification errors, and non-normality. Additionally, the parameter estimates should exhibit stability. If there are no diagnostic concerns, it means that the goodness of fit requirements for ARDL models have been met. The results of diagnostic tests, reported in Table 8, were based on various tests such as the Jarque-Bera test, the Breusch-Godfrey series correlation test, the heteroskedasticity test, and Ramsey's stability test. All these tests revealed that the F-statistics were not statistically significant. However, these results indicate that the model used does not have any diagnostic issues. Moreover, the variables of the study, which include Industrial gross domestic value-added, Renewable energy production, carbon emission, export, and import, also do not exhibit any diagnostic problems, as evidenced in Table 8.

To guarantee the stability of the model, we utilized the Cumulative Sum (CUSUM) graph and the Cumulative Sum of Squares (CUSUMSQ) graph (Figure 2). Both graphs in the figure indicate that all the data points plotted fall within the red boundaries. This serves as a confirmation of the stability of the employed model.

5 Discussion

This study aimed to assess the relationship between industrial economic growth, the supply of renewable energy, the export of carbon emissions, and imports. To ascertain the presence of a long-term link, a cointegration test was conducted, while an error correction model was generated to investigate the short-term association. The results of the limits test revealed the existence of a significant and enduring association between the variables. Moreover, in recent times, energy has emerged as a crucial determinant in bolstering the economy, in conjunction with conventional elements such as labor, capital, entrepreneurship, technology, and land, particularly within the framework of climate change. By utilizing the EKC hypothesis, researchers in the field of environmental economics have demonstrated that there is a correlation between the expansion of the economy and the generation of carbon dioxide, [23] and [24]. Several other research have also established a connection between this relationship and the supply and use of energy. Numerous pieces of data provide credence to the notion that climate change hurts the expansion of economically. Considering that the operations of industries, the production of energy, and the consumption of energy are important contributors to carbon emissions, the policies that are now in place push for renewable energy as a method of minimizing the adverse effects of climate change.

Nevertheless, the constrained accessibility of renewable energy on a worldwide level, particularly in developing nations, has resulted in an inverse correlation between economic expansion and the provision and utilization of renewable energy. Hence, it was imperative to investigate the presence of a comparable correlation between the expansion of the industry's economy, the provision of renewable energy, and carbon emissions, while considering trade openness as a controlling variable. This study employed ARDL to evaluate the correlation between industrial gross domestic product (GDP), renewable energy generation, carbon dioxide emissions, and export and import in the context of Saudi Arabia. The research results show a negative connection between economic growth, carbon dioxide emissions, import, and export. This suggests that a one percentage point rise in these variables is associated with a corresponding increase in industry economic growth. Most previous studies have proven this negative correlation.

6 Conclusions & Recommendations

This connection is based on the Environmental Kuznets Curve hypothesis, which was proposed by [23]. Subsequent research has established a correlation between this association and the provision and utilization of energy. There exists substantial data indicating that the adverse consequences of climate change exert a harmful influence on the trajectory of economic growth.

This research employed the ARDL model to investigate the relationship among industrial GDP, renewable energy output, carbon dioxide emissions, exports, and imports in the context of Saudi Arabia. The results of the study indicated a significant positive relationship between the growth of the industrial sector and carbon emissions, exports, and imports. This suggests that a marginal rise of one percent in these factors would have a commensurate beneficial impact on industrial economic growth. The projected positive correlation is consistent with predicted outcomes. The results confirm the concept that economic expansion results in a deterioration of environmental conditions. As predicted in advance, the expansion of the industrial economy was expected to increase carbon emissions, aligning with the premise of the Environmental Kuznets Curve. However, a contrasting correlation was found between the generation of renewable energy and the expansion of the industrial economy, which supports previous empirical studies.

The report offers suggestions for the advancement of sustainable energy sources to decrease reliance on the consumption of fossil fuels. Additionally, it recognizes different forms of renewable energy, including solar, wind, and hydroelectric power. The research primarily examines the oil industry sector because of its direct influence. The research proposes the allocation of dedicated Research and Development (R&D) money towards renewable energy, with a specific focus on the industrial sector. This allocation aims to comprehensively investigate the many socioeconomic dimensions associated with the development of bioenergy. Based on the research and development results, the paper proposes a cooperative effort to create vocational programs focused on renewable energy at higher education institutions in Saudi Arabia. Finally, the research proposes that it would be beneficial for the government to implement tariffs that would enable renewable energy producers operating in the industrial sector to profit from selling excess energy to the national grid. This approach is prevalent in nations that have achieved substantial advancements in the generation of renewable energy at the rural scale.

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Conflict of Interest

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