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ASSESSING THE IMPACT OF ECONOMIC AND ENERGY FACTORS ON CO₂ EMISSIONS: A CASE STUDY OF SAUDI ARABIA

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Abstract. This study seeks to evaluate the applicability of the Environmental Kuznets Curve (EKC) hypothesis in the Saudi Arabian context, a country characterized by its oil-dependent and resource-abundant economy from 1980 to 2022. This study provides insights into Saudi Arabia's progress towards sustainable development by exploring the relationship between CO₂ emissions per capita and economic, demographic, and energy-related factors. The primary objective is determining whether economic growth aligns with environmental sustainability, as outlined in Vision 2030. Utilizing an Autoregressive Distributed Lag (ARDL) model, this study evaluates the short- and long-term relationships between CO₂ emissions per capita and independent variables, including GDP per capita, the squared term of GDP per capita, foreign direct investment (FDI) per capita, energy production per capita, trade openness, and population growth. These findings confirm the existence of an inverted U-shaped relationship between GDP per capita and CO₂ emissions, thereby supporting the EKC hypothesis. Energy generation and population growth significantly contribute to higher pollution levels, and trade openness and FDI positively impact environmental quality by reducing CO₂ emissions. These results highlight the importance of Vision 2030, which emphasizes attracting foreign investment, promoting trade liberalization, and transitioning to renewable energy. This study underscores the need for policymakers to implement comprehensive strategies that support economic growth while achieving long-term environmental sustainability. These findings enhance the understanding of emission dynamics in resource-rich nations and offer valuable guidance for sustainable development planning.

Keywords: Environmental Kuznets Curve (EKC); CO₂ Emissions; trade openness; energy generation; Foreign Direct Investment

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JEL Classifications: Q01, Q56, Q5

1. Introduction

The Environmental Kuznets Curve (EKC) hypothesis outlines a nonlinear relationship in which economic growth initially exacerbates environmental degradation. Still, this trend shifts towards improvement at higher income levels (Banday & Ismail, 2017). It posits that environmental damage typically increases during the early stages of economic development yet declines in the long run as a country achieves higher income levels. Initially, economic growth contributed to rising pollution due to limited investment in cleaner technologies. However, as income levels rise, opportunities to adopt sustainable practices emerge, resulting in enhanced environmental quality over time. In the nascent stages of growth, capital is predominantly allocated to production rather than pollution control. As income grows, the demand for environmentally friendly products has escalated, prompting increased investment in pollution mitigation overproduction. Like other resource-rich nations, Saudi Arabia strives to balance economic growth with sustainability, guided by Vision the 2030s commitment to attaining net-zero emissions by 2030 (Sarwar et al., 2021). This study examines Saudi Arabia's

economic data from 1980 to 2022, emphasizing significant transformations, particularly under the auspices of Vision 2030. Historically, Saudi Arabia's economy has depended significantly on hydrocarbons, with GDP trends closely tied to fluctuations in global oil prices (Figure 1). As of 2023, the country is the third-largest oil producer, a leading exporter, and a key player in OPEC, representing 40% of the Middle East's oil consumption and ranking fifth worldwide in liquid fuel consumption (U.S. Energy Information Administration, n.d.). Vision 2030 emphasizes enhancing electricity generation through natural gas and renewable sources (Figure 2). Remarkably, renewable energy experienced a growth of 153% between 2022 and 2023, although it still accounts for less than 1% of the total energy mix (U.S. Energy Information Administration, n.d.). By 2030, Saudi Arabia aims to generate 50% of its electricity from renewable sources, bolster energy security, diminish reliance on fossil fuels, and fulfil environmental objectives (Berradia et al., 2023). Developing solar and wind energy is expected to decrease domestic oil consumption, increase exports, and yield significant economic benefits (Al Shammre, 2024). CO₂ emissions closely mirror fossil fuel usage, and the shift towards renewable energy has considerable potential for mitigation (Figure 3). The country's trade openness, primarily driven by oil exports, facilitates its integration into global markets, although it remains less extensive than that of more diversified economies, such as Singapore (Figure 4). Saudi Arabia's exports mainly comprise crude oil, refined petroleum, and petrochemicals, with Asia being the leading destination. By contrast, imports include machinery, vehicles, and food products that are essential for industrialization and domestic consumption (U.S. Energy Information Administration (EIA), n.d.; Sultan & Haque, 2018). Historically, foreign direct investment (FDI) inflows have focused on oil, petrochemicals, and infrastructure from major economies. Recently, reforms have targeted emerging sectors such as renewables, tourism, and entertainment, aligning with diversification goals and strategically reducing oil dependency (Mahmood & Alkhateeb, 2018; Samargandi et al., 2022). The researcher highlights several key features in this study that set it apart from prior examinations of the Environmental Kuznets Curve (EKC) hypothesis in Saudi Arabia. This study covers a broader and more contemporary timeframe that reflects the country's significant economic development and environmental initiatives. As a leading oil producer and exporter, Saudi Arabia has historically depended on abundant natural resources for economic growth. However, this reliance has resulted in considerable CO₂ emissions, making the country one of the most prominent global emitters. In response, the nation introduced Vision 2030, aimed at diversifying the economy and promoting sustainability through renewable energy and environmental reforms. This study integrates factors such as foreign direct investment (FDI), population growth (POP), trade openness (TRADE), and energy production (EP) into a comprehensive model. Unlike prior studies that focused on energy consumption, this research emphasizes energy production, thereby addressing inefficiencies related to transmission and distribution. Moreover, these research results confirm the EKC hypothesis in Saudi Arabia from 1980 to 2022, showing that CO₂ emissions initially rise with economic growth but decrease at higher income levels. Energy production and population growth increase pollution, whereas FDI and trade openness help reduce emissions. This study underlines the importance of Vision 2030 strategies in transitioning to renewable energy, attracting foreign investment, liberalizing trade, and promoting sustainable development. These findings highlight the need for resource-rich nations to balance their economic growth with environmental stewardship. This paper is structured into four main sections: theoretical background, research objectives and methodology, results and discussion, and conclusions.

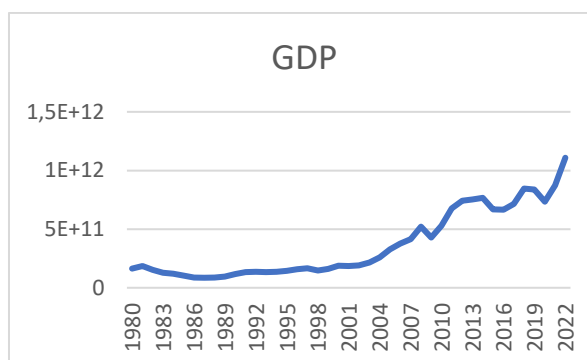


Figure 1. GDP of Saudi Arabia from 1980 to 2022
Data Source: World Bank

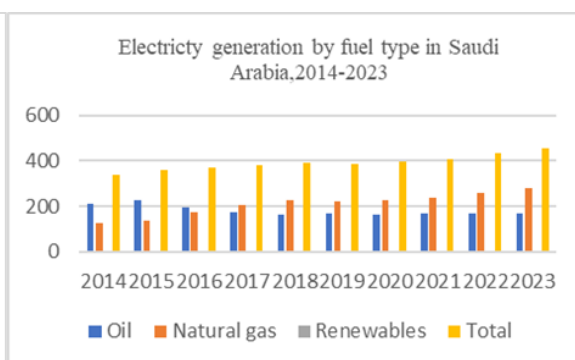


Figure 2. Electricity generation in Saudi Arabia.
Data Source: EIA

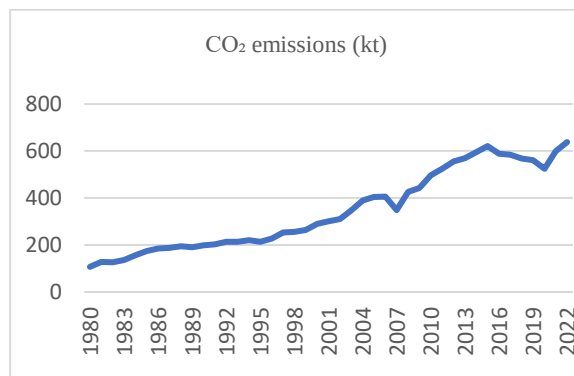


Figure 3. CO₂ emissions in Saudi Arabia
Data Source: EIA

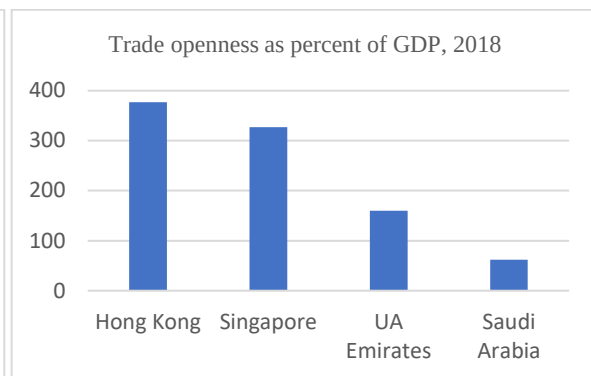


Figure 4. Trade openness
Data Source: the Global economy

2. Theoretical Background

Numerous studies have investigated the EKC hypothesis to explore the relationship between economic growth and carbon dioxide emissions. These studies utilized a range of variables and methodologies to analyze these connections. This paper is organized the existing research into two sections. The first examines studies that use panel data, whereas the second focuses on those that employ time-series data.

The first part of previous studies focused on analyzing panel data to examine the EKC hypothesis. Banday and Ismail (2017) evaluated panel data for the BRICS countries from 1995 to 2013, focusing on tourism revenue, economic development, and carbon emissions. Their findings confirm the EKC hypothesis, highlighting that while developing countries implement policies for long-term environmental improvement, economic growth can harm the environment in the short term. Similarly, Arouri et al. (2012) used panel error correction models (ECM) to study energy usage, GDP, and CO₂ emissions in the MENA region from 1981 to 2005. It was found that energy utilization significantly increased pollution in the long run, and the EKC hypothesis was confirmed for the region. However, Jebli et al. (2014), analyzing data from sub-Saharan African countries between 1980 and 2010, found that the EKC hypothesis did not hold in these economies. The results showed that while GDP per capita reduced CO₂ emissions in the long term, the squared term of GDP per capita positively affected emissions.

The second part of previous studies focused on those using time-series data to explore the EKC hypothesis. Sinha et al. (2017) analyzed India from 1971 to 2015 and found that renewable energy adoption significantly reduced pollution and confirmed an inverted U-shaped EKC pattern. Shahbaz et al. (2015) studied Portugal from 1971 to 2008, revealing that energy use, urbanization, and trade openness increased CO₂ emissions, with pollution declining after income reached a certain threshold. Shahbaz et al. (2014) validated the EKC hypothesis in the UAE (1975–2011), noting that electricity use and exports supported environmental sustainability, while urbanization increased emissions. Al-Mulali et al. (2014) found that the EKC did not apply in Vietnam (1981–2011), as fossil fuel use drove pollution, while renewable energy had little effect. Conversely, Al-Mulali et al. (2015) confirmed the EKC in Kenya (1980–2012), showing that fossil fuels, urbanization, and trade openness worsened pollution, whereas renewable energy improved sustainability. Mahmood et al. (2019) validated the EKC in Egypt (1990–2014), finding that energy use harmed the environment, while FDI had a positive impact. Numerous studies have examined the relationship between economic growth and environmental quality in Saudi Arabia, with mixed findings on the EKC hypothesis. Alruweili (2023) identified a nonlinear relationship between economic growth and environmental degradation, where emissions initially rise with economic growth but decline after reaching a certain threshold from 1981 to 2017. Trade openness and energy use have been highlighted as the key drivers of CO₂ emissions. Omri et al. (2018), analyzing data from 1990 to 2014, found that per capita income initially increased emissions but reduced them after surpassing a threshold, supporting the EKC hypothesis. Similarly, Alsaedi et al. (2022) confirmed the EKC hypothesis for 1980–2018, citing GDP and energy use as the major contributors to emissions. Mahmood and Alkhateeb (2017) validated the EKC hypothesis for 1970–2016, noting that trade reduced pollution. In contrast, Asif (2017) found no evidence supporting the EKC hypothesis in Saudi Arabia from 1971–2011.

Previous studies on the EKC framework in the context of Saudi Arabia have relied on outdated time series data. This highlights the necessity for more recent research that considers the impact of Saudi Vision 2030 on both the economy and the environment. In contrast, this study analyzed data up to 2022 and evaluated the EKC while considering factors that previous research did not address. The findings will help policymakers identify elements that negatively impact the environment as well as those that can foster both environmental quality and economic growth.

3. Research Objective and Methodology

3.1. Model Specification

This study investigates the upside-down U-shaped correlation between economic growth and pollution in Saudi Arabia following Panayotou's (1997) generalized EKC hypothesis. The model incorporates squared GDP per capita (GDP^2) as an explanatory variable for CO_2 emissions per capita (CO_2). Furthermore, the study seeks to identify the key determinants of CO_2 emissions, including trade openness (TRADE), energy generation per capita (EP), foreign direct investment per capita (FDI), and population growth (POP). Based on the EKC hypothesis, rising GDP is associated with increased CO_2 emissions during the early phases of economic development. At this stage, countries invest more in producing goods and services than in pollution abatement. However, countries tend to allocate more resources towards pollution control than production as income levels rise. The following equation supports the EKC hypothesis and identifies the contributors to CO_2 emissions:

$$CO_{2t} = f(GDP_t, GDP^2_t, EP_t, FDI_t, POP_t, TRADE_t) \quad (1)$$

Time-series data from Saudi Arabia, covering 1980 to 2022, were analyzed using the ARDL approach to test the EKC hypothesis. Before estimating the model, an Augmented Dickey-Fuller test was conducted to ensure that all the variables were integrated at the first or second difference. After confirming the stationarity of all the series, the ARDL model was estimated using the method outlined by Pesaran et al. (2001). The estimated model is expressed as follows:

$$\Delta CO_{2t} = \beta_0 + \beta_1 CO_{2t-1} + \beta_2 GDP_{t-1} + \beta_3 GDP^2_{t-1} + \beta_4 EP_{t-1} + \beta_5 FDI_{t-1} + \beta_6 TRADE_{t-1} + \beta_7 POP_{t-1} + \sum \delta_{1j} \Delta CO_{2t-j} + \sum \delta_{2j} \Delta GDP_{t-j} + \sum \delta_{3j} \Delta GDP^2_{t-j} + \sum \delta_{4j} \Delta EP_{t-j} + \sum \delta_{5j} \Delta FDI_{t-j} + \sum \delta_{6j} \Delta TRADE_{t-j} + \sum \delta_{7j} \Delta POP_{t-j} + \psi_t \quad (2)$$

An F-bound test was performed to assess the existence of cointegration. The null hypothesis for Equation 2 is $H_0: \beta_1 = \beta_2 = \beta_3 = \beta_4 = \beta_5 = \beta_6 = \beta_7 = 0$. If the F-bound test statistic surpasses the upper bound of the critical value, it provides evidence of cointegration. The short-run model was estimated using the following approach:

$$\Delta CO_{2t} = \beta_0 + \sum \gamma_{1j} \Delta CO_{2t-j} + \sum \gamma_{2j} \Delta GDP_{t-j} + \sum \gamma_{3j} \Delta GDP^2_{t-j} + \sum \gamma_{4j} \Delta EP_{t-j} + \sum \gamma_{5j} \Delta FDI_{t-j} + \sum \gamma_{6j} \Delta TRADE_{t-j} + \sum \gamma_{7j} \Delta POP_{t-j} + \nu ECT_{t-1} + \psi_t \quad (3)$$

where ν is the coefficient of the error correction term (ECT), and a short-run relationship between the variables exists if ν is negative and significant. The parameters of the difference variables captured the short-run effects.

3.2. Data

Time-series data for Saudi Arabia from 1980 to 2022 were obtained from the World Bank for GDP per capita, population growth, and foreign direct investment per capita, while CO_2 emissions per capita and energy generation data were obtained from the Energy Information Administration (EIA). CO_2 emissions, measured in metric tons, serve as the dependent variable representing pollution, while GDP per capita (in constant 2010 USD) is the primary independent variable measuring economic growth. To test the EKC hypothesis, GDP is expected to initially increase CO_2 emissions, with GDP squared (GDP^2) capturing the inverted U-shaped relationship proposed by Panayotou (1997). Previous studies such as those by Sinha et al. (2017), Alajmi (2022), and Arouri et al. (2012) found that an increase in GDP initially contributes to an increase in pollution, eventually leading to environmental improvement. Unlike most EKC studies focusing on energy consumption, this

research follows Alajmi (2022) by using energy production to minimize transmission losses. Energy generation is assumed to drive CO₂ emissions, whereas FDI is expected to reduce them, aligning with Mahmood et al. (2019). Population growth is considered a factor in increasing emissions, which is consistent with the findings of Alajmi (2022). Additionally, trade openness is assumed to enhance environmental quality, building on Mahmood and Alkhateeb (2017).

4. Results and Discussion

4.1. Descriptive and Summary Statistics

Table 1 presents the descriptive data analysis for a dataset of 43 observations from Saudi Arabia from 1908 to 2022. The dependent variable, CO₂ emissions per capita (CO₂), ranged from 1.05E-05 to 1.90E-05, with a mean of 1.44E-05 and a standard deviation of 2.36E-06. The independent variables include GDP per capita (GDP) from 5998.224 to 30447.88; energy production per capita (EP) from 3.44E-08 to 1.20E-06, foreign direct investment (FDI) from -1310.558 to 428.4983, population growth (POP) from -0.129847 to 4.934164, and trade openness (TRADE) from 0.497135 to 0.961026. The Jarque-Bera test indicates that CO₂, GDP, POP, and TRADE are normally distributed, whereas EP, FDI, and GDP² are not. The Durbin-Watson test showed an observed value of 0.547091, indicating positive serial autocorrelation. Autoregressive models, such as the autoregressive distributed lag (ARDL) model, have been proposed to address this issue.

Table 1. Descriptive data analysis.

	CO ₂	EP	FDI	GDP ²	GDP	POP	TRADE
Mean	1.44E-05	8.32E-07	-173.2834	2.40E+08	13901.56	3.080331	0.725487
Median	1.36E-05	8.73E-07	-19.01907	1.21E+08	10997.05	2.798785	0.695039
Maximum	1.90E-05	1.20E-06	428.4983	9.27E+08	30447.88	4.934164	0.961026
Minimum	1.05E-05	3.44E-08	-1310.558	35978694	5998.224	-0.129847	0.497135
Std. Dev.	2.36E-06	2.83E-07	404.0153	2.21E+08	6885.137	1.194761	0.119063
Skewness	0.330564	-1.906703	-1.252623	1.059702	0.553896	-0.335760	0.337089
Kurtosis	1.794855	6.188747	3.927041	3.387324	2.000649	2.836340	2.094669
Jarque-Bera	3.385292	44.27239	12.78472	8.316725	3.988080	0.855922	2.282836
Probability	0.184032	0.000000	0.001674	0.015633	0.136144	0.651837	0.319366
Sum	0.000618	3.58E-05	-7451.186	1.03E+10	597767[.0	132.4542	31.19595
Sum Sq. Dev.	2.35E-10	3.35E-12	6855592.	2.05E+18	1.99E+09	59.95309	0.595394
Observations	43	43	43	43	43	43	43
Durbin-Watson stat	0.547091						

4.2. Model Estimation

Table 2 presents the results of the Augmented Dickey-Fuller test performed to assess the stationarity of data. The findings indicate that all variables achieve stationarity at the first difference I(1) across three scenarios: intercept, intercept, and trend, and none, all at the 1% significance level. Thus, an ARDL model was applied. Following this, an F-bound test for cointegration was performed, and the results are shown in Table 3. The calculated F-statistic value of 8.966375 exceeds the critical value bounds at the 1%, 5%, and 10% significance levels. This finding indicates the presence of an equilibrating relationship, suggesting a long-run association and confirming the existence of cointegration. The diagnostic tests summarized in Table 3 confirm the robustness and reliability of the ARDL model. The Jarque-Bera test ($p = 0.9889$) indicated that the residuals followed a normal distribution, validating the model's statistical inferences. The Ramsey RESET test ($t = 0.5166$, $p = 0.6179$; $F = 0.2669$, $p = 0.6179$) confirmed that the model was correctly specified with no omitted variables. The Breusch-Godfrey serial correlation LM test shows no evidence of serial correlation up to two lags, and the Breusch-Pagan-Godfrey test supports the presence of homoscedasticity. Finally, Figure 5 shows the CUSUM test results, indicating that the model's parameters remain stable over time, as the test statistic is within the critical bounds. The goodness-of-fit measures in Table 4 indicate that the ARDL model explains 99.71% of the variance in CO₂ emissions, with an R-squared value of 0.9917 and an Adjusted R-squared value of 0.9685. Prob(F-statistic) = 0.000000 confirmed the model's overall significance. The Akaike Information

Criterion (AIC = -26.49915) and Schwarz Criterion (SC = -25.26214) reflect model efficiency, whereas the Durbin-Watson statistic (2.567863) indicates no residual autocorrelation.

Table 2. Results of unit root tests

variable	Augmented Dickey-Fuller test statistic					
	Level			1 st diff		
	intercept	trend and intercept	non	intercept	trend and intercept	non
CO ₂	-1.500844			-6.517977***	-6.411793***	-6.464136***
EP	-3.198252**	-7.855783***	-0.201146	-6.066605***	-5.525515***	-6.385660***
GDP	0.514728			-4.180204***	-4.997954***	-4.249474***
GDP ²	1.083403			-4.567223***	-5.421937***	-4.370751***
FDI	-2.569519			-5.935461***	-5.789773***	-5.984618***
TRADE	-1.913183			-4.709999***	-4.676644***	-4.720244***
POP	-1.218834			-5.960843***	-5.778015***	-5.749734***

*** indicates significance at the 1% level, while ** denotes significance at the 5% level.

Table 3. Diagnostic tests

Serial Correlation: Breusch-Godfrey Serial Correlation LM Test:	F-value=1.095469	P-value=0.3798
Heteroskedasticity Test: Breusch-Pagan-Godfrey	F-value=2.646810	P-value=0.0540
F-Bounds test	F- value =8.966375 Critical F-values: At 10% (2.940), 5% (3.280), 1% (3.990)	
Jarque-Bera test for residuals normality	Jarque-Bera test =0.0222 p-value= 0.9889	
Ramsey RESET Test	T-Value= 0.5166 , P-value= 0.6179 F-Value= 0.2669, P-value= 0.6179	

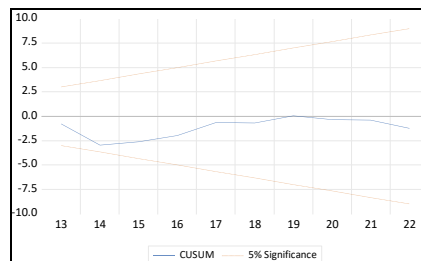


Figure 5. CUSUM test

Table 4. Goodness of fit

Goodness of fit	
R-squared=0.991711	Prob(F-statistic)=0.000000
Adjusted R-squared=0.968503	Mean dependent var=1.47E-05
S.E. of regression=4.00E-07	S.D. dependent var=2.25E-06
Sum squared resid=1.60E-12	Schwarz criterion=-25.26214
Log likelihood=545.7334	Hannan-Quinn criter.= -26.05532
F-statistic=42.73138	Durbin-Watson stat=2.567863
Akaike info criterion (AIC)=-26.49915	

Table 5 summarizes the ARDL analysis results for Equations 2 and 3, revealing the long- and short-term relationships among the variables.

Table 5. Results of ARDL cointegration

Variable	Coefficient	Std.Error	t-Statistic	Prob.
Long Run				
EPt	60.31351	25.71973	2.345029	0.0254
GDPt	5.72E-09	2.38E-09	2.402400	0.0223
GDP ² t	-1.38E-13	6.20E-14	-2.227906	0.0330
FDIt	-1.84E-08	8.18E-09	-2.252118	0.0313
TRADEt	-6.44E-05	3.19E-05	-2.022182	0.0516
POPt	4.25E-08	8.97E-07	0.047370	0.9625
Intercept	-3.92E-05	2.20E-05	-1.780190	0.0845
Short Run				
D(GDP)	1.00E-09	1.71E-10	5.859135	0.0000
D(GDP(-1))	-4.96E-09	4.30E-10	-11.53467	0.0000
D(GDP(-2))	-2.33E-09	2.95E-10	-7.880564	0.0000
D(GDP(-3))	-2.39E-09	2.68E-10	-8.906597	0.0000
D(GDP ²)	-3.05E-14	4.23E-15	-7.218660	0.0000
D(GDP ² (-1))	1.06E-13	9.49E-15	11.17580	0.0000
D(GDP ² (-2))	3.97E-14	6.56E-15	6.046499	0.0000
D(GDP ² (-3))	5.50E-14	6.60E-15	8.330466	0.0000
D(FDI)	2.51E-09	4.84E-10	5.188896	0.0001
D(FDI(-1))	2.78E-09	6.02E-10	4.612973	0.0002
D(FDI(-2))	6.75E-09	6.79E-10	9.940191	0.0000
D(EP)	16.29577	1.557487	10.46286	0.0000
D(EP(-1))	-2.512196	0.559110	-4.493205	0.0003
D(TRADE(-1))	4.64E-05	4.06E-06	11.42178	0.0000
D(TRADE(-2))	3.25E-05	3.25E-06	10.00825	0.0000
D(TRADE(-3))	2.11E-05	2.32E-06	9.133300	0.0000
D(POP)	6.70E-07	1.65E-07	4.065896	0.0008
D(POP(-1))	-1.12E-06	2.09E-07	-5.379503	0.0000
ECT t-1	-0.332636	0.030123	-11.04277	0.0000

In the long run, GDP positively impacts CO₂ emissions ($p < 0.05$), while GDP² has a significantly negative effect, supporting the EKC hypothesis in Saudi Arabia. Similar findings are noted in studies by Alruweili (2023), Omri et al. (2018), and Mahmood et al. (2017). Energy production (EP) significantly increases CO₂ emissions at the 5% level, reflecting the country's reliance on fossil fuels (EPA, 2023) and aligning with Alajmi (2022). FDI significantly reduces CO₂ emissions ($p < 0.05$), consistent with Mahmood et al. (2019), highlighting the need for policies that attract FDI to boost economic and environmental outcomes. Trade also negatively impacts CO₂ emissions at the 10% level, as supported by Mahmood et al. (2017). Population (POP), however, showed no significant impact on CO₂ emissions, possibly because of the time frame of the analysis, suggesting that a more extended study period may provide more precise insights. In the short run, GDP, GDP², FDI, and TRADE significantly affect CO₂ emissions, with EP contributing to higher emissions. The error correction term (ECT) of -0.332636 is negative and statistically significant at the 1% level, indicating that 33.26% of the deviations from equilibrium are corrected within one period. These findings suggest that over time, CO₂ emissions in Saudi Arabia decrease as income rises, underscoring the importance of transitioning to renewable energy sources such as biofuels, hydrogen, wind, and solar power to improve environmental quality.

Conclusions

This study applied the Environmental Kuznets Curve (EKC) hypothesis to assess the impact of economic growth, energy production, population growth, foreign direct investment (FDI), and trade openness on CO₂ emissions in Saudi Arabia from 1980 to 2022. The ARDL model was used to estimate the variables' short- and long-term relationships. The findings confirm the EKC hypothesis for Saudi Arabia during this period, aligning with the Vision 2030 targets for promoting economic and environmental sustainability. This study found that energy production, primarily from fossil fuels, increases pollution. Additionally, population growth is linked to higher CO₂ emissions. Conversely, the findings of this study indicate that FDI and trade openness enhance environmental quality. These results may encourage policymakers to continue implementing the plans outlined in Vision 2030, which aim to increase the use of renewable energy across various sectors, attract more foreign

investment, and ease trade regulations. Governments can foster economic growth by pursuing these strategies while prioritizing environmental conservation.

Among the limitations of this study is the potential influence of the COVID-19 lockdown on the emissions data. Like many other countries, Saudi Arabia likely experienced a decline in economic activity and emissions during the pandemic, which may have distorted the results in the post-2020 period. Future research could mitigate this issue by examining pre- and post-pandemic data to understand long-term trends and effects better.

References

- Al Shammre, A. S. (2024). The impact of using renewable energy resources on sustainable development in the Kingdom of Saudi Arabia. *Sustainability*, 16(3), 1324. <https://doi.org/10.3390/su16031324>
- Al-Mulali, U., Saboori, B., & Ozturk, I. (2014). Investigating the Environmental Kuznets Curve hypothesis in Vietnam. *Energy Policy*, 76, 123–131. <https://doi.org/10.1016/j.enpol.2014.11.019>
- Al-Mulali, U., Solarin, S. A., & Ozturk, I. (2015). Investigating the presence of the Environmental Kuznets Curve (EKC) hypothesis in Kenya: An autoregressive distributed lag (ARDL) approach. *Natural Hazards*, 80(3), 1729–1747. <https://doi.org/10.1007/s11069-015-2050-x>
- Alajmi, R. G. (2022). Carbon emissions and electricity generation modeling in Saudi Arabia. *Environmental Science and Pollution Research*, 29(16), 23169–23179. <https://doi.org/10.1007/s11356-021-17354-0>
- Alruweili, F. (2023). Impact of GDP growth on the ecological footprint: Theoretical and empirical evidence from Saudi Arabia. *International Journal of Advanced and Applied Sciences*, 10(5), 120–128. <https://doi.org/10.21833/ijaas.2023.05.015>
- Alsaedi, M. A., Abnisa, F., Alaba, P. A., & Farouk, H. U. (2022). Investigating the relevance of the Environmental Kuznets Curve hypothesis in Saudi Arabia: Towards energy efficiency and minimal carbon dioxide emissions. *Clean Technologies and Environmental Policy*, 24(4), 1285–1300. <https://doi.org/10.1007/s10098-021-02244-3>
- Aroui, M. E. H., Youssef, A. B., M'henni, H., & Rault, C. (2012). Energy consumption, economic growth, and CO₂ emissions in Middle East and North African countries. *Energy Policy*, 45, 342–349. <https://doi.org/10.1016/j.enpol.2012.02.042>
- Asif, M. (2017). Environmental Kuznets Curve for Saudi Arabia: An endogenous structural breaks-based cointegration analysis. *Journal of Social Science Studies*, 5(1), 149–166. <https://doi.org/10.5296/jss.v5i1.12196>
- Banday, U. J., & Ismail, S. (2017). Does tourism development lead positive or negative impact on economic growth and environment in BRICS countries? A panel data analysis. *Economics Bulletin*, 37(1), 553–567.
- Berradia, H., Abid, M., Gheraia, Z., & Hajji, R. (2023). Renewable Energy Consumption-Economic Growth Nexus in Saudi Arabia: Evidence from a Bootstrap ARDL Bounds Testing Approach. *WSEAS Transactions on Environment and Development*, 19, 33–44. <https://doi.org/10.37394/232015.2023.19.4>
- Jebli, M. B., Youssef, S. B., & Ozturk, I. (2014). The role of renewable energy consumption and trade: Environmental Kuznets Curve analysis for Sub-Saharan Africa countries. Munich Personal RePEc Archive.
- Mahmood, H., & Alkhateeb, T. T. Y. (2018). Foreign direct investment, domestic investment and oil price nexus in Saudi Arabia. *International Journal of Energy Economics and Policy*, 8(4), 147–151.
- Mahmood, H., Furqan, M., Tawfik, T., Alkhateeb, Y., & Fawaz, M. M. (2019). Testing the Environmental Kuznets Curve in Egypt: Role of foreign investment and trade. *International Journal of Energy Economics and Policy*, 9(1), 307–315. <https://doi.org/10.32479/ijeep.7271>
- Mahmood, H., & Alkhateeb, T.T.Y. (2017). Trade and environment nexus in Saudi Arabia: An Environmental Kuznets Curve hypothesis. *International Journal of Energy Economics and Policy*, 7(6), 291–295. <http://orcid.org/0000-0001-8215-9522>
- Omri, A., Euch, J., Hasaballah, A. H., & Al-Tit, A. (2018). Determinants of environmental sustainability: Evidence from Saudi Arabia. *Science of the Total Environment*, 657, 1592–1601. <https://doi.org/10.1016/j.scitotenv.2018.12.111>
- Panayotou, T. (1997). Demystifying the Environmental Kuznets Curve: Turning a black box into a policy tool. *Environment and Development Economics*, 2(4), 465–484. <https://doi.org/10.1017/S1355770X97000259>

Pesaran, M. H., Shin, Y., & Smith, R. J. (2001). Bounds testing approaches to the analysis of level relationships. *Journal of Applied Econometrics*, 16(3), 289–326. <https://doi.org/10.1002/jae.616>

Samargandi, N., Alghfais, M. A., & AlHuthail, H. M. (2022). Factors in Saudi FDI inflow. *SAGE Open*, 12(1), 1–13. <https://doi.org/10.1177/21582440211067242>

Sarwar, S., Streimikiene, D., Waheed, R., Dignah, A., & Mikalauskiene, A. (2021). Does Vision 2030 and value-added tax lead to sustainable economic growth? The case of Saudi Arabia. *Sustainability*, 13(19), 11090. <https://doi.org/10.3390/su131911090>

Shahbaz, M., Dube, S., Ozturk, I., & Jalil, A. (2015). Testing the Environmental Kuznets Curve hypothesis in Portugal. *International Journal of Energy Economics and Policy*, 5(2), 475–481. <https://www.econjournals.com/index.php/ijeep/article/view/1126>

Shahbaz, M., Sbia, R., Hamdi, H., & Ozturk, I. (2014). Economic growth, electricity consumption, urbanization, and environmental degradation relationship in the United Arab Emirates. *Ecological Indicators*, 45, 622–631. <https://doi.org/10.1016/j.ecolind.2014.05.022>

Sinha, A., Muhammad, S., & Shahbaz, M. (2017). Estimation of the Environmental Kuznets Curve for CO₂ emissions: Role of renewable energy generation in India. Munich Personal RePEc Archive, 79863, 1–25.

Sultan, Z. A., & Haque, M. I. (2018). Oil exports and economic growth: An empirical evidence from Saudi Arabia. *International Journal of Energy Economics and Policy*, 8(5), 281–287. www.econjournals.com/index.php/ijeep/article/view/6688

U.S. Energy Information Administration. (n.d.). *Saudi Arabia*. Retrieved January 19, 2025, from <https://www.eia.gov/international/analysis/country/SAU>

U.S. Environmental Protection Agency (EPA). (2023, October 20). Sources of greenhouse gas emissions. Retrieved January 19, 2025, from <https://www.eia.gov/international/analysis/country/SAU>

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