International Journal of Energy Economics and Policy

ISSN: 2146-4553

available at http: www.econjournals.com

International Journal of Energy Economics and Policy, 2026, 16(2), 598-607.

Examining the Impact of Economic Globalization on Environmental Degradation in Saudi Arabia

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Received: 23 September 2025 **Accepted:** 12 January 2026 **DOI:** https://doi.org/10.32479/ijeep.22517

ABSTRACT

Environmental degradation has emerged as a pressing global challenge that requires continuous empirical assessment, motivating researchers to examine it. To this end, this study examines the asymmetric impact of globalization, economic growth and trade openness on the CO_2 emissions in the presence of environmental Kuznets curve (EKC) in Saudi Arabia for the 1970-2022 period. In order to investigate the effect of positive and negative shocks on the independent variable on the dependent variable, a nonlinear autoregressive distributive lag (ARDL) is used. The findings confirm that the effects of globalization and trade openness are significant and nonlinear. However, the effect of negative shocks of globalization and trade openness is more dominant on the CO_2 emissions in in Saudi Arabia than the positive shocks of both variables. Moreover, the present study tests the presence of the Environmental Kuznets Curve (EKC) hypothesis in Saudi Arabia, and the findings confirm the presence of an inverted U-shape curve in the Saudi Arabia economy. Policymakers should reinforce environmental regulations, broaden green financing initiatives, and adopt international best practices to ensure that globalization supports environmental goals in the long-term.

Keywords: Environment, Economic Globalization, Sustainability, Nonlinear Autoregressive Distributed Lag, Environmental Kuznets Curve
JEL Classifications: F64, Q56

1. INTRODUCTION

Over the past decades, environmental degradation has emerged as one of the most pressing global challenges, driven largely by rapid economic expansion, accelerated globalization, and increased integration of countries into international trade networks (Kumar and Wu, 2025; Chen et al., 2025; Nsair and Alzubi, 2025). Rising levels of carbon dioxide (CO_2) emissions, considered the primary contributor to anthropogenic climate change, have pushed policymakers, researchers, and international organizations to re-evaluate development strategies and explore sustainable pathways that balance economic growth with environmental conservation (IPCC, 2024). In this context, understanding the complex interactions between economic performance, global integration, and environmental outcomes has become increasingly vital, particularly for economies undergoing structural transformation. A substantial body of empirical literature highlights that economic expansion, while essential for improving living standards, often comes at the cost of environmental pressure, especially in the early stages of development (Grossman and Krueger, 1995). Moreover, globalization and trade have further shaped environmental outcomes through multiple channels, including technology transfer, structural transformation, and increased production and transportation activities (Antweiler et al., 2001; Managi et al., 2009). In this context, understanding the complex interactions between economic performance, global integration, and environmental outcomes has become increasingly vital, particularly for economies undergoing structural transformation.

Saudi Arabia, as one of the world's largest oil producers and a major global energy supplier, occupies a unique position in the discourse on environmental sustainability. Historically, the country's economic growth model has relied heavily on hydrocarbon extraction and energy-intensive industries, contributing substantially to CO_2 emissions. However, in recent years, Saudi Arabia has embarked on an ambitious transformation under Vision 2030, which aims to diversify the economy, expand non-oil sectors, and promote environmental sustainability through renewable energy investments, technological advancement, and regulatory reform. Against this backdrop, understanding the long-run environmental dynamics of the Saudi economy is critical, particularly the role of globalization and trade openness, which continue to shape the country's development trajectory.

The relationship between economic growth and environmental degradation has been widely explored through the Environmental Kuznets Curve (EKC) hypothesis, which posits that pollution levels initially rise with growth but eventually decline once a country reaches a certain level of income. While many empirical studies have tested the EKC in various contexts, results remain mixed, and the specific mechanisms behind the turning point often differ across countries (Rees, 2003; Buşăn, 2012; Zhou et al., 2025; Odei et al., 2025). Furthermore, literature increasingly recognizes that globalization and trade openness play a pivotal role in influencing environmental outcomes. Global integration can foster technology transfer, promote cleaner production processes, and enhance energy efficiency. Conversely, it may also stimulate industrial expansion, increase transportation emissions, and reinforce dependence on energy-intensive sectors. These contradictory channels underscore the need for context-specific analysis, especially for economies like Saudi Arabia that are deeply integrated into global markets.

A major limitation of existing studies is that they assume that the impact of economic growth, globalization, and trade on CO_2 emissions is symmetrical. However, economic realities are inherently nonlinear, and policymakers often respond differently to positive versus negative shocks. For example, a decline in globalization may disrupt access to clean technologies more severely than an increase that enhances environmental quality. Similarly, reductions in trade flows may force domestic industries to rely more heavily on carbon-intensive inputs. Therefore, the linear models fail to capture such asymmetric effects, leading to incomplete or misleading policy implications.

In response to these limitations, this study employs the nonlinear autoregressive distributed lag (NARDL) approach, which allows for testing both short- and long-run asymmetries in the relationship between economic variables and environmental quality. By decomposing economic globalization and trade openness into positive and negative changes, the NARDL model enables a more nuanced understanding of how different types of shocks influence CO_2 emissions. This methodological advancement is particularly valuable for Saudi Arabia, where fluctuations in global energy markets, investment flows, and trade patterns significantly shape sustainable development efforts.

Another motivation for this research stems from the evolving globalization landscape. Recent decades have witnessed episodes of global financial instability, geopolitical tensions, supply-chain disruptions, and shifts in trade policies. These events highlight the importance of exploring not only the level of globalization but also the consequences of sudden changes, whether expansions or contractions, on environmental outcomes. The asymmetry analysis offered by the NARDL framework provides a powerful tool for capturing these dynamics. Despite extensive global research, empirical studies focusing on Saudi Arabia remain limited, especially those adopting nonlinear frameworks and long historical datasets. The few existing studies primarily examine linear relationships or focus on short-run dynamics, neglecting the asymmetric nature of economic behavior. Furthermore, limited investigations use data extending beyond 2020, a period marked by significant structural reforms and shifts in global economic integration.

This study aims to fill these gaps by providing a comprehensive and updated examination of the impact of economic growth, globalization, and trade openness on CO_2 emissions in Saudi Arabia using annual data from 1970 to 2022. By doing so, it contributes to both the environmental economics literature and the policy debate on sustainable development within resource-dependent economies.

The primary objectives of this study are threefold. First, it seeks to test the validity of the Environmental Kuznets Curve hypothesis in Saudi Arabia using a robust nonlinear econometric framework. Second, it aims to assess the asymmetric effects of economic globalization and trade openness on CO_2 emissions, distinguishing between positive and negative shocks. Third, it evaluates the long-run and short-run dynamics to provide policymakers with comprehensive insights into how different economic forces shape environmental quality over time.

The study offers several key contributions to literature. (i) Methodologically, the use of the NARDL approach represents a significant improvement over conventional linear models by capturing nonlinearities and asymmetries that are essential for accurate environmental analysis. (ii) Empirically, the study utilizes an extensive historical dataset spanning more than five decades, making it one of the most comprehensive examinations of the globalization–emissions nexus in Saudi Arabia. (iii) Conceptually, it integrates economic growth, globalization, and trade openness into a unified nonlinear framework, allowing for a deeper understanding of their combined effects on environmental sustainability. (iv) From a policy perspective, the findings provide evidence-based recommendations that support Saudi Arabia's Vision 2030 objectives by highlighting the importance of stable global integration and sustainable economic diversification. Overall, this study contributes to the growing recognition that environmental policymaking in highly globalized and resource-rich economies requires attention not only to economic growth patterns but also to the direction, stability, and composition of globalization and trade flows. By addressing these issues through an advanced nonlinear modelling approach, the research provides a solid foundation for designing more resilient and environmentally sustainable development strategies in Saudi Arabia.

The remainder of this paper is structured as follows. Section 2 reviews the existing literature on the relationship between economic globalization and CO_2 emissions. Section 3 describes the data and outlines the methodological framework. Section 4 presents and discusses the empirical findings. Finally, Section 5 concludes the study and offers key policy implications.

2. LITERATURE REVIEW

2.1. Globalization- Carbon Emissions nexus: Theoretical Insights

The role of economic globalization in influencing CO_2 emissions has sparked considerable debate among researchers and policymakers. The environmental impact of economic globalization remains a subject of theoretical uncertainty. Economic globalization encompasses various factors, including the movement of goods and services, diverse trade partnerships, foreign direct investment (FDI), international debt, income transfers, and reserves (Gygli et al., 2019). It essentially involves the unrestricted flow of foreign capital, goods, and services. The ongoing discussion about globalization's effect on the environment, particularly CO_2 emissions, revolves around understanding how trade and investment flows influence environmental quality (Gallagher, 2009). Given that FDI and trade are pivotal aspects of economic globalization, numerous hypotheses and theoretical frameworks have been developed by scholars to examine the impact of globalization on CO_2 emissions.

Following the influential work of Grossman and Krueger (1991) on the environmental implications of North American Free Trade Agreement (NAFTA), contemporary research commonly distinguishes three primary channels through which globalization affects the environment: scale effects, composition effects, and technique effects. (i) The scale effect refers to the environmental pressures that accompany economic expansion. Increased production fueled by trade openness typically leads to greater resource utilization—labor, capital, and natural resources—ultimately resulting in higher levels of environmental degradation (Antweiler et al., 2001). In this view, as economies grow due to expanded trade, pollution initially rises alongside intensified economic activities. (ii) The composition effect captures how trade liberalization reshapes a country's industrial structure. As nations specialize based on their comparative advantage, some industries expand while others contract. The environmental impact depends on whether expanding sectors are cleaner or dirtier relative to shrinking ones (Cole, 2004). If specialization favors cleaner industries, globalization can contribute to environmental improvements; if it favors more pollution-intensive sectors, the opposite outcome may occur. (iii) The technique effect represents improvements in production processes that lead to cleaner outputs. Trade openness facilitates the diffusion of green technologies and environmental goods, lowering their costs and encouraging their adoption (Dean et al., 2009). Additionally, rising incomes associated with trade may shift consumer preferences towards environmentally sustainable goods and services, creating further incentives for greener production methods. However, the positive potential of the technique effect critically depends on the efficiency of technology transfer mechanisms and the strength of domestic environmental policies.

2.2. Globalization- Carbon Emissions Nexus: Empirical Evidence

Previous empirical studies, in line with theoretical debates, have employed various econometric methods and globalization indicators to explore the relationship between globalization and CO_2 emissions, resulting in three distinct strands of findings. The first strand supports the pollution-haven hypothesis. For example, Akadiri et al. (2019b), using random and fixed effects estimators, found that globalization leads to higher CO_2 emissions in 15 countries. Similarly, Abdouli et al. (2018), utilizing OLS, generalized method of moments (GMM), and fixed/random effects estimators, demonstrated that foreign direct investment (FDI) leads to increased CO_2 emissions in BRICTS countries. Shahbaz et al. (2018a) also found that globalization contributes to higher emissions in 25 developed countries in Asia, North America, Western Europe and Oceania. Further, You and Lv (2018), using a spatial econometric approach, showed that economic globalization directly raises CO_2 emissions in 83 countries.

Acheampong et al. (2019), employing random and fixed effects estimators, revealed that FDI increases CO_2 emissions, while trade openness mitigates CO_2 emissions in 46 sub-Saharan African nations. Meng et al. (2018) also found that trade openness generates higher CO_2 emissions in 101 countries. Akadiri et al. (2019a), using the ARDL approach, found that globalization leads to higher CO_2 emissions in the short run but lowers them in the long run in Italy. Similarly, Khan and Ullah (2019) indicated that economic, political, and social globalization contributes to higher CO_2 emissions in Pakistan. In South Africa, Kohler (2013) applied the ARDL estimation approach and concluded that trade openness results in higher CO_2 emissions. Likewise, Shahbaz et al. (2018b) found that globalization raises CO_2 emissions in Japan. In India, Shahbaz et al. (2016a) reported a similar finding, showing that globalization exacerbates CO_2 emissions. Koengkan et al. (2020) examined the asymmetric effects of economic, social, and political globalization on CO_2 emissions in 18 Latin American and Caribbean countries and found that globalization, both positively and negatively, worsens CO_2 emissions. Lastly, Usman et al. (2020), using the ARDL approach, revealed that globalization increases CO_2 emissions in the USA in both the short and long run.

The second strand of empirical studies supports the pollution-halo hypothesis. For example, Lee and Min (2014) found that globalization reduces CO_2 emissions across a panel of 225 countries. Liu et al. (2017) also revealed that FDI leads to lower CO_2 emissions in 112 Chinese cities. Similarly, Lv and Xu (2018) demonstrated that FDI reduces CO_2 emissions in 15 emerging economies. Rahman (2020), using FMOLS and DOLS methods, showed that globalization lowers CO_2 emissions, while Shahbaz et al. (2016b) observed that globalization reduces CO_2 emissions in a panel of 19 African countries. In a similar vein, Chen et al. (2019) found that globalization reduces CO_2 emissions in 16

Central and Eastern African countries. Zaidi et al. (2019) also concluded that globalization reduces CO_2 emissions in the Asia Pacific Economic Cooperation (APEC) countries. For the case of five South-East Asian countries, Zhu et al. (2016) suggested that FDI leads to a reduction in CO_2 emissions. Acheampong (2018), using the system GMM approach, found that trade openness helps mitigate CO_2 emissions in regions including Asia-Pacific, MENA and sub-Saharan Africa regions. Using FMOLS method, Al-Mulali et al. (2015) indicated that trade openness reduces CO_2 emissions in 23 European countries. In a separate study, Hasanov et al. (2018) reported that exports reduce both trade-based and consumption-based CO_2 emissions, while imports contribute to increased trade-based and consumption-based CO_2 emissions. In South Africa, Shahbaz et al. (2013) found that trade openness reduces CO_2 emissions, and Zhang and Zhou (2016) found that FDI reduces CO_2 emissions across Western, Eastern, and Central China. Furthermore, Adebayo and Acheampong (2022) revealed a consistent positive feedback relationship between globalization and carbon emissions in Australia.

The third strand of the literature suggests that globalization does not significantly impact CO_2 emissions. For instance, Haseeb et al. (2018) applied dynamic seemingly unrelated regression and the Dumitrescu-Hurlin Causality approach and found that globalization does not affect CO_2 emissions in BRICS countries. Similarly, Boutabba (2014) concluded that trade openness has no effect on CO_2 emissions in India. Dogan and Turkekul (2016), using the ARDL approach, also found no significant relationship between trade and CO_2 emissions in the USA. Xu et al. (2018) discovered that globalization does not influence CO_2 emissions in Saudi Arabia. Lastly, Uzuner et al. (2020), in their examination of the asymmetric effect of globalization on CO_2 emissions in Turkey, found that both positive and negative changes in globalization have no significant impact on CO_2 emissions.

From a critical standpoint, the use of trade openness or foreign direct investment (FDI) as sole indicators of globalization captures only narrow dimensions, trade and investment intensity, potentially leading to mixed and inconclusive empirical findings. Such inconsistencies may mislead policymakers attempting to design effective environmental strategies. To overcome these limitations, this study employs the comprehensive globalization index developed by Dreher (2006), which incorporates economic, political, and social dimensions of globalization. The next section discusses the methodology adopted in this study.

3. DATA AND METHODOLOGY

3.1. Data

In the current study, we utilize annual data from 1970 to 2022 to achieve the research objectives. The variables considered in this analysis include CO_2 emissions, economic globalization, economic growth, and trade. The time range is constrained by the availability of data for these variables. The variables used in this study include CO_2 emissions per capita (denoted as CO_2), GDP per capita (denoted as GDP), trade (denoted as TR), and the economic globalization Index (denoted as ECOG). The Economic Globalization Index is sourced from the Swiss Federal Institute of Technology (Dreher, 2006), while the data for the other variables are obtained from the World Bank database. Table 1 presents the basic descriptive statistics for these variables, including the mean, standard deviation, and the minimum and maximum values.

Table 1 presents the descriptive statistics for the key variables used in the analysis: CO_2 emissions ($lnCO_2$), economic globalization (lnECOG), economic growth (lnGDP), squared economic growth ($lnGDP^2$), and trade openness (lnTR), over 54 annual observations.

The mean values of the variables indicate relatively stable long-term trends. CO_2 emissions ($lnCO_2$) average around 0.076, suggesting moderate annual variation in per capita emissions over the sample period. Economic globalization (lnECOG) displays a mean of 4.12 with a narrow standard deviation (0.063), reflecting gradual and consistent integration of the Saudi economy into global markets. GDP (lnGDP) shows a comparatively high mean of 10.25, consistent with Saudi Arabia's status as a high-income, resource-rich economy. As expected, the squared GDP term ($lnGDP^2$) exhibits a much larger scale, with a mean of 105.24, capturing the nonlinear growth–environment relationship relevant to the EKC hypothesis. Trade openness (lnTR) has a mean of 4.30 with moderate dispersion.The data ranges reveal substantial variability. CO_2 emissions record the widest range (from −0.60 to 0.54), indicating periods of both contraction and expansion in emissions, likely reflecting fluctuations in energy demand and structural economic changes. GDP and GDP^2 also show wide ranges, capturing significant long-term macroeconomic dynamics.

The distributional properties suggest departures from normality for some variables. Skewness statistics indicate that $lnCO_2$ and lnECOG exhibit mild negative skewness, whereas lnGDP and $lnGDP^2$ are positively skewed, implying longer right tails typically associated with income growth. Kurtosis values close to 3 indicate near-normal distributions for most variables, except $lnCO_2$, which

Table 1: Descriptive statistics

Variables	$lnCO_2$	lnECOG	lnGDP	$LnGDP^2$	lnTR
Mean	0.076447	4.126744	10.25254	105.2416	4.302576
Median	0.180438	4.139958	10.07576	101.5210	4.278516
Maximum	0.546127	4.274790	10.98337	120.6345	4.792641
Minimum	−0.603151	3.964728	9.887295	97.75860	3.906276
Standard Deviation	0.347825	0.063106	0.359713	7.514566	0.175627
Skewness	−0.350501	−0.437859	1.077994	1.098338	0.219018
Kurtosis	1.645292	3.566931	2.560924	2.600051	2.720984
Jarque-Bera	5.234934	2.448659	10.89241	11.21702	0.606880
Observations	53	53	53	53	53

has a kurtosis of 1.64, pointing to a flatter distribution. Jarque–Bera statistics provide further evidence regarding normality. For ln CO_2, lnGDP, and lnGDP², the Jarque–Bera values are statistically significant at conventional levels, suggesting rejection of the null hypothesis of normality. However, lnECOG and lnTR do not show significant departures from normality. These results justify the use of econometric techniques, such as NARDL, that do not require strict normality assumptions and can handle nonlinear structures.

3.2. Methodology

This study investigates the asymmetric impact of globalization, economic growth, and trade openness on CO_2 emissions and additionally tests the validity of the Environmental Kuznets Curve (EKC) within the context of the Saudi Arabian economy. Accordingly, the empirical analysis is based on the following equation:

$$CO_2 = F(DP, GDP^2, TR, ECOG) \quad (1)$$

The linear specification of the above equation is presented as follows:

$$lnCO2_t = \alpha_0 + \alpha_1 lnGDP_t + \alpha_2 lnGDP_t^2 + \alpha_3 lnTR_t + \alpha_4 lnECOG_t + \varepsilon_t \quad (2)$$

In econometric analysis, several modeling techniques, such as the Autoregressive Distributed Lag (ARDL) framework, are widely applied to investigate both short- and long-run relationships among variables. Multiple regression analysis is also commonly used when dealing with several independent variables (Hussain et al., 2018; Butler et al., 2020). These approaches help capture linear and nonlinear dynamics, with the ARDL model standing out for its capacity to account for asymmetries in the behavior of economic data. While standard linear regression is effective for identifying basic linear associations, it does not address potential nonlinear or asymmetric patterns. Building on earlier conceptual contributions by Szczepańska-Woszczyna and Kurowska-Pysz (2016), Shin et al. (2014) extended the traditional ARDL framework by developing the Nonlinear ARDL (NARDL) approach. This advanced methodology is particularly suited for capturing both short-term adjustments and asymmetric long-run effects, making it well aligned with the objective of this study, which focuses on identifying differential impacts of independent variables on the dependent variable.

$$CO2_t = \beta_0 + \beta_1 GDP_t + \beta_2 GDP_t^2 + \beta_3 TR_t^+ + \beta_4 TR_t^- + \beta_5 ECOG_t^+ + \beta_6 ECOG_t^- + \mu_t \quad (3)$$

In this equation, the environmental degradation is represented by CO_2 emissions, while TR denotes trade openness and ECOG represents economic globalization. GDP and GDP² denote the gross domestic product and its squared term, respectively. The co-integrating vectors are estimated as β_1 through β_6. Additionally, the equation accounts for the asymmetric (positive and negative) effects of the key variables, such as, trade openness and gross domestic product on the CO_2 emissions.

Building upon Equation (2) and following the specification by Shin et al. (2014), the extended asymmetric ARDL model can be expressed as follows:

$$\begin{aligned}\Delta CO2_t &= \alpha_0 + \alpha_1 CO2_{t-1} + \alpha_2 GDP_{t-1} + \alpha_3 GDP_{t-1}^2 + \alpha_4 TR_{t-1}^+ \\ &+ \alpha_5 TR_{t-1}^- + \alpha_6 ECOG_{t-1}^+ + \alpha_7 ECOG_{t-1}^- + \\ &\sum_{i=1}^{m} \gamma_{1i} \Delta CO2_{t-i} + \sum_{i=0}^{m} \gamma_{2i} \Delta GDP_{t-i} \\ &+ \sum_{i=0}^{m} \gamma_{3i} \Delta GDP_{t-i}^2 + \sum_{i=0}^{n} \gamma_{4i} \Delta TR_{t-i}^+ \\ &+ \sum_{i=0}^{p} \gamma_{5i} \Delta TR_{t-i}^- + \sum_{i=0}^{q} \gamma_{6i} \Delta ECOG_{t-i}^+ \\ &+ \sum_{i=0}^{r} \gamma_{7i} \Delta ECOG_{t-i}^- + \mu_t \end{aligned} \quad (14)$$

Equation (4) incorporates multiple lag orders, represented by *m*, *n*, *p*, *q*, and *r*. The asymmetric effects of trade openness and economic globalization shocks, whether positive or negative on the CO_2 emissions are captured by the coefficients α_4, α_5, α_6, and α_7. Additionally, short-run dynamics are reflected through the coefficients γ_{4i}, γ_{5i}, γ_{6i}, and γ_{7i}. Notably, the NARDL approach enables the investigation of both short-run adjustments and potential nonlinear long-run relationships among the variables.

The asymmetric ARDL model process involves several key steps. Initially, stationarity tests such as the Augmented Dickey–Fuller (ADF) and Phillips–Perron (PP) are conducted to examine the order of integration of the variables. Although these tests are not a strict requirement for ARDL application, it is important to confirm that none of the variables are integrated at order I(2), as ARDL is valid for I(0), I(1), or a combination of both. This view is supported by such as Kurowska-Pysz et al. (2018) and Hussain et al. (2019), who argue that the presence of I(2) series is the only limitation to using ARDL. Therefore, verifying the stationarity of the series ensures the robustness of subsequent findings. In the second step, model selection is guided by the Schwarz Information Criterion (SIC) and the general-to-specific approach, as proposed by Katrakilidis and Trachanas (2012). Finally, the presence of a long-run relationship among the variables is tested using the bounds testing approach. Upon confirmation of cointegration, the asymmetric ARDL model is estimated, allowing for the derivation of asymmetric cumulative dynamic multipliers in response to percentage changes in the variables TR_{t-1}^+, TR_{t-1}^-, $ECOG_{t-1}^+$ and $ECOG_{t-1}^-$, as illustrated below.

$$m_h^+ = \sum_{j=0}^{h} \frac{\partial CO2_{t+j}}{\partial TR_t^+}; m_h^- = \sum_{j=0}^{h} \frac{\partial CO2_{t+j}}{\partial TR_t^-} \quad (5)$$

$$m_h^+ = \sum_{j=0}^{h} \frac{\partial CO2_{t+j}}{\partial ECOG_t^+}; m_h^- = \sum_{j=0}^{h} \frac{\partial CO2_{t+j}}{\partial ECOG_t^-} \quad (6)$$

4. RESULTS

Before estimating the empirical models, the stationarity properties of the variables were assessed. As with the conventional ARDL framework, the nonlinear ARDL (NARDL) approach developed by

Shin et al. (2014) requires that the variables be integrated of order zero [I(0)], order one [I(1)], or a combination of both in order to validly test for cointegration. To determine the integration order, the Augmented Dickey–Fuller (ADF) and Phillips–Perron (PP) tests were applied. As reported in Table 2, the results indicate that ECOG and $ECOG^2$ are stationary at level, whereas CO_2, GDP, and TR are non-stationary in their level forms. However, all variables become stationary after first differencing, confirming that they are integrated of order one [I(1)].

Furthermore, this study employed a structural break unit root test, specifically the Zivot and Andrews (1992) test, which accounts for potential structural breaks as initially suggested by Perron (1989). Considering the possibility of structural changes in the time series data, the Zivot and Andrews test was applied, and the results presented in Table 3 indicate that all variables are stationary at the first difference, i.e., integrated of order one [I(1)], except ECOG and $ECOG^2$ are stationary at level. Thus, it is confirmed that the ARDL approach is appropriate for the current analysis, as none of the variables are integrated of order two [I(2)].

Moreover, Abdelli et al. (2024) emphasized that identifying long-term relationships depends critically on selecting the optimal lag length. Similarly, Abid et al. (2022) cautioned that using too many or too few lags could compromise the robustness of the model and result in biased estimations. In light of this, the current study adopts a lag length of one, as determined by the Schwarz Information Criterion (SIC). The results of the bounds testing and nonlinear estimations are presented in Table 2. The F-statistic exceeds the critical values, confirming the existence of a nonlinear long-run relationship among CO_2 emissions, GDP, economic globalization and trade openness in KSA. Based on these findings, the study proceeds to estimate the nonlinear ARDL coefficients.

After establishing the presence of significant nonlinear relationships among CO_2 emissions, GDP, GDP^2, economic globalization, and trade openness, the analysis proceeds to estimate the long-run coefficients, as reported in Table 4. The empirical analysis provides strong evidence of nonlinear and asymmetric relationships between CO_2 emissions, and the key determinants examined in this study—namely economic globalization (ECOG), trade openness (TR), and economic growth (GDP and GDP^2). The use of the NARDL framework reveals a rich set of dynamic interactions that would not be visible using traditional linear models. These findings carry important implications for understanding the environmental consequences of globalization and economic activity in Saudi Arabia, particularly in the context of its ongoing transformation under Vision 2030 and its commitment to achieving net-zero emissions.

A central finding concerns the relationship between income and environmental quality. The significant positive coefficient of GDP and negative coefficient of GDP^2 in the long run confirm the presence of an Environmental Kuznets Curve (EKC) pattern. This inverted-U relationship suggests that while economic expansion initially increases CO_2 emissions, the effect diminishes and eventually reverses as income rises. The computed turning point indicates that KSA is now positioned on the downward-sloping segment of the curve. Solving for the turning point of the inverted-U ($\ln GDP^* = -\beta_1/2\beta_2$) gives a log-income around 10.033, which corresponds to a GDP per capita on the order of ≈ 22.783×10^3 (in the same units used in the dataset). In practical terms, this implies that the country has reached an income level at which technological progress, cleaner production processes, structural changes toward service-oriented sectors, and more stringent environmental policies begin to offset the pollution impacts associated with growth. These results are consistent with prior empirical studies such as Suki et al. (2020) who find evidence of the EKC for Malaysia. However, our results are inconsistent with the results of Pata and Caglar (2021) who found that that the EKC hypothesis does not hold for China.

The asymmetric effects of economic globalization constitute another notable outcome. Both positive and negative shocks in ECOG lead to increases in CO_2 emissions, yet negative shocks exert a substantially larger impact. Specifically, a negative shock

Table 2: ARDL bounds test

Models	F- Statistics	Critical value (%)	Lower Bound Value	Upper bound value
F (CO_2/GDP, GDP^2, $ECOG^+$, $ECOG^-$, TR^+, TR^-)	65.625	1	3.56	5.27
		5	2.91	4.132
		10	2.37	3.52

Calculated F-statistics: 65.625 (Significant at 0.05 of the marginal value). Critical values are quoted from Pesaran et al., (2001)

Table 3: Results from the unit root tests

Statistic	Level				
	CO_2	ECOG	GDP^2	GDP	TR
ADF	−0.965	−2.756*	−0.770	−0.774	−2.521
PP	−0.901	−2.716*	−1.093	−1.088	−2.398
ZA test value	−0.806	−3.625**	−1.707	−2.652	−2.138
ZA test break	2000	2014	2004	2010	1993
First difference					
ADF	−9.589***	−8.614***	−4.609***	−4.624***	−9.639***
PP	−8.021***	−8.580***	−4.493***	−4.511***	−9.688***
ZA test value	−8.381**	−6.025***	−5.972***	−6.374***	−6.456***
ZA test break	2009	2015	2010.	2009	2006

Significant levels of 1%, and 10% are represented by ***, and *, respectively

Table 4: Asymmetric NARDL results

Variables	Panel A: Long-run coefficients		Variables	Panel B: Short-run coefficients	
	Coeff.	P-value		Coeff	P-value
GDP	0.215***	0.000	GDP^+	0.218***	0.000
GDP^2	−0.021**	0.041	GDP^{2+}	−0.136*	0.071
$ECLO^+$	0.102**	0.025	$ECLO^+$	0.191*	0.086
$ECLO^-$	0.214***	0.000	ECLO	0.206**	0.047
TR^+	0.125*	0.051	TR^+	0.178**	0.039
TR^-	0.218**	0.033	TR^-	0.368*	0.065
Constant	3.581***	0.000	ECT(−1)	−0.501***	0.000
Panel C: Test of asymmetry					
W_{LR}^{ECLO}	35.647**		W_{SR}^{ECLO}	6.542***	
W_{LR}^{TR}	42.658**		W_{SR}^{TR}	18.069**	
Panel D: Diagnostic Tests					
Adjusted R^2	0.875				
R^2	0.912				
Normality test	0.301				
LM test	8.954				
Heteroscedasticity test	1.155				
Ramsey RESET test	0.110				
CUSUM	Stable				
CUSUM SQ	Stable				

in economic globalization raises emissions by 0.214%, compared to a 0.102% rise associated with a positive shock. This asymmetric pattern implies that globalization is not environmentally neutral: reductions in global integration are particularly harmful. While increases in globalization may expand economic activity and boost energy use, largely through scale effects, they also facilitate the diffusion of cleaner technologies, managerial expertise, stricter environmental standards, and green financial flows. Conversely, decreases in globalization disrupt these beneficial channels, intensifying reliance on domestic, often more pollution-intensive, production processes. These findings align with the arguments of Chen and Lee (2020), and Khurshid et al. (2024) who demonstrate that globalization can reduce emissions in the long term through technological spillovers but may worsen environmental conditions in countries facing declining openness or economic isolation.

The results for trade openness (TR) also demonstrate a clear pattern of asymmetry. Both positive and negative trade shocks increase emissions, but negative shocks again exert a larger effect. The long-run coefficients show a 0.125% increase in CO_2 emissions for a negative trade shock versus 0.218% for a positive shock, indicating that disruptions in trade inflows or outflows can be particularly damaging in the short run. This may occur when firms switch from imported, often cleaner intermediate goods to domestic substitutes that are more carbon intensive. Trade interruptions may also destabilize global value chains, pushing production into less efficient local facilities. These findings echo those of Zhou et al. (2025) and Bacchetta et al. (2025), who show that trade liberalization encourages technology diffusion and cleaner production, while trade restrictions undermine environmental performance.

In general, the asymmetry detected in ECOG and TR suggests that globalization-related variables exhibit a high degree of environmental sensitivity to negative shocks in KSA. This resonates with recent studies on the Gulf economies, such as those by Waheed et al. (2021) and Ebaidalla and Abusin (2022), who argue that the GCC region is structurally dependent on imports for high-tech and energy efficient inputs, making negative trade or globalization shocks disproportionately harmful. The results support the conclusion that the environmental consequences of globalization in Saudi Arabia depend not only on the degree of openness but also on its stability and direction.

5. CONCLUSION AND POLICY RECOMMENDATIONS

5.1. Conclusion

This study investigates the presence of the Environmental Kuznets Curve (EKC) in Saudi Arabia by examining the effects of economic growth, its squared term, and economic globalization on CO_2 emissions, using annual data covering the period 1970–2022. This study applies the NARDL technique to capture both asymmetric short-run adjustments and nonlinear long-run relationships. The empirical results reveal strong evidence of nonlinear and asymmetric relationships among the variables, highlighting patterns that conventional linear models would fail to capture. A key finding is the confirmation of the Environmental Kuznets Curve (EKC) for the Saudi economy. The positive coefficient of GDP and the negative coefficient of GDP^2 indicate that economic expansion initially increases CO_2 emissions, but after exceeding a certain income threshold, further growth contributes to environmental improvement. These results imply that Saudi Arabia has progressed to a level of development where technological advancements, economic diversification, and cleaner modes of production begin to reduce environmental degradation.

Equally important are the asymmetrical effects of economic globalization. Both positive and negative globalization shocks increase CO_2 emissions, but declines in globalization exert a significantly larger impact. This suggests that interruptions in global integration, through reduced trade flows, weaker cross-border investment, or limited technological exchange, can severely undermine environmental quality. Trade openness displays a similar behavior, with both types of shocks contributing to higher emissions, although negative shocks again have a stronger effect. These findings indicate that instability in trade and globalization can disrupt access to cleaner technologies and environmentally efficient production inputs, pushing domestic industries toward more carbon-intensive alternatives. Together, the results emphasize that not only the level but also the direction and stability of globalization and trade flows are crucial for environmental sustainability in Saudi Arabia.

5.2. Policy Recommendations

Given these findings, several policy implications emerge. First, Saudi Arabia should continue accelerating economic diversification and technological upgrading. Since the country appears to be on the downward side of the EKC, expanding investment in less carbon-intensive sectors—such as advanced manufacturing, renewable energy, and digital technologies—can further reinforce the decline in emissions. Second, it is essential to maintain stable globalization channels. Abrupt declines in openness have considerable environmental costs; therefore, sustaining foreign investment, trade partnerships, and international cooperation remains critical for accessing advanced green technologies and efficiency-enhancing innovations.

Third, policymakers should encourage green-oriented FDI by offering targeted incentives for multinational firms investing in environmentally friendly industries. This would strengthen the technique effect of globalization and reduce reliance on emissions-intensive domestic production. Fourth, improving trade openness in environmental goods and strengthening ties to global green supply chains can help counteract the negative effects observed during trade disruptions. Facilitating imports of clean technologies and renewable-energy equipment can accelerate national decarbonization efforts.

Moreover, reinforcing environmental regulation remains vital. Stronger emissions standards, performance disclosure requirements, and carbon-pricing tools can help consolidate the EKC dynamics by steering the economy toward sustainable growth. Enhancing industrial energy-efficiency programs, especially in sectors sensitive to globalization shocks, will also reduce vulnerability to external disruptions. Finally, building economic resilience through diversified export markets and local capacity development in low-carbon technologies can mitigate the large environmental impact of negative globalization and trade shocks.

5.3. Limitations

Despite providing valuable insights, this study has several limitations. First, the analysis relies on aggregate national data, which may conceal sector-specific dynamics or regional variations within Saudi Arabia. More granular data could capture heterogeneous environmental responses across industries. Second, the NARDL model, while powerful in detecting asymmetries, does not fully address potential endogeneity issues between globalization and emissions; instrumental-variable approaches could strengthen causal interpretation. Third, the study focuses on CO_2 emissions as the sole indicator of environmental degradation, while other ecological dimensions—such as particulate emissions, ecological footprint—may reveal additional insights. Finally, globalization is captured through an aggregate index, which may mask distinct effects of its economic, political, and social components.

5.4. Directions for Future Research

Future research could address these limitations in several ways. First, studies may incorporate sector-level or regional data to analyze how different parts of the Saudi economy respond to globalization and growth shocks. Such an approach would help identify priority sectors for targeted environmental policies. Second, employing causal inference methods, such as instrumental variables, structural VAR models, or panel-based techniques, could provide stronger evidence on the direction of causality between globalization, trade, and emissions. Third, future research could explore additional environmental indicators or construct composite environmental-quality measures to capture broader ecological outcomes. Moreover, examining the separate effects of economic, social, and political globalization could offer more detailed insights into which dimension most strongly influences environmental performance. Researchers may also investigate the role of renewable energy consumption, green finance, and technological innovation as mediating channels in the globalization–emissions nexus. Finally, extending the analysis to GCC countries or conducting cross-country comparisons could help determine whether the asymmetric patterns observed in Saudi Arabia are unique to its economic structure or reflect broader regional dynamics.

6. ACKNOWLEDGEMENT

This work was funded by the Deanship of Graduate Studies and Scientific Research at Jouf University under grant No. (DGSSR-2025-03-01561).

REFERENCES

Abdelli, H., Gheraia, Z., Sekrafi, H., Abid, M. (2024), The asymmetric impact of government expenditure on economic growth: Evidence from a NARDL model. International Journal of Advanced and Applied Sciences, 11(3), 92-101.

Abdouli, M., Kamoun, O., Hamdi, B. (2018), The impact of economic growth, population density, and FDI inflows on CO_2 emissions in BRICTS countries: Does the Kuznets curve exist? Empirical Economics, 54(4), 1717-1742.

Abid, M., Gheraia, Z., Abdelli, H., Hajji, R. (2022), How does informal economy affect ecological footprint? Empirical evidence from Saudi Arabia. Sustainable Development, 5(6), 7.

Acheampong, A.O. (2018), Economic growth, CO_2 emissions and energy consumption: What causes what and where? Energy Economics, 74, 677-692.

Acheampong, A.O., Adams, S., Boateng, E. (2019), Do globalization and

renewable energy contribute to carbon emissions mitigation in Sub-Saharan Africa? Science of the Total Environment, 677, 436-446.
Adebayo, T.S., Acheampong, A.O. (2022), Modelling the globalization-CO_2 emission nexus in Australia: Evidence from quantile-on-quantile approach. Environmental Science and Pollution Research, 29(7), 9867-9882.
Akadiri, S.S., Lasisi, T.T., Uzuner, G., Akadiri, A.C. (2019), Examining the impact of globalization in the environmental Kuznets curve hypothesis: The case of tourist destination states. Environmental Science and Pollution Research, 26(12), 12605-12615.
Al-Mulali, U., Ozturk, I., Lean, H.H. (2015), The influence of economic growth, urbanization, trade openness, financial development, and renewable energy on pollution in Europe. Natural Hazards, 79(1), 621-644.
Antweiler, W., Copeland, B.R., Taylor, M.S. (2001), Is free trade good for the environment? American Economic Review, 91(4), 877-908. Antweiler, W., Copeland, B.R., Taylor, M.S. (2001), Is free trade good for the environment? American Economic Review, 91(4), 877-908.
Bacchetta, M., Bekkers, E., Solleder, J.M., Tresa, E. (2025), The potential impact of environmental goods trade liberalization on trade and emissions. Energy Economics, 141, 108051.
Boutabba, M.A. (2014), The impact of financial development, income, energy and trade on carbon emissions: Evidence from the Indian economy. Economic Modelling, 40, 33-41.
Buşăn, G. (2012), Contradictory nature of the relationship between economic growth, economic development and the natural environment. Anale. Seria Ştiinţe Economice Timişoara, 18(Suppl), 337-341.
Butler, A.E., Battista, K., Leatherdale, S.T., Meyer, S.B., Elliott, S.J., Majowicz, S.E. (2020), Environmental factors of youth milk and milk alternative consumption. American Journal of Health Behavior, 44(5), 666-680.
Chen, N., Sun, Z., Xu, Z., Xu, J. (2025), A review of international trade impacts on sustainable development. Marine Development, 3(1), 1-16.
Chen, S., Saud, S., Bano, S., Haseeb, A. (2019), The nexus between financial development, globalization, and environmental degradation: Fresh evidence from Central and Eastern European Countries. Environmental Science and Pollution Research, 26(24), 24733-24747.
Chen, Y., Lee, C.C. (2020), Does technological innovation reduce CO_2 emissions? Cross-country evidence. Journal of Cleaner Production, 263, 121550.
Cole, M.A. (2004), Trade, the pollution haven hypothesis and the environmental kuznets curve: Examining the linkages. Ecological Economics, 48(1), 71-81.
Dean, J.M., Lovely, M.E., Wang, H. (2009), Are Foreign investors attracted to weak environmental regulations? Evaluating the evidence from China. Journal of Development Economics, 90(1), 1-13.
Dogan, E., Turkekul, B. (2016), CO_2 emissions, real output, energy consumption, trade, urbanization and financial development: Testing the EKC hypothesis for the USA. Environmental Science and Pollution Research, 23(2), 1203-1213.
Dreher, A. (2006), Does globalization affect growth? Evidence from a new index of globalization. Applied Economics, 38(10), 1091-1110.
Ebaidalla, E.M., Abusin, S. (2022), The effect of ICT on CO_2 emissions in the GCC countries: Does globalization matter? International Journal of Energy Economics and Policy, 12(6), 56-66.
Gallagher, K.P. (2009), Economic globalization and the environment. Annual Review of Environment and Resources, 34(1), 279-304.
Grossman, G.M., Krueger, A.B. (1991), Environmental Impacts of a North American Free Trade Agreement. [NBER Working Paper No. 3914].
Grossman, G.M., Krueger, A.B. (1995), Economic growth and the environment. The Quarterly Journal of Economics, 110(2), 353-377.
Gygli, S., Haelg, F., Potrafke, N., Sturm, J.E. (2019), The KOF globalisation index-revisited. The Review of International Organizations, 14, 543-574.
Hasanov, F.J., Liddle, B., Mikayilov, J.I. (2018), The impact of international trade on CO_2 emissions in oil exporting countries: Territory vs consumption emissions accounting. Energy Economics, 74, 343-350.
Haseeb, A., Xia, E., Saud, S., Ahmad, A., Khurshid, H. (2019), Does information and communication technologies improve environmental quality in the era of globalization? An empirical analysis. Environmental Science and Pollution Research, 26, 8594-8608.
Hussain, H.I., Abidin, I.S.Z., Ali, A., Kamarudin, F. (2018), Debt maturity and family related directors: Evidence from a developing market. Polish Journal of Management Studies, 18, 118-134.Hussain, H.I., Ali, A., Thaker, H.M.T., Ali, M. (2019), Firm performance and family related directors: Empirical evidence from an emerging market. Contemporary Economics, 13(2), 187-204.
Hussain, I., Hussain, J., Ali Khan, A., Khan, Y. (2019), An analysis of the asymmetric impact of exchange rate changes on GDP in Pakistan: Application of non-linear ARDL. Economic Research-Ekonomska Istraživanja, 32(1), 3094-3111.
IPCC. (2024), Sixty-First Session of the IPCC: Decisions Adopted by the Panel. Geneva: IPCC.
Katrakilidis, C., Trachanas, E. (2012), What drives housing price dynamics in Greece: New evidence from asymmetric ARDL cointegration. Economic Modelling, 29(4), 1064-1069.
Khan, D., Ullah, A. (2019), Testing the relationship between globalization and carbon dioxide emissions in Pakistan: Does environmental Kuznets curve exist? Environmental Science and Pollution Research, 26(15), 15194-15208.
Khurshid, N., Fiaz, A., Ali, K., Rashid, M. (2024), Unleashing the effect of energy efficiency, knowledge spillover, and globalization on environmental sustainability: An VECM analysis for policy empirics. Environment Development and Sustainability, 26(3), 6027-6049.
Koengkan, M., Poveda, Y.E., Fuinhas, J.A. (2020), Globalisation as a motor of renewable energy development in Latin America countries. GeoJournal, 85(6), 1591-1602.
Kohler, M. (2013), CO_2 emissions, energy consumption, income and foreign trade: A South African perspective. Energy Policy, 63, 1042-1050.
Kumar, P., Wu, H. (2025), Evaluating the dual impact of economic drivers on environmental degradation in developing countries: A study of technology innovation, foreign direct investment, and trade openness. Journal of Energy and Environmental Policy Options, 8(1), 24-36.
Kurowska-Pysz, J., Wróblewski, Ł., Szczepańska-Woszczyna, K. (2018), Identification and Assessment of Barriers to the Development of Cross-Border Cooperation. In: Innovation Management and Education Excellence through Vision 2020, Proceedings of the 31st International Business Information Management Association Conference, Milan, Italy, 25-26April 2018. : King of Prussia, PA, USA: International Business Information Management Association, p3317-3327.
Lee, K.H., Min, B. (2014), Globalization and carbon constrained global economy: A fad or a trend? Journal of Asia Pacific Business, 15(2), 105-121.
Liu, Y., Hao, Y., Gao, Y. (2017), The environmental consequences of domestic and foreign investment: Evidence from China. Energy Policy, 108, 271-280.
Lv, Z., Xu, T. (2019), Trade openness, urbanization and CO_2 emissions: Dynamic panel data analysis of middle-income countries. The Journal of International Trade Economic Development, 28(3), 317-330.
Managi, S., Hibiki, A., Tsurumi, T. (2009), Does trade openness improve

environmental quality? Journal of Environmental Economics and Management, 58(3), 346-363.

Meng, J., Mi, Z., Guan, D., Li, J., Tao, S., Li, Y., Feng, K., Liu, J., Wang, X., Zhang, Q., Davis, S.J. (2018), The rise of South-South trade and its effect on global CO_2 emissions. Nature Communications, 9(1), 1871.

Nsair, R., Alzubi, A.B. (2025), Globalization, financial risk, and environmental degradation in China: The role of human capital and renewable energy use. Sustainability, 17(15), 6810.

Odei, S.A., Dunyo, S.K., Anderson, H.J. (2025), Research and development, economic growth, CO_2 emissions and environmental Kuznets curve. Sustainable Futures, 9, 100541.

Pata, U.K., Caglar, A.E. (2021), Investigating the EKC hypothesis with renewable energy consumption, human capital, globalization and trade openness for China: Evidence from augmented ARDL approach with a structural break. Energy, 216, 119220.

Perron, P. (1989), The great crash, the oil price shock, and the unit root hypothesis. The Econometric Society, 57, 1361-1401.

Rahman, M.M. (2020), Environmental degradation: The role of electricity consumption, economic growth and globalisation. Journal of Environmental Management, 253, 109742.

Rees, W.E. (2003), Economic development and environmental protection: An ecological economics perspective. Environmental Monitoring and Assessment, 86(1), 29-45.

Saint Akadiri, S., Alkawfi, M.M., Uğural, S., Akadiri, A.C. (2019), Towards achieving environmental sustainability target in Italy. The role of energy, real income and globalization. Science of the Total Environment, 671, 1293-1301.

Shahbaz, M., Mallick, H., Mahalik, M.K., Loganathan, N. (2016a), Does globalization impede environmental quality in India? Ecological Indicators, 52, 379-393.

Shahbaz, M., Shahzad, S.J.H., Mahalik, M.K. (2018b), Is globalization detrimental to CO_2 emissions in Japan? New threshold analysis. Environmental Modeling Assessment, 23(5), 557-568.

Shahbaz, M., Shahzad, S.J.H., Mahalik, M.K., Hammoudeh, S. (2018a), Does globalisation worsen environmental quality in developed economies? Environmental Modeling Assessment, 23(2), 141-156.

Shahbaz, M., Solarin, S.A., Ozturk, I. (2016b), Environmental Kuznets curve hypothesis and the role of globalization in selected African countries. Ecological Indicators, 67, 623-636.

Shahbaz, M., Tiwari, A.K., Nasir, M. (2013), The effects of financial development, economic growth, coal consumption and trade openness on CO_2 emissions in South Africa. Energy Policy, 61, 1452-1459.

Shin, Y., Yu, B., Greenwood-Nimmo, M. (2014), Modelling asymmetric cointegration and dynamic multipliers in a nonlinear ARDL framework. In: Festschrift in Honor of Peter Schmidt: Econometric Methods and Applications. Berlin: Springer, p281-314.

Suki, N.M., Sharif, A., Afshan, S., Suki, N.M. (2020), Revisiting the environmental Kuznets curve in Malaysia: The role of globalization in sustainable environment. Journal of Cleaner Production, 264, 121669.

Szczepańska-Woszczyna, K., Kurowska-Pysz, J. (2016), Sustainable business development through leadership in SMEs. Ekonomia i Zarządzanie, 8(3), 57-69.

Usman, O., Akadiri, S.S., Adeshola, I. (2020), Role of renewable energy and globalization on ecological footprint in the USA: Implications for environmental sustainability. Environmental Science and Pollution Research, 27(24), 30681-30693.

Uzuner, G., Akadiri, S.S., Lasisi, T.T. (2020), The asymmetric relationship between globalization, tourism, CO_2 emissions, and economic growth in Turkey: Implications for environmental policy making. Environmental Science and Pollution Research, 27(26), 32742-32753.

Waheed, R., Sarwar, S., Mighri, Z. (2021), Role of high technology exports for energy efficiency: Empirical evidence in the context of Gulf Cooperation Council countries. Energy Environment, 32(5), 803-819.

Xu, Z., Baloch, M.A., Danish, K., Meng, F., Zhang, J., Mahmood, Z. (2018), Nexus between financial development and CO_2 emissions in Saudi Arabia: Analyzing the role of globalization. Environmental Science and Pollution Research, 25(28), 28378-28390.

You, W., Lv, Z. (2018), Spillover effects of economic globalization on CO_2 emissions: A spatial panel approach. Energy Economics, 73, 248-257.Zaidi, S.A.H., Zafar, M.W., Shahbaz, M., Hou, F. (2019), Dynamic linkages between globalization, financial development and carbon emissions: Evidence from Asia pacific economic cooperation countries. Journal of Cleaner Production, 228, 533-543.

Zhang, C., Zhou, X. (2016), Does foreign direct investment lead to lower CO_2 emissions? Evidence from a regional analysis in China. Renewable and Sustainable Energy Reviews, 58, 943-951.

Zhou, J., Kafeel, K., Khan, S., Zhang, S., Suplata, M. (2025a), Will reducing the service trade barrier improve environmental performance in OECD countries?. Environment, Development and Sustainability, 1-28.

Zhou, Y., Zhang, Z., Lin, B. (2025b), The impact of economic growth targets on environmental pollution: A study from Chinese cities. Growth and Change, 56(1), e70014.

Zhu, H., Duan, L., Guo, Y., Yu, K. (2016), The effects of FDI, economic growth and energy consumption on carbon emissions in ASEAN-5: Evidence from panel quantile regression. Economic Modelling, 58, 237-248.

Zivot, E., D. W. K. Andrews, D.W.K., 1992. Further Evidence on the Great Crash, the Oil-Price Shock, and the Unit-Root Hypothesis. Journal of Business and Economic Statistics, 10(3), 251-270.