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Nexus between Environmental Quality with Economic Growth, Renewable Energy Consumption, and Foreign Direct Investment in Vietnam: Evidence from Non-linear ARDL approach

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Abstract

Purpose: The purpose of this article is to examine the relationship between economic growth and environmental quality in Vietnam.

Methodology: The research employed is the non-linear Autoregressive Distributed Lag (NARDL) approach, utilizing time-series data from 1986 to 2022. The strength of NARDL lies in its consideration of both increasing and decreasing trends in independent variables such as Economic Growth, Energy from Renewable Resources and Foreign Direct Investment (FDI) in a non-linear relationship with the dependent variable, CO2.

Findings: The research findings indicate that overall economic growth is positively associated with an increase in CO2 emissions, aligning with the Environmental Kuznets Curve (EKC) theory in the first stage of the inverted U-shape. However, the EKC hypothesis is not supported in later stages, as environmental degradation persists despite economic growth. Renewable resources in primary energy have increased from 6% in 1986 to 16% in 2022, while FDI has risen from 0.03% of GDP in 1986 to 4.3% of GDP in 2021, resulting in a reduction in CO2 emissions. In other words, the Pollution Haven Hypothesis does not hold in Vietnam. With a net-zero CO2 target by 2050, Vietnam necessitates rapid, short-term changes to neutralize carbon emissions effectively in the long term.

Unique Contribution to Theory, Practice and Policy: To simultaneously ensure economic growth while adhering to Vietnam's carbon neutrality objectives, followings solutions are recommended: (1) increasing the proportion of renewable energy sources and reducing fossil fuel dependency; (2) incorporating modern, environmentally friendly technologies in the industrial sector to diminish resource-intensive practices and reduce dependence on fossil fuels; (3) establishing a legal framework and conditions to attract FDI in technology-intensive sectors, thereby mitigating carbon emissions.

Keywords: *Zero Carbon target, Environmental Degradation, EKC hypothesis, Renewable Energy*

1. INTRODUCTION

Environmental quality is increasingly concerning for countries as economies rely more on resource exploitation, leading to environmental degradation (Begum et al., 2015). The increasing concentration of CO2 in the atmosphere continues to disrupt the initial carbon balance, adversely impacting the production processes (Xu & Lin, 2018). Economic development contributes to an enhanced quality of life for people. However, in developing countries, the relationship between the environment and economic growth is a trade-off, as economic development has adversely affected environmental quality (G. M. Grossman & A. B. Krueger, 1995). This issue has led to the Environmental Kuznets Curve (EKC) hypothesis. The EKC hypothesis delineates the relationship between per capita income (i.e., economic development) and environmental degradation through an inverted U-shaped curve. In the initial stages of economic development, environmental degradation tends to increase; however, in the later stages of the U-shaped curve, ultimately, the environment improves after reaching a certain level of economic development (Mehmood & Tariq, 2020; Weimin et al., 2022). This study also relies on the Environmental Kuznets Curve (EKC) hypothesis to investigate the environmental quality and the factors influencing it in Vietnam, where technologies are being implemented and energy-efficient practices are employed to reduce CO2 emissions.

Regarding industrial production in Vietnam, where the industrial sector plays a crucial role, the average annual growth rate reached 7% from 2011 to 2022. The industrial sector constitutes over 35% of Vietnam's GDP (Vietnam General Statistics Office, 2022). However, industrial production contributes to environmental degradation through carbon dioxide emissions. The production process requires the use of energy sources, primarily non-renewable resources, which are extensively utilized in industrial production in developing countries (Wang et al., 2020). Growth-led policies are increasingly focused on industrial production, regardless of the trade-off with the diminishing quality of the environment (Tsaurai, 2018). When the environment is not a priority, low-emission technologies are still being used, as the technologies currently provide better cost efficiency (Lechtenböhmer et al., 2016). Utilizing high technology in industrial production plays a crucial role in reducing reliance on fossil fuels (Zhang et al., 2016); this also serves as a foundation for the Vietnamese government to consider researching and proposing strategies for employing high technology and energy-efficient technologies.

Regarding foreign direct investment (FDI), Vietnam has an open economy to enhance exports and imports. This includes importing capital and technology through the attraction of foreign direct investment. Foreign direct investment brings numerous short-term and long-term benefits to the country (Stiglitz, 2004). FDI holds a high proportion of the investment capital, contributing to the intensified economic development in Vietnam. In Vietnam, the industrial sector attracts a significant share of foreign direct investment, accounting for approximately 50% of the total FDI. FDI capital tends to concentrate on processing and manufacturing industries. The objective of foreign investors in Vietnam is to leverage advantages such as the abundant labor force, low labor costs, and tax incentives. Foreign direct investment will impact carbon dioxide emissions in both the short and long term (Seker et al., 2015). In some cases, foreign direct investment (FDI) is considered to have a positive impact on the environment in the long run (Wang

& Huang, 2022), Because FDI is associated with the transfer of technology from developed to less developed countries and involves a greater utilization of renewable energy (Paramati et al., 2017) alternatively, countries receiving FDI should require the implementation of clean production processes and adherence to environmental standards (Mahmood et al., 2023).

Energy is becoming a fundamental issue, serving as a crucial input for the economic development process (Abbasi, Shahbaz, et al., 2021). In this context, energy from non-renewable sources, such as fossil fuels, oil, and coal, contributes to the increase in CO2 emissions (Abbasi & Adedoyin, 2021). As energy consumption rises, it implies an increase in the production process; however, there is a need to transition to the use of renewable energy to contribute to reducing CO2 emissions both in the short and long term (Szetela et al., 2022) and improve the quality of the environment (Abbasi, Adedoyin, et al., 2021; den Elzen et al., 2016).

Vietnam's goal is to transition to renewable energy successfully, increase the proportion of renewable energy usage, and significantly contribute to achieving the goal of carbon neutrality by 2050. The greenhouse gas emissions are expected to be around 400 million tons by 2030 and reduced to approximately 100 million tons by 2050. The targets of reducing greenhouse gas emissions by 17-26% by 2030 and about 90% by 2050 are ambitious, requiring a long-term perspective on carbon neutrality.

Examining the relationship between environmental quality, resource use, and economic growth is important as Vietnam commits to achieving net-zero emissions by 2050 and aims for sustainable development by increasing the use of renewable resources. The choice between growth and the environment is always a challenge in economic development; therefore, this study aims to (1) Examine the mix of factors such as ERR, and FDI to assess asymmetry, evaluating both increasing and decreasing trends in their effects on CO2 emissions in the long term using the non-linear ARDL method, which is advantageous compared to studying linear relationships only; (2) Investigate factors that have a significant share in CO2 emissions, considering Vietnam's commitment to COP26 for carbon neutrality by 2050; (3) Conduct a test for the existence of the Environmental Kuznets Curve (EKC) hypothesis and the Pollution Haven Hypothesis in Vietnam, then provide suggestions in terms of production technology and the utilization of renewable resources based on the study's findings.

2. LITERATURE REVIEW

The Kuznets curve was introduced by a Russian economist Simon Kuznets in the 1950s who explored the inverted U-shape curve between income inequality and growth. After his work, the empirical work with the modification to capture the environmental degradation was done by (G. M. Grossman & A. Krueger, 1995), who adopted the similar phenomena of quadratic relationship but between economic growth and environmental degradation. The authors used GDP per capita to measure growth and air pollutants (Sulfur dioxide and Smoke) for measuring environmental degradation. The results showed that a U-shape relationship exists between the two variables.

Further studies on the Kuznets curve hypothesis, as explained by (Lorente & Álvarez-Herranz, 2016) has shown that the Kuznets curve does not stop at the inverted U-shape, but there is a next stage, when economic growth increases, causing environmental degradation to start increasing again, considered as the Kuznets curve has an N-shape. The stages of the N-shaped Kuznets curve can be explained as follows: in the first stage, economic growth increases due to scale expansion; in the second stage, the environment is protected by advancements in technology. However, in the third stage, as technology becomes outdated and innovation reaches its limits, environmental degradation begins to increase again (Koilo, 2019; Zhang, 2021). According to study by (Blampied, 2021) has been mentioned the idea of growth comes first, then environmental protection. Because, the benefits of economic growth are important for the prosperity and well-being of the economy and its citizens, it promotes advances in technology, improves health, education and the overall quality of life (Tim Everett, 2010), and growth tends to be linked with improvements in environmental quality (Shafik, 1994).

CO2 emissions are trending upward in developing countries (Liu et al., 2021), as industrial production increases (Dinda, 2004; Ouyang & Lin, 2015). Most studies consider CO2 as an indicator of environmental quality (Bekun et al., 2019; Shi et al., 2020). According to the author (Chen et al., 2019) there is a one-way relationship from GDP to CO2. However, many other studies indicate a two-way relationship between GDP and CO2, which exists in both the short term and the long term (Acheampong, 2018; You et al., 2022).

This study also examines the consumption of renewable resources. Renewable resources play an important role in sustainable economic development, because green technology and eco-technological innovation are developed to minimize the negative effects of pollution (Chiu & Lee, 2020; Shahbaz et al., 2018), economic growth driven by the consumption of renewable energy will reduce CO2 emissions (Yang et al., 2021).

In developing countries, FDI contributes to local budgets and economic growth. FDI is expected to be accompanied by advanced technology and clean technology to both bring high value to products and protect the environment, as the author (Zhu et al., 2016) pointed out that foreign investment reduces CO2 in Southeast Asian countries. The pollution haven hypothesis suggests that developing countries are more likely to experience pollution and degradation when they open their economies to foreign investors (Eskeland & Harrison, 2003; Javorcik & Wei, 2003). This is also a way that wealthier countries (with higher incomes) implement stricter environmental protection measures and transfer polluting goods to developing countries (Copeland, 2008). However, currently, developing countries are also implementing stricter environmental regulations in response to the increasing environmental degradation (Acheampong & Opoku, 2023; Opoku et al., 2022).

There are many research methods examining the relationship between CO2 and factors such as economic growth, FDI, resource consumption, urbanization, tourism, and transportation. These methods use econometric models to analyze both linear and non-linear relationships. Some studies are summarized in Table 1 below:

Table 1: Synthesis of some studies on the impact of factors on environmental quality

Determinants	Methodology	Time	Country	Environmental Kuznets curve validation	Authors
GDP, FDI, Urbanization, Energy consumption, Government education expenditures.	Pooled Mean Group Estimator.	1986 – 2017	5 ASEAN developing countries	Existence of EKC	(Tebourbi et al., 2023)
GDP, Renewable energy consumption, Capital account openness.	Second-generation panel data regression models, Quantiles with fixed-effects estimators.	1996 - 2018	ASEAN countries	The inverted-U EKC hypothesis seems to hold true for Singapore.	(Kostakis, 2024)
GDP, Energy consumption, Urbanization.	Auto-Regressive Distributed Lag (ARDL) modeling based on the Pooled Mean Group (PMG) estimator, Common Correlated Effects Pooled Mean Group (CCE - PMG),	1990 - 2020	Africa countries	Low-income countries reveals a U-shaped relationship	(Simbi et al., 2024)
GDP, Renewable energy consumption	Fuzzy-set qualitative comparative analysis (fsQCA)		The Gulf Cooperation Countries (GCC), and ASEAN countries	No study about EKC	(Naz et al., 2024)
GDP Green supply chain management, Various recycling practices (including bio-waste, municipal waste, and packaging waste).	Linear and nonlinear panel ARDL models	2000 - 2022	EU countries	No study about EKC	(Mohsin et al., 2024)
Tourism, Renewable Energy	Two-step GMM estimator	1990 – 2015	Europe and Central Asia countries	Existence of EKC	(Salahodjaev et al., 2022)
GDP, renewable energy nonrenewable energy	Fully Modified Ordinary Least Squares (FMOLS), Dynamic Ordinary Least Squares (DOLS)	1990 – 2016	5 ASEAN countries	Existence of EKC	(Mehmood, 2022)
GDP, Energy consumption, Urbanization	Fixed effect, Random effect, Newey West, Generalized least square.	2003 – 2016	5 ASEAN countries	Existence of EKC	(Adeel-Farooq et al., 2023)
GDP, FDI, Real income, Trade openness, Tourism, Renewable energy.	ARDL - PMG, Granger causality	1995–2018	6 ASEAN countries	Existence of EKC	(Pata et al., 2023)

This study uses country-specific data for Vietnam, while most studies use panel data. Using country-specific data is also important, because panel data tend to generalize regression estimates across many economies, while environmental policies vary from one country to another. Therefore, the relationship between CO2 emissions and energy consumption can be analyzed for a specific country (Blanchard & Perotti, 2002).

3. METHODOLOGY

Non-Linear Autoregressive Distributed Lag Model

This study uses time-series data, from 1986 to 2022. According to Tabachnick et al. (2013) and Pham et al. (2022), With time-series data (statistics by year), the sample size is determined by the formula (n - k) > 20, where k is the number of independent variables in the model, and n is the number of period (years). In this study, the number of periods is 36 years (from 1986 to 2022), with 4 independent variables. According to the formula, the result is (36 - 4) = 32, therefore the sample size meets the requirements of this study.

The nonlinear autoregressive distributed lag model is analyzed through multiple steps, progressing from the general model to cointegration testing, evaluating the Error Correction Term (ECT) model, assessing long-term relationships, and conducting an analysis of asymmetric dynamic multiplier graphs. Therefore, this study examines relationships among factors from a simple model and systematically progresses through these analytical stages.

The linear ARDL model as Eq. 1:

$$\ln CO2_t = \alpha_0 + \sum_{j=1}^{p} \gamma_j \ln CO2_{t-j} + \sum_{i=0}^{q} \alpha_{1,i} \ln GDP_{t-i} + \sum_{i=0}^{q} \alpha_{2,i} \ln ERR_{t-i} + \sum_{i=0}^{q} \alpha_{3,i} \ln FDI_{t-i} + \varepsilon_t \quad (\text{Eq. }1)$$

Symbol p, q represent the optimal lags for each variable in the model. The selection of optimal lags for variables can be performed by relying on AIC (Akaike Information Criterion) or SIC (Schwarz Information Criterion) criteria. In this study, the EViews software is used, and the software automatically selects the optimal lag for each variable s suggested by Nsor-Ambala and Amewu (2023). The ε_t is an IID process with zero mean and constant variance, σ_ε^2.

The Non-linear ARDL (NARDL) model also introduces an additional asymmetric component, which is absent in the standard ARDL. This study examines the increase and decrease of energy from renewable sources, and foreign direct investment about carbon dioxide emissions. Specifically, in Eq. 1, decompose the independent variable of lnERR into two sets, denoted by $\ln ERR^+$, $\ln ERR^-$ are partial sum of positive and negative change. Thus, the decomposition series can be expressed as Eq. 2:

$$\ln CO2_t = \alpha_0 + \alpha_1 \ln GDP_t + \alpha_2^+ \ln ERR_t^+ + \alpha_2^- \ln ERR_t^- + \alpha_3 \ln FDI_t + \varepsilon_t \quad (\text{Eq. }2)$$

To examine the nature of the increase and decrease in the values of the regressors, the general model of NARDL, Eq. 3.

$$Y_t = \sum_{j=1}^{p} \gamma Y_{t-j} + \sum_{i=0}^{q} (\alpha_i^+ X_{t-i}^+ + \alpha_i^- X_{t-i}^-) + \varepsilon_t \quad (\text{Eq. }3)$$

In this study, the NARDL model takes the form of Eq. 4:

$$\ln CO2_t = \sum_{j=1}^{p} \gamma \ln CO2_{t-j} + \sum_{i=0}^{q} \alpha_1 \ln GDP_{t-i} + \sum_{i=0}^{q} (\alpha_2^+ ERR_{t-i}^+ + \alpha_2^- ERR_{t-i}^-) + \sum_{i=0}^{q} (\alpha_3 FDI_{t-i}) + \varepsilon_t \quad (Eq. 4)$$

Table 2: Description of variables in the dataset

Variable	Unit measurement	Period	Data source
CO2	Annual CO_2 emissions (tons)	Annual data, from 1986 to 2021	Global Carbon Budget (2022)
GDP	USD per capita, constant 2015, US$	Annual data, from 1986 to 2022	World Bank Indicators, 2023
ERR	Share of primary energy from renewable sources (%)	Annual data, from 1986 to 2022	Energy Institute Statistical Review of World Energy (2023)
FDI	Foreign direct investment, net inflows (% of GDP)	Annual data, from 1986 to 2021	World Bank Indicators, 2023

Table 3 provides descriptive statistics for the variables used in the study. The variables have different units of measurement; therefore, when implementing procedures for the NARDL model, the values of the variables are transformed using logarithms, as mentioned in the Eq. 1:

Table 3: Descriptive statistics of variables

Indicator	CO2 (Million tons per year)	GDP (GDP per Capita, US$, constant 2015)	ERR (% of primary energy)	FDI (NetFlow FDI, % GDP)
Mean	110.84	1700.84	19.19	4.88
Median	81.90	1474.74	20.06	4.43
Standard Deviation	97.14	930.66	5.19	2.72
Kurtosis	0.23	-0.81	1.18	0.69
Skewness	1.10	0.61	-1.12	0.40
Minimum	17.40	598.92	5.44	0.00
Maximum	341.00	3655.46	26.75	11.94
Observations	36	37	37	36

4. RESULTS

4.1. Test for Data Stationary

The study utilized the Augmented Dickey-Fuller (ADF) test and Phillips-Perron (PP) test to confirm the stationarity of the variables. The unit root test results (Table 4) indicated that the variables lnCO2, lnGDP are stationary at order I(1), while the variables lnERR, lnFDI are stationary at level I(0). This demonstrates that the NARDL method is suitable for determining relationships between these variables.

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Table 4: Unit root tests

Null Hypothesis: The variable has a unit root

Variable	Model	ADF		PP		Order of stationary
		Level	First Difference	Level	First Difference	
lnCO2	Constant	0.533ns	-4.904***	0.319ns	-5.382***	
	Trend	-3.994**	-4.930***	-2.981ns	-5.391***	I(1)
	None	3.743	-1.514	5.274	-3.808***	
lnGDP	Constant	-1.607	-4.063***	0.300	-4.175***	
	Trend	-0.922	-4.458***	-3.115	-4.312***	I(1)
	None	2.174	-0.123	14.728	0.105	
lnERR	Constant	-3.126**	-4.144***	-3.164**	-4.522***	
	Trend	-2.881	-4.200**	-2.869	-4.637***	I(0)
	None	0.808	-4.055	0.672	-4.405***	
lnFDI	Constant	-4.298***	-8.349***	-11.704***	-8.045***	
	Trend	-3.833**	-8.638***	-10.753***	-8.328***	I(0)
	None	-4.854***	-8.399	-4.062***	-8.098***	

Note: ***, **, * at the 1%, 5%, and 10% statistical significance, respectively.
Augmented Dickey-Fuller Unit Root Test (ADF) and Phillips-Perron Unit Root Test (PP)

4.2. Estimation of the long-run relationship

Before delving into the detailed analysis of the long-term relationship, the study evaluated the results of the NARDL model (Table 5) to determine the impact of lnGDP, $lnERR^{+}$, $lnERR^{-}$, lnFDI on lnCO2 emissions. The corresponding optimal lags were identified as (2,2,1,2). The NARDL model is statistically significant at the 1% level. The model indicated that the factors under investigation explain up to 81% of the variation in carbon dioxide emissions. Overall, CO2 emissions are increasing due to economic growth from the previous year (significant at the 1% level). However, CO2 emissions also show a decreasing trend with an increase in renewable energy, and an increase in foreign direct investment (significant at levels of 1%, 5%, and 10% respectively).

Table 5: The estimation results of the NARDL model
Selected model: NARDL (2,2,1,2)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
CO2(-1)	-0.8226	0.1864	-4.4122	0.0002
GDP(-1)	1.8272	0.3436	5.3172	0.0000
@CUMDP(RR(-1))	-0.1670	0.0712	-2.3445	0.0285
@CUMDN(RR(-1))	0.1554	0.1267	1.2262	0.2331
FDI(-1)	-0.0063	0.0166	-0.3778	0.7092
D(CO2(-1))	0.1926	0.1530	1.2592	0.2212
D(GDP)	0.4398	0.8249	0.5332	0.5993
D(GDP(-1))	-2.0362	1.1513	-1.7687	0.0908
D(FDI)	0.0840	0.0314	2.6735	0.0139
D(RR)	-0.2880	0.0595	-4.8369	0.0001
D(RR(-1))	-0.1614	0.0760	-2.1240	0.0451
C	2.2545	1.4996	1.5034	0.1470
Model statistics				
R-squared	0.8756			
Adjusted R-squared	0.8134			
F-statistic	14.0731			
Probability (F-statistic)	0.0000			

Before analyzing the long-term relationship, the study conducted the NARDL Bound Test to confirm a long-term relationship between the factors and environmental quality in Vietnam. The results of the NARDL Bound Test in Table 6 show that the calculated F-value is higher than the upper bound value corresponding to a 5% statistical significance level. Therefore, it is possible to reject the null hypothesis (H0) and accept the alternative hypothesis (H1): There exists cointegration among variables in the long run, or other words, there is a long-term relationship between environmental quality (proxied by CO2 emissions) and economic growth, renewable energy and foreign direct investment.

Table 6: NARDL Bound Test estimation

Null Hypothesis: No levels relationship

F-statistic	F-bounds test statistics		
	Significance	I(0)	I(1)
	10%	2.7520	3.9940
6.1016	5%	3.3540	4.7740
	1%	4.7680	6.6700

At the same time, examining the asymmetry for the long-term ERR factor, Table 7 shows that there is an asymmetry of ERR in relation to environmental quality (proxy through CO2 variable). Thus, dividing ERR into 2 trends is appropriate for this study.

Table 7: Coefficient symmetry tests

Null hypothesis: Coefficient is symmetric

Degrees of freedom (simple tests): F(1,22), Chi-square(1)

Variable	Statistic	Value	Probability
Long-run			
lnERR	F-statistic	6.9952	0.0148
	Chi-square	6.9952	0.0082

After confirming cointegration between factors, i.e., understanding it as having a long-run relationship between variables, in Table 8, the estimation results of the NARDL model show that economic growth has a positive impact on CO2 emissions with statistical significance at the 1% level. This implies that when economic growth, GDP, increases by 1%, CO2 emissions increase by 2.22%.

Meanwhile, increasing energy from renewable sources by 1% results in a 0.2% decrease in CO2 emissions (with statistical significance at the 1% level). A decrease in renewable energy also reduces CO2 emissions, but without statistical significance, which is evident in the dynamic multiplier graph of energy from renewable sources with carbon emissions (Figure 1). The black line represents the partial sum of positive changes in renewable energy, while the orange line represents the partial sum of adverse changes in renewable energy. The figure demonstrates a difference when ERR increases (proxy lnERR+) and ERR (proxy lnERR-) decreases, impacting CO2 emissions. This difference is statistically significant, as confirmed by the red line – the test line showing a significant difference within the 95% confidence interval.

Foreign direct investment (FDI) increasing by 1% results in a 0.7% reduction in CO2 emissions, however, without statistically significant.

Table 8: Estimation of the long-run relationship NARDL model

Dependent Variable: LNCO2

Variable	Coefficient	Std. Error	t-Statistic	Prob.
lnGDP(-1)	2.2211	0.2208	10.0587	0.0000
lnERR$^+$(-1)	-0.2030	0.0743	-2.7313	0.0105
lnERR$^-$(-1)	0.1888	0.1750	1.0792	0.2891
lnFDI	-0.0076	0.0200	-0.3824	0.7048
Diagnostic tests				
Tests	Prob. F	Prob. Chi-square		
Breusch-Godfrey Serial Correlation LM test	0.5119	0.3325		
Breusch-Pagan-Godfrey Heteroscedasticity test	0.6913	0.6053		

Note: ***, ** and * show significance at 1, 5 and 10% level respectively.

Breusch-Godfrey LM Serial Correlation test; Breusch-Pagan-Godfrey Heteroscedasticity test; Cumulative Sum (CUSUM) stability test; Cumulative Sum of Square (CUSUM-Sq.) stability test.

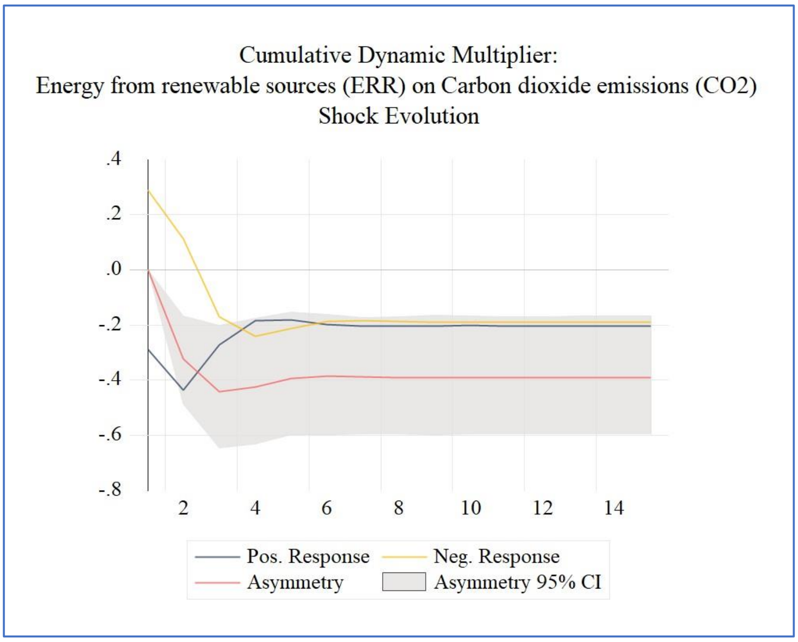

Figure 1: Non-linear ARDL dynamic multiplier effect graphs

Regarding model testing, Table 8 also presented the diagnostic values of the NARDL model. The statistics indicate the absence of misspecification, serial correlation, and heteroscedasticity. Figure 2 also displays the results for CUSUM and CUSUMQ, indicating that the overall model is stable. The CUSUM line and CUSUMQ line are within the statistically significant region at the 5% level.

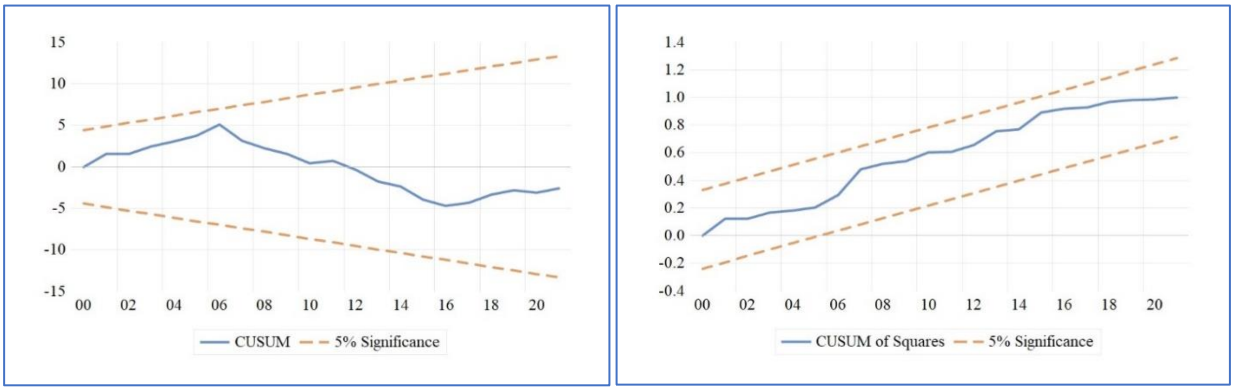

Figure 2: Non-linear ARDL CUSUM and CUSUMSQ graphs

4.3. Error correction model

The results of the NARDL Bound Test confirm the existence of long-run cointegration among the factors. However, to examine the relationship from the short run to the long run, the Error Correction Term (ECT) model with a parameter (CointEq(-1) = -0.8226) (Table 9) has a negative and statistically significant value at the 1% level. This indicates the presence of a long-run relationship among the factors. The relationship will converge, and growth paths will reach long-run equilibrium (or steady-state in the long run). During the process of reaching the steady-state path, the amount of CO2 will be restrained, while economic development continues, i.e., environmental quality is improved with increased economic growth.

Table 9: Error Correction Model

Variable	Coefficient	Std. Error	t-statistic	Prob.
COINTEQ*	-0.8226	0.1370	-6.0046	0.0000
D(CO2(-1))	0.1926	0.1327	1.4514	0.1586
D(GDP)	0.4398	0.6526	0.6739	0.5063
D(GDP(-1))	-2.0362	0.8542	-2.3838	0.0247
D(RR)	-0.2880	0.0434	-6.6416	0.0000
D(RR(-1))	-0.1614	0.0614	-2.6276	0.0142
D(FDI)	0.0840	0.0185	4.5338	0.0001
C	2.2545	0.3694	6.1037	0.0000

Model statistics	
R-squared	0.8756
Adjusted R-squared	0.8421
F-statistic	26.1357
Probability (F-statistic)	0.0000

Note: Δ is the difference operator

5. DISCUSSION

In 2022, Vietnam's economic growth reached its highest level in the 10 years from 2011 to 2022, as the economy rebounded from the impacts of the COVID-19 pandemic. The GDP growth rate was 8.02%, with the industrial and construction sectors contributing significantly at 7.78%, accounting for approximately 38% of the GDP. Despite global economic uncertainties and challenges, the growth in most countries and regions indicated instability. Vietnam's economic growth was highly praised, demonstrating the effectiveness of the government's efforts to support economic recovery.

As shown in Figure 3, the GDP scale continues to expand, reaching USD 408.8 billion in 2022 at current prices, compared to USD 195.6 billion in 2012. This doubling of GDP over the past decade translates to a per capita GDP of nearly $4,200 in 2022. However, entering 2023, Vietnam's economy is facing various difficulties. According to the Asian Development Outlook report (September 2023), Vietnam's economic growth is projected to slow to 5.8% in 2023 and 6.0% in 2024[1].

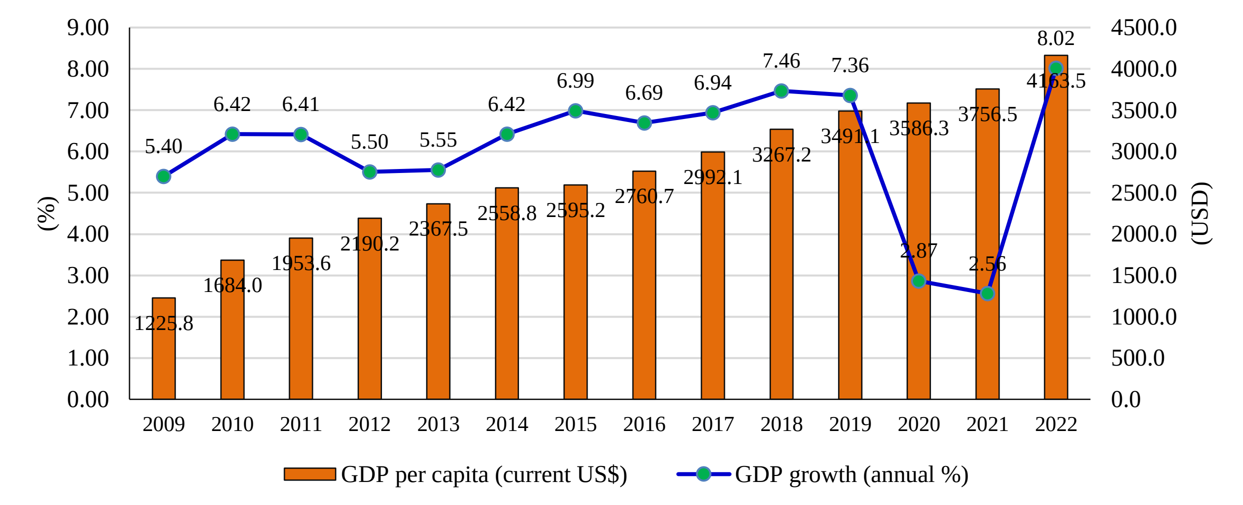

Figure 3: Economic growth and per capita GDP in Vietnam from 2009 to 2022

Returning to the NARDL model estimation results, economic GDP growth has a positive relationship with CO2 emissions. In other words, Vietnam faces environmental degradation as per capita income increases in the short and long term. Figure 4 illustrates that the growth rate of CO2 follows the growth rate of GDP per capita; however, the growth rate of CO2 emissions is higher than the growth rate of GDP. This result aligns with previous studies conducted in Vietnam by Shahbaz et al. (2019) and Al-Mulali et al. (2015), finding that the Environmental Kuznets Curve (EKC) hypothesis cannot be achieved at later stages, as CO2 levels continue to rise despite an increase in per capita income. The positive relationship in the long run is also consistent with the findings of (Binh, 2011). A study by (Vo et al., 2019) also indicated that some countries in the Southeast Asian region, such as the Philippines, do not reveal the Environmental Kuznets Curve (EKC) hypothesis in the long-run relationship between economic growth and environmental quality. In contrast, in Thailand, research results have shown the Environmental Kuznets Curve (EKC) (Chng, 2019). However, some low-income and low-middle-income countries in South Asia, such as Nepal, Bangladesh, and India, still follow an inverted U-shape trend according to a study by (Syed Muhammad Faraz et al., 2022). The SAARC countries (Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan, and Sri Lanka) exhibit a long-run relationship where

[1] Vietnamese economy remains resilient despite weak external environment: ADB. https://link.gov.vn/dmoQVQex

economic growth contributes to environmental degradation, as indicated by a study by (Rani et al., 2023). A recent study in Turkey has supported the inverted U-shape relationship according to the Environmental Kuznets Curve (EKC), where energy intensity is identified as a source causing a decrease in environmental quality (Shokoohi et al., 2022). Therefore, in this study, the findings imply that the Vietnamese economy, like other middle-income countries, exploits resources and energy sources, leading to higher CO2 emissions (Linh & Lin, 2014). Another reason is that Vietnam is focusing on developing the industrial sector, a cause that aligns with previous research by (Shahbaz et al., 2019), as the industry consumes a significant amount of fossil energy, leading to environmental degradation.

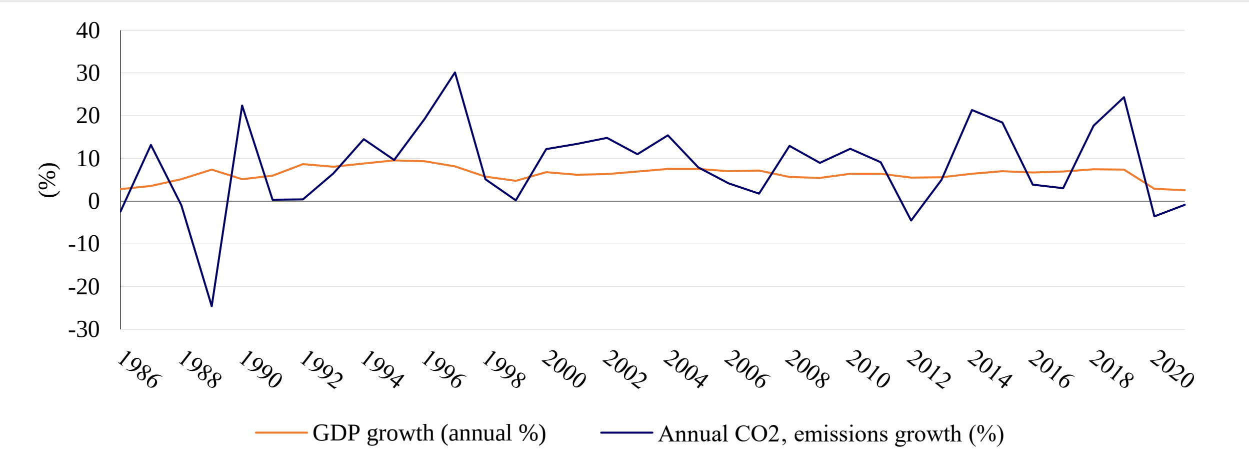

Figure 4: GDP growth and CO2 emissions growth in Vietnam from 1986 to 2022

The results have demonstrated that energy intensity from non-renewable resources negatively impacts CO2 emissions in the long run, and using renewable energy positively affects environmental quality (Awan et al., 2022). Real-world experiments during the COVID-19 pandemic, when oil demand decreased, showed an improvement in environmental quality, with reductions in CO2 emissions during lockdowns, highlighting the relationship between the energy sector and CO2 emissions (Ope Olabiwonnu et al., 2022). The study conducted across 107 countries by (Abbasi et al., 2023) indicates that nuclear energy and renewable energy follow the Environmental Kuznets Curve (EKC) hypothesis with an inverted N-shape, leading to pollution reduction, while non-renewable energy enhances pollution. Renewable energy consumption in developed countries like the United States reduces CO2 emissions at the lowest to medium and the highest quantiles (Raggad, 2023). However, in OPEC countries, renewable energy has an insignificant impact on carbon intensity. Instead, technological innovation, creativity, and energy-efficient measures are employed to control carbon intensity (Aziz et al., 2023). Renewable energy consumption, environmental taxes, and economic growth are longitudinally linked to CO2 emissions. Eco-friendly innovations also reduce the use of non-renewable energy sources (Ameer et al., 2023). In developed European countries, GDP per capita and CO2 emissions exhibit a relationship following the Environmental Kuznets Curve (EKC) hypothesis. The increased use of renewable energy sources, especially solar, wind, and bioenergy, reduces CO2 emissions. The study emphasizes the utilization of advanced technologies (J.-h. Wang et al., 2022). Alternative energy sources to fossil fuels and energy efficiency improvements can reduce pollution (Farhana et al., 2022). The relationship between energy, GDP, and CO2 always co-occurs, and renewable

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energy reduces CO_2 emissions in countries in sub-Saharan Africa (Ebhota & Tabakov, 2021). Research results on renewable energy consumption in Vietnam also indicate a negative effect on greenhouse gas emissions, suggesting that renewable energy could reduce greenhouse gas emissions (Nguyen et al., 2022). Thus, the findings of this study align with research in other countries and in Vietnam, affirming that renewable energy positively impacts environmental quality. However, in Figure 5, it is shown that CO_2 emissions increase at a faster rate than renewable energy consumption, supporting the idea that, in addition to increasing the use of renewable energy, it is crucial to use energy efficiently in industrial production, research, and technology innovation to create environmentally friendly products.

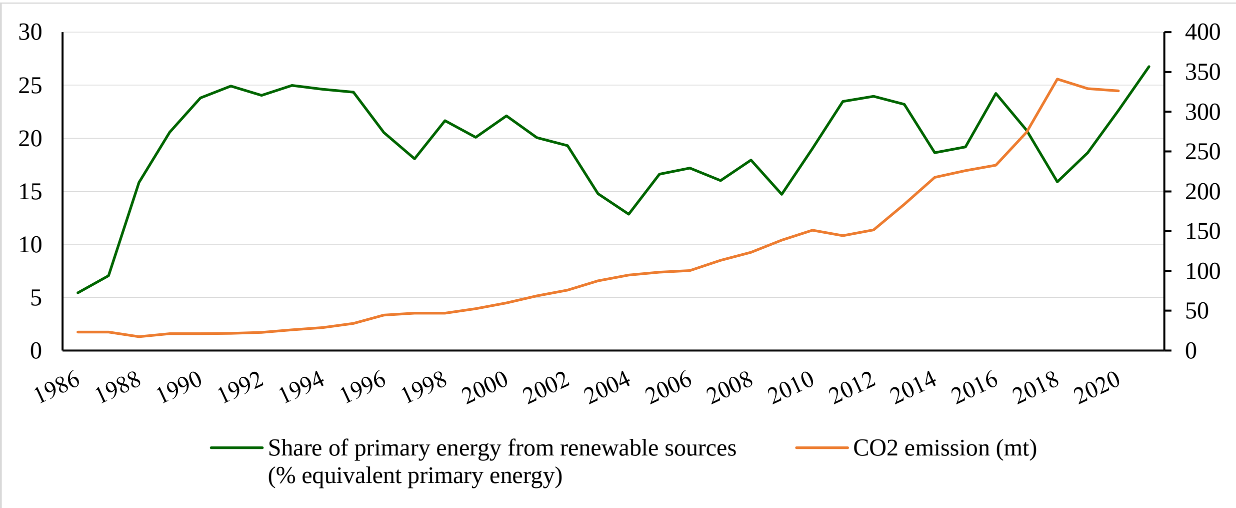

Figure 5: Share of primary energy from renewable sources and CO_2 emissions in Vietnam from 1986 to 2022

In Vietnam, thermal power plants using coal and gas-fired thermal power plants are significant contributors to greenhouse gas emissions (Roy et al., 2021). Other industries, such as cement, must compromise by adopting carbonation technologies to reduce CO_2 emissions, which may impact cement plant profits (Proaño et al., 2020). This study aligns with the findings of (Mahmood et al., 2020), which assert that increasing industrialization has a more significant effect on CO_2 emissions than reducing industrialization; however, the authors also highlight that technological progress can still have adverse effects on the environment. Recent studies have introduced a novel approach, utilizing the concept of lean manufacturing to optimize resource utilization and minimize waste, where companies strive to improve output efficiency by adjusting production parameters (Singh et al., 2021). Additionally, industries such as iron and cement manufacturing in Vietnam need dedicated production and environmental processing areas to mitigate their environmental impact (Cravioto et al., 2021). Therefore, the results of this study, in line with previous research, affirm that industrial production in Vietnam contributes to environmental degradation. This supports the idea that to enhance environmental conditions, industries should establish separate production zones and improve energy efficiency.

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In terms of industrial production, in Vietnam in 2022, there are four primary industries, with the processing and manufacturing industry accounting for the most significant proportion of GDP (24.7%), followed by electricity production and distribution (3.99%), mining industry (2.82%), and finally water supply (0.49%). Industrial production continues to grow relatively, with the average industrial value-added increasing by 7% per year from 2011 to 2022, contributing 38% to GDP in 2023 (Vietnam General Statistics Office, 2022). The industrial and CO_2 emission growth rates are high, as depicted in Figure 6. Previous research by H. Zhang et al. (2022) showed that the iron and steel production industry contributed significantly to CO_2 emissions in the studied areas in China, and the flow from production to energy had a statistically significant impact on CO_2 emissions. Similarly, within the steel production sector, research by (S. Zhang et al., 2022) demonstrated that the steel output, resource-saving, and energy-efficient practices determined the amount of CO_2 emissions. While some countries participating in global value chains benefit from reducing pollution emissions in their own countries, developing countries face challenges in dealing with increased pressure to reduce carbon emissions (S. Wang et al., 2022).

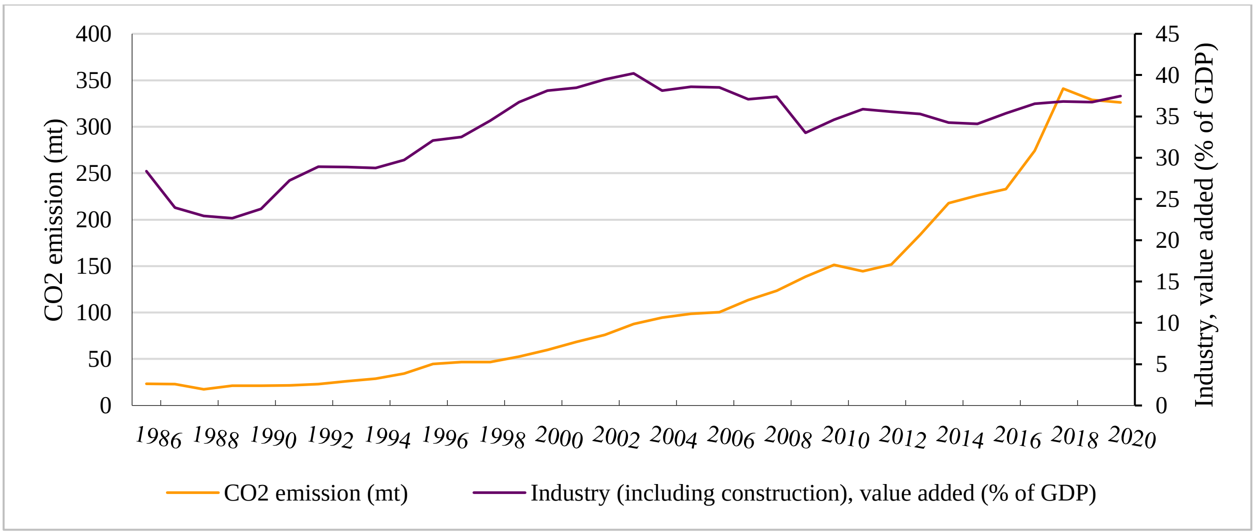

Figure 6: Share of industry of GDP and CO_2 emissions in Vietnam from 1986 to 2022

Economic growth is positively correlated with the annual increase in Foreign Direct Investment (FDI) in Vietnam. FDI capital holds a significant share of the overall investment in the entire economy. The rise in FDI has expanded the production scale in various economic sectors, thereby creating conditions to promote economic growth. In a study by (Firoj et al., 2023), the author revealed a long-term relationship following the Environmental Kuznets Curve (EKC). However, it did not provide evidence that FDI contributes to environmental pollution in Bangladesh. The sensitivity of FDI to the environment is high (Chishti, 2023). The relationship between FDI and economic growth is bidirectional, and low-middle-income countries support the pollution haven hypothesis (Yin et al., 2021).

The study conducted across 15 OECD countries supports the Pollution Haven Hypothesis. Results from various sectors, including mining and manufacturing from FDI lead to an increase in CO_2 emissions (Marques & Caetano, 2022); similar findings are reported by (Esmaeili et al., 2023; Liu et al., 2022), indicating that FDI can negatively impact environmental quality. However, the findings of this study show a positive impact of FDI on environmental quality in Vietnam, contrary to (Tran et al., 2023), who conducted a study in Vietnam and found that an increase in FDI leads to an increase in greenhouse gas emissions in the country. This emphasizes the need for FDI inflows to actively engage in green technology transfer, fulfill social responsibilities, and build and enhance awareness of a green economy among workers and consumers.

6. CONCLUSIONS

By employing the non-linear Autoregressive Distributed Lag (ARDL) method, this paper investigates long-term relationships between various regressors, including economic growth, the share of renewable energy usage, and foreign direct investment, with environmental degradation (measured through carbon dioxide emissions). One of the main reasons for conducting this study is to examine both increasing and decreasing (asymmetric) trends of renewable energy regressor in the context of the rising carbon dioxide emissions in Vietnam. The study results indicate a cointegrated relationship among the factors, wherein Vietnam's economic growth does not follow the Environmental Kuznets Curve (EKC) hypothesis and the relationship between FDI and environmental quality is not statistically significant. This implies that high economic growth still requires high energy consumption and produces substantial greenhouse gas emissions. The study also reveals that an increase in the use of renewable energy and foreign direct investment has a positive impact, reducing carbon dioxide emissions in the long run.

7. RECOMMENDATIONS

To simultaneously ensure economic growth while adhering to Vietnam's carbon neutrality objectives, followings solutions are recommended:

Firstly, the key strategies involve decreasing reliance on fossil fuels, increasing the utilization of renewable energy, and continuing the upward trend in harnessing energy from wind and solar sources. Moreover, as outlined in Vietnam's energy plan, the gradual reduction of thermal power in the energy supply has gained approval.

Secondly, modern technology may require some industries to sacrifice profits to protect the environment, particularly in the industrial sector. Renewable energy, modern technology, and efficient energy use are the pathways for development to enhance environmental quality while ensuring both short-term and long-term economic growth. This aligns with the commitment made by Vietnam at COP26 to achieve carbon neutrality by 2050.

Thirdly, there is a need to focus on less resource-intensive industries and attract environmentally friendly technologies. For industries with high $CO2$ emissions, strategic planning must allocate them to specific zones. Applying a circular economy model and using energy efficiently from fossil fuels are recommended for FDI in industrial sectors. The industrial production sector needs to transition technology, gradually prioritizing technology-intensive sectors over resource-intensive ones.

Ethical Approval

This article contains no studies with human participants or animals performed by authors.

Data Availability Statement

The data supporting this study's findings are available from the first author upon reasonable request.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

REFERENCES

Abbasi, K. R., & Adedoyin, F. F. (2021). Do energy use and economic policy uncertainty affect CO(2) emissions in China? Empirical evidence from the dynamic ARDL simulation approach. *Environ Sci Pollut Res Int*, *28*(18), 23323-23335. https://doi.org/10.1007/s11356-020-12217-6

Abbasi, K. R., Adedoyin, F. F., Abbas, J., & Hussain, K. (2021). The impact of energy depletion and renewable energy on CO2 emissions in Thailand: Fresh evidence from the novel dynamic ARDL simulation. *Renewable Energy*, *180*, 1439-1450. https://doi.org/https://doi.org/10.1016/j.renene.2021.08.078

Abbasi, K. R., Awan, A., Bandyopadhyay, A., Rej, S., & Banday, T. P. (2023). Investigating the inverted N-shape EKC in the presence of renewable and nuclear energy in a global sample. *Clean Technologies and Environmental Policy*, *25*(4), 1179-1194. https://doi.org/10.1007/s10098-022-02436-5

Abbasi, K. R., Shahbaz, M., Jiao, Z., & Tufail, M. (2021). How energy consumption, industrial growth, urbanization, and CO2 emissions affect economic growth in Pakistan? A novel dynamic ARDL simulations approach. *Energy*, *221*, 119793. https://doi.org/https://doi.org/10.1016/j.energy.2021.119793

Acheampong, A. O. (2018). Economic growth, CO2 emissions and energy consumption: What causes what and where? *Energy Economics*, *74*, 677-692. https://doi.org/https://doi.org/10.1016/j.eneco.2018.07.022

Acheampong, A. O., & Opoku, E. E. O. (2023). Environmental degradation and economic growth: Investigating linkages and potential pathways. *Energy Economics*, *123*, 106734. https://doi.org/https://doi.org/10.1016/j.eneco.2023.106734

Adeel-Farooq, R. M., Raji, J. O., & Qamri, G. M. (2023). Does financial development influence the overall natural environment? An environmental performance index (EPI) based insight from the ASEAN countries. *Environment, Development and Sustainability*, *25*(6), 5123-5139. https://doi.org/10.1007/s10668-022-02258-x

Al-Mulali, U., Saboori, B., & Ozturk, I. (2015). Investigating the environmental Kuznets curve hypothesis in Vietnam. *Energy Policy*, *76*, 123-131. https://doi.org/https://doi.org/10.1016/j.enpol.2014.11.019

Ameer, W., Ali, M. S. e., Farooq, F., Ayub, B., & Waqas, M. (2023). Renewable energy electricity, environmental taxes, and sustainable development: empirical evidence from E7 economies. *Environmental Science and Pollution Research*. https://doi.org/10.1007/s11356-023-26930-5

Awan, A., Kocoglu, M., Banday, T. P., & Tarazkar, M. H. (2022). Revisiting global energy efficiency and CO2 emission nexus: fresh evidence from the panel quantile regression model. *Environmental Science and Pollution Research*, *29*(31), 47502-47515. https://doi.org/10.1007/s11356-022-19101-5

Aziz, G., Sarwar, S., Shahbaz, M., Malik, M. N., & Waheed, R. (2023). Empirical relationship between creativity and carbon intensity: a case of OPEC countries. *Environmental Science and Pollution Research*, *30*(13), 38886-38897. https://doi.org/10.1007/s11356-022-24903-8

Begum, R. A., Sohag, K., Abdullah, S. M. S., & Jaafar, M. (2015). CO2 emissions, energy consumption, economic and population growth in Malaysia. *Renewable and Sustainable Energy Reviews*, *41*, 594-601. https://doi.org/https://doi.org/10.1016/j.rser.2014.07.205

Bekun, F. V., Alola, A. A., & Sarkodie, S. A. (2019). Toward a sustainable environment: Nexus between CO2 emissions, resource rent, renewable and nonrenewable energy in 16-EU countries. *Science of The Total Environment*, *657*, 1023-1029. https://doi.org/https://doi.org/10.1016/j.scitotenv.2018.12.104

Binh, P. T. (2011). Energy consumption and economic growth in Vietnam: Threshold cointegration and causality analysis [Article]. *International Journal of Energy Economics and Policy*, *1*(1), 1-17. https://www.scopus.com/inward/record.uri?eid=2-s2.0-84868582404&partnerID=40&md5=c85f878bb73e047ff721e092bfef8eed

Blampied, N. (2021). Economic growth, environmental constraints and convergence: The declining growth premium for developing economies. *Ecological Economics*, *181*, 106919. https://doi.org/https://doi.org/10.1016/j.ecolecon.2020.106919

Blanchard, O., & Perotti, R. (2002). An Empirical Characterization of the Dynamic Effects of Changes in Government Spending and Taxes on Output*. *The Quarterly Journal of Economics*, *117*(4), 1329-1368. https://doi.org/10.1162/003355302320935043

Chen, Y., Wang, Z., & Zhong, Z. (2019). CO2 emissions, economic growth, renewable and non-renewable energy production and foreign trade in China. *Renewable Energy*, *131*, 208-216. https://doi.org/https://doi.org/10.1016/j.renene.2018.07.047

Chishti, M. Z. (2023). Exploring the dynamic link between FDI, remittances, and ecological footprint in Pakistan: Evidence from partial and multiple wavelet based-analysis. *Research in Globalization*, *6*, 100109. https://doi.org/https://doi.org/10.1016/j.resglo.2022.100109

Chiu, Y.-B., & Lee, C.-C. (2020). Effects of financial development on energy consumption: The role of country risks. *Energy Economics*, *90*, 104833. https://doi.org/https://doi.org/10.1016/j.eneco.2020.104833

Chng, Z. Y. R. (2019). Environmental degradation and economics growth: Testing the environmental Kuznets Curve Hypothesis (EKC) in six ASEAN countries. *Journal of Undergraduate Research at Minnesota State University, Mankato*, *19*(1), 1.

Copeland, B. R. (2008). The pollution haven hypothesis. *Handbook on Trade and the Environment*, *2*(7).

Cravioto, J., Yamasue, E., Nguyen, D.-Q., & Huy, T.-D. (2021). Benefits of a regional co-processing scheme: The case of steel/iron and cement industries in Vietnam, Laos, and Cambodia. *Journal of Cleaner Production*, *312*, 127702. https://doi.org/https://doi.org/10.1016/j.jclepro.2021.127702

den Elzen, M., Fekete, H., Höhne, N., Admiraal, A., Forsell, N., Hof, A. F., Olivier, J. G. J., Roelfsema, M., & van Soest, H. (2016). Greenhouse gas emissions from current and enhanced policies of China until 2030: Can emissions peak before 2030? [Article]. *Energy Policy*, *89*, 224-236. https://doi.org/10.1016/j.enpol.2015.11.030

Dinda, S. (2004). Environmental Kuznets Curve Hypothesis: A Survey. *Ecological Economics*, *49*(4), 431-455. https://doi.org/https://doi.org/10.1016/j.ecolecon.2004.02.011

Ebhota, W. S., & Tabakov, P. Y. (2021). Development of domestic technology for sustainable renewable energy in a zero-carbon emission-driven economy. *International Journal of Environmental Science and Technology*, *18*(5), 1253-1268. https://doi.org/10.1007/s13762-020-02920-9

Eskeland, G. S., & Harrison, A. E. (2003). Moving to greener pastures? Multinationals and the pollution haven hypothesis. *Journal of Development Economics*, *70*(1), 1-23. https://doi.org/https://doi.org/10.1016/S0304-3878(02)00084-6

Esmaeili, P., Balsalobre Lorente, D., & Anwar, A. (2023). Revisiting the environmental Kuznetz curve and pollution haven hypothesis in N-11 economies: Fresh evidence from panel quantile regression. *Environmental Research*, *228*, 115844. https://doi.org/https://doi.org/10.1016/j.envres.2023.115844

Farhana, K., Kadirgama, K., Mahamude, A. S. F., & Mica, M. T. (2022). Energy consumption, environmental impact, and implementation of renewable energy resources in global textile industries: an overview towards circularity and sustainability. *Materials Circular Economy*, *4*(1), 15. https://doi.org/10.1007/s42824-022-00059-1

Firoj, M., Sultana, N., Khanom, S., Rashid, M. H. U., & Sultana, A. (2023). Pollution haven hypothesis and the environmental Kuznets curve of Bangladesh: an empirical investigation. *Asia-Pacific Journal of Regional Science*, *7*(1), 197-227. https://doi.org/10.1007/s41685-022-00258-3

Grossman, G. M., & Krueger, A. (1995). Economic Growth and the Environment. *The Quarterly Journal of Economics*, *110*(2), 353-377. https://EconPapers.repec.org/RePEc:oup:qjecon:v:110:y:1995:i:2:p:353-377.

Grossman, G. M., & Krueger, A. B. (1995). Economic Growth and the Environment*. *The Quarterly Journal of Economics*, *110*(2), 353-377. https://doi.org/10.2307/2118443

Javorcik, B. S., & Wei, S.-J. (2003). Pollution Havens and Foreign Direct Investment: Dirty Secret or Popular Myth? , *3*(2). https://doi.org/doi:10.2202/1538-0645.1244 (Contributions in Economic Analysis & Policy)

Koilo, V. (2019). Evidence of the Environmental Kuznets Curve: Unleashing the Opportunity of Industry 4.0 in Emerging Economies. *Journal of Risk and Financial Management*, *12*(3).

Kostakis, I. (2024). An empirical investigation of the nexus among renewable energy, financial openness, economic growth, and environmental degradation in selected ASEAN economies. *Journal of Environmental Management*, *354*, 120398. https://doi.org/https://doi.org/10.1016/j.jenvman.2024.120398

Lechtenböhmer, S., Nilsson, L. J., Åhman, M., & Schneider, C. (2016). Decarbonising the energy intensive basic materials industry through electrification – Implications for future EU electricity demand. *Energy*, *115*, 1623-1631. https://doi.org/https://doi.org/10.1016/j.energy.2016.07.110

Linh, D. H., & Lin, S.-M. (2014). CO 2 Emissions, Energy Consumption, Economic Growth and FDI in Vietnam. *Managing Global Transitions: International Research Journal*, *12*(3).

Liu, X., Li, X., Shi, H., Yan, Y., & Wen, X. (2021). Effect of economic growth on environmental quality: Evidence from tropical countries with different income levels. *Science of The Total Environment*, *774*, 145180. https://doi.org/https://doi.org/10.1016/j.scitotenv.2021.145180

Liu, Y., Sadiq, F., Ali, W., & Kumail, T. (2022). Does tourism development, energy consumption, trade openness and economic growth matters for ecological footprint: Testing the Environmental Kuznets Curve and pollution haven hypothesis for Pakistan. *Energy*, *245*, 123208. https://doi.org/https://doi.org/10.1016/j.energy.2022.123208

Lorente, D. B., & Álvarez-Herranz, A. (2016). Economic growth and energy regulation in the environmental Kuznets curve. *Environmental Science and Pollution Research*, *23*(16), 16478-16494. https://doi.org/10.1007/s11356-016-6773-3

Mahmood, H., Alkhateeb, T. T. Y., & Furqan, M. (2020). Industrialization, urbanization and CO2 emissions in Saudi Arabia: Asymmetry analysis. *Energy Reports*, *6*, 1553-1560. https://doi.org/https://doi.org/10.1016/j.egyr.2020.06.004

Mahmood, H., Saqib, N., Adow, A. H., & Abbas, M. (2023). FDI, exports, imports, and consumption-based CO(2) emissions in the MENA region: spatial analysis. *Environ Sci Pollut Res Int*, *30*(25), 67634-67646. https://doi.org/10.1007/s11356-023-27245-1

Marques, A. C., & Caetano, R. V. (2022). Do greater amounts of FDI cause higher pollution levels? Evidence from OECD countries. *Journal of Policy Modeling*, *44*(1), 147-162. https://doi.org/https://doi.org/10.1016/j.jpolmod.2021.10.004

Mehmood, U. (2022). The role of economic globalization in reducing CO2 emissions: implications for sustainable development in South Asian nations. *Environment, Development and Sustainability*. https://doi.org/10.1007/s10668-022-02823-4

Mehmood, U., & Tariq, S. (2020). Globalization and CO(2) emissions nexus: evidence from the EKC hypothesis in South Asian countries. *Environ Sci Pollut Res Int*, *27*(29), 37044-37056. https://doi.org/10.1007/s11356-020-09774-1

Mohsin, A. K. M., Gerschberger, M., Plasch, M., Ahmed, S. F., Rahman, A., & Rashed, M. (2024). Examining the synergy of green supply chain practices, circular economy, and economic growth in mitigating carbon emissions: Evidence from EU countries. *Journal of Environmental Management*, *371*, 123109. https://doi.org/https://doi.org/10.1016/j.jenvman.2024.123109

Naz, F., Tanveer, A., Karim, S., & Dowling, M. (2024). The decoupling dilemma: Examining economic growth and carbon emissions in emerging economic blocs. *Energy Economics*, *138*, 107848. https://doi.org/https://doi.org/10.1016/j.eneco.2024.107848

Nguyen, H. T., Nguyen, S. V., Dau, V.-H., Le, A. T. H., Nguyen, K. V., Nguyen, D. P., Bui, X.-T., & Bui, H. M. (2022). The nexus between greenhouse gases, economic growth, energy and trade openness in Vietnam. *Environmental Technology & Innovation*, *28*, 102912. https://doi.org/https://doi.org/10.1016/j.eti.2022.102912

Nsor-Ambala, R., & Amewu, G. (2023). Linear and non-linear ARDL estimation of financial innovation and economic growth in Ghana. *Journal of Business and Socio-economic Development*, *3*(1), 36-49. https://doi.org/10.1108/jbsed-09-2021-0128

Ope Olabiwonnu, F., Haakon Bakken, T., & Anthony Jnr, B. (2022). The role of hydropower in renewable energy sector toward co2 emission reduction during the COVID-19 pandemic. *International Journal of Green Energy*, *19*(1), 52-61. https://doi.org/10.1080/15435075.2021.1930005

Opoku, E. E. O., Acheampong, A. O., Dzator, J., & Kufuor, N. K. (2022). Does environmental sustainability attract foreign investment? Evidence from developing countries. *Business Strategy and the Environment*, *31*(7), 3542-3573. https://doi.org/https://doi.org/10.1002/bse.3104

Ouyang, X., & Lin, B. (2015). An analysis of the driving forces of energy-related carbon dioxide emissions in China's industrial sector. *Renewable and Sustainable Energy Reviews*, *45*, 838-849. https://doi.org/https://doi.org/10.1016/j.rser.2015.02.030

Paramati, S. R., Mo, D., & Gupta, R. (2017). The effects of stock market growth and renewable energy use on CO2 emissions: Evidence from G20 countries. *Energy Economics*, *66*, 360-371. https://doi.org/https://doi.org/10.1016/j.eneco.2017.06.025

Pata, U. K., Dam, M. M., & Kaya, F. (2023). How effective are renewable energy, tourism, trade openness, and foreign direct investment on CO2 emissions? An EKC analysis for ASEAN countries. *Environmental Science and Pollution Research*, *30*(6), 14821-14837. https://doi.org/10.1007/s11356-022-23160-z

Pham, M. H., Nguyen, A. T., & Le, P. T. (2022). The relationship between ghg emissions and economic growth in Vietnam. *Science & Technology Development Journal - Economics - Law and Management*. https://doi.org/10.32508/stdjelm.v6i1.802

Proaño, L., Sarmiento, A. T., Figueredo, M., & Cobo, M. (2020). Techno-economic evaluation of indirect carbonation for CO2 emissions capture in cement industry: A system dynamics approach. *Journal of Cleaner Production*, *263*, 121457. https://doi.org/https://doi.org/10.1016/j.jclepro.2020.121457

Raggad, B. (2023). Quantile causality and dependence between renewable energy consumption, WTI prices, and CO2 emissions: new evidence from the USA. *Environmental Science and Pollution Research*, *30*(18), 52288-52303. https://doi.org/10.1007/s11356-023-25899-5

Rani, T., Wang, F., Rauf, F., Ain, Q. u., & Ali, H. (2023). Linking personal remittance and fossil fuels energy consumption to environmental degradation: evidence from all SAARC countries. *Environment, Development and Sustainability*, *25*(8), 8447-8468. https://doi.org/10.1007/s10668-022-02407-2

Roy, S., Lam, Y. F., Hung, N. T., Chan, J. C. L., & Fu, J. S. (2021). Development of 2015 Vietnam emission inventory for power generation units. *Atmospheric Environment*, *247*, 118042. https://doi.org/https://doi.org/10.1016/j.atmosenv.2020.118042

Salahodjaev, R., Sharipov, K., Rakhmanov, N., & Khabirov, D. (2022). Tourism, renewable energy and CO2 emissions: evidence from Europe and Central Asia. *Environment, Development and Sustainability*, *24*(11), 13282-13293. https://doi.org/10.1007/s10668-021-01993-x

Seker, F., Ertugrul, H. M., & Cetin, M. (2015). The impact of foreign direct investment on environmental quality: A bounds testing and causality analysis for Turkey. *Renewable and Sustainable Energy Reviews*, *52*, 347-356. https://doi.org/https://doi.org/10.1016/j.rser.2015.07.118

Shafik, N. (1994). Economic Development and Environmental Quality: An Econometric Analysis. *Oxford Economic Papers*, *46*, 757-773. http://www.jstor.org/stable/2663498

Shahbaz, M., Haouas, I., & Hoang, T. H. V. (2019). Economic growth and environmental degradation in Vietnam: Is the environmental Kuznets curve a complete picture? *Emerging Markets Review*, *38*, 197-218. https://doi.org/https://doi.org/10.1016/j.ememar.2018.12.006

Shahbaz, M., Nasir, M. A., & Roubaud, D. (2018). Environmental degradation in France: The effects of FDI, financial development, and energy innovations. *Energy Economics*, *74*, 843-857. https://doi.org/https://doi.org/10.1016/j.eneco.2018.07.020

Shi, H., Li, X., Liu, X., Wang, S., Liu, X., Zhang, H., Tang, D., & Li, T. (2020). Global protected areas boost the carbon sequestration capacity: Evidences from econometric causal analysis. *Science of*

The Total Environment, *715*, 137001. https://doi.org/https://doi.org/10.1016/j.scitotenv.2020.137001

Shokoohi, Z., Dehbidi, N. K., & Tarazkar, M. H. (2022). Energy intensity, economic growth and environmental quality in populous Middle East countries. *Energy*, *239*, 122164. https://doi.org/https://doi.org/10.1016/j.energy.2021.122164

Simbi, C. H., Yao, F., Zhang, J., Tenaw, D., Sugira Murekezi, J., Magati, M. T., Hirwa, H., Al-Sakkaf, A. S., Kayiranga, A., & Peng, J. (2024). Balancing growth and preservation: Unravelling Africa's carbon-economic nexus through the environmental kuznets curve. *Heliyon*, *10*(20), e39269. https://doi.org/https://doi.org/10.1016/j.heliyon.2024.e39269

Singh, C., Singh, D., & Khamba, J. S. (2021). Understanding the key performance parameters of green lean performance in manufacturing industries. *Materials Today: Proceedings*, *46*, 111-115. https://doi.org/https://doi.org/10.1016/j.matpr.2020.06.328

Stiglitz, J. E. (2004). Capital-market Liberalization, Globalization, and the IMF. *Oxford Review of Economic Policy*, *20*(1), 57-71. https://doi.org/10.1093/oxrep/grh004

Syed Muhammad Faraz, R., Ikram, A., Muhammad Yasir, M., Maaz, A., Syed Zain Ul, A., & Sadia, M. (2022). RENEWABLE ENERGY CONSUMPTION TOWARDS ENVIRONMENTAL SUSTAINABILITY: EVIDENCE OF EKC HYPOTHESIS IN THE FRAMEWORK OF ECONOMIC GROWTH AND CO2 EMISSIONS. *PalArch's Journal of Archaeology of Egypt / Egyptology*, *19*(2), 1238-1253. https://archives.palarch.nl/index.php/jae/article/view/11177

Szetela, B., Majewska, A., Jamroz, P., Djalilov, B., & Salahodjaev, R. (2022). Renewable Energy and CO2 Emissions in Top Natural Resource Rents Depending Countries: The Role of Governance [Original Research]. *Frontiers in Energy Research*, *10*. https://doi.org/10.3389/fenrg.2022.872941

Tabachnick, B. G., Fidell, L. S., & Ullman, J. B. (2013). *Using multivariate statistics* (Vol. 6). pearson Boston, MA.

Tebourbi, I., Nguyen, A. T. T., Yuan, S.-F., & Huang, C.-Y. (2023). How do social and economic factors affect carbon emissions? New evidence from five ASEAN developing countries. *Economic Research-Ekonomska Istraživanja*, *36*(1), 1-24. https://doi.org/10.1080/1331677x.2022.2120038

Tim Everett, M. I., Gian Paolo Ansaloni and Alex Rubin. (2010). *Economic Growth and the Environment*. Department for Environment Food and Rural Affairs, UK. https://assets.publishing.service.gov.uk/media/5a799f30ed915d0422069d36/pb13390-economic-growth-100305.pdf

Tran, T. K., Lin, C.-Y., Tu, Y.-T., Duong, N. T., Pham Thi, T. D., & Shoh-Jakhon, K. (2023). Nexus between natural resource depletion and rent and COP26 commitments: Empirical evidence from Vietnam. *Resources Policy*, *85*, 104024. https://doi.org/https://doi.org/10.1016/j.resourpol.2023.104024

Tsaurai, K. (2018). Greenhouse Gas Emissions and Economic Growth in Africa: Does Financial Development Play any Moderating Role? *International Journal of Energy Economics and Policy*, *8*, 267-274.

Vietnam General Statistics Office. (2022). Socio-Economic Situation in The Fourth Quarter and 2022. https://www.gso.gov.vn/en/data-and-statistics/2023/01/socio-economic-situation-in-the-fourth-quarter-and-2022/

Vo, A. T., Vo, D. H., & Le, Q. T. (2019). CO2 Emissions, Energy Consumption, and Economic Growth: New Evidence in the ASEAN Countries. *Journal of Risk and Financial Management*, *12*(3).

Wang, J.-h., Mamkhezri, J., Khezri, M., Karimi, M. S., & Khan, Y. A. (2022). Insights from European nations on the spatial impacts of renewable energy sources on CO2 emissions. *Energy Reports*, *8*, 5620-5630. https://doi.org/https://doi.org/10.1016/j.egyr.2022.04.005

Wang, S., Wang, X., & Chen, S. (2022). Global value chains and carbon emission reduction in developing countries: Does industrial upgrading matter? *Environmental Impact Assessment Review*, *97*, 106895. https://doi.org/https://doi.org/10.1016/j.eiar.2022.106895

Wang, Y., & Huang, Y. (2022). Impact of Foreign Direct Investment on the Carbon Dioxide Emissions of East Asian Countries Based on a Panel ARDL Method [Original Research]. *Frontiers in Environmental Science*, *10*. https://doi.org/10.3389/fenvs.2022.937837

Wang, Y., Sun, X., Wang, B., & Liu, X. (2020). Energy saving, GHG abatement and industrial growth in OECD countries: A green productivity approach. *Energy*, *194*(C), S0360544219325289. https://EconPapers.repec.org/RePEc:eee:energy:v:194:y:2020:i:c:s0360544219325289

Weimin, Z., Sibt-e-Ali, M., Tariq, M., Dagar, V., & Khan, M. K. (2022). Globalization toward environmental sustainability and electricity consumption to environmental degradation: does EKC inverted U-shaped hypothesis exist between squared economic growth and CO2 emissions in top globalized economies. *Environmental Science and Pollution Research*, *29*(40), 59974-59984. https://doi.org/10.1007/s11356-022-20192-3

Xu, B., & Lin, B. (2018). Investigating the role of high-tech industry in reducing China's CO2 emissions: A regional perspective. *Journal of Cleaner Production*, *177*, 169-177. https://doi.org/https://doi.org/10.1016/j.jclepro.2017.12.174

Yang, H., Shahzadi, I., & Hussain, M. (2021). USA carbon neutrality target: Evaluating the role of environmentally adjusted multifactor productivity growth in limiting carbon emissions. *Journal of Environmental Management*, *298*, 113385. https://doi.org/https://doi.org/10.1016/j.jenvman.2021.113385

Yin, Y., Xiong, X., & Hussain, J. (2021). The role of physical and human capital in FDI-pollution-growth nexus in countries with different income groups: A simultaneity modeling analysis. *Environmental Impact Assessment Review*, *91*, 106664. https://doi.org/https://doi.org/10.1016/j.eiar.2021.106664

You, W., Zhang, Y., & Lee, C.-C. (2022). The dynamic impact of economic growth and economic complexity on CO2 emissions: An advanced panel data estimation. *Economic Analysis and Policy*, *73*, 112-128. https://doi.org/https://doi.org/10.1016/j.eap.2021.11.004

Zhang, H., Sun, W., Li, W., & Ma, G. (2022). A carbon flow tracing and carbon accounting method for exploring CO2 emissions of the iron and steel industry: An integrated material–energy–carbon hub. *Applied Energy*, *309*, 118485. https://doi.org/https://doi.org/10.1016/j.apenergy.2021.118485

Zhang, J. (2021). Environmental Kuznets Curve Hypothesis on CO2 Emissions: Evidence for China. *Journal of Risk and Financial Management*, *14*(3).

Zhang, S., Yi, B., Guo, F., & Zhu, P. (2022). Exploring selected pathways to low and zero CO2 emissions in China's iron and steel industry and their impacts on resources and energy. *Journal of Cleaner Production*, *340*, 130813. https://doi.org/https://doi.org/10.1016/j.jclepro.2022.130813

Zhang, W., Kramer, E. M., & Davis, C. C. (2016). Differential Expression of CYC2 Genes and the Elaboration of Floral Morphologies in Hiptage, an Old World Genus of Malpighiaceae. *International Journal of Plant Sciences*, *177*(7), 551-558. https://doi.org/10.1086/687225

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. https://doi.org/https://doi.org/10.1016/j.econmod.2016.05.003

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