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The impact of economic growth on CO2 emissions in East Asian and North African Countries during the period 1990-2020 using the CS-ARDL model

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***Abstract*---**Using the CS-ARDL model, this study examines how economic growth affects CO2 emissions in East Asian and North African nations between 1990 and 2020. Control variables like population size, trade openness, GDP per capita, and power use are included in the analysis. The results show a strong long-term cointegrating link between CO2 emissions and economic growth. There is a clear correlation between rising economic growth and rising power consumption and rising CO2 emissions over the long run, with the latter having a greater impact. Population size and trade openness have less of an association with CO2 emissions. The outcomes exhibit resilience against multiple empirical obstacles, such as autocorrelation, heteroskedasticity, and model misspecification. Diagnostic checks verify the validity of the CS-ARDL estimations and the stability of the long-run parameters. The study offers crucial insights into the connection between environmental impact and economic growth, arguing that energy consumption and economic aspects should be considered in CO2 emission reduction programs.

***Keywords*---**Economic Growth, CO2 Emissions, Environmental Impact, MENA Countries, CS-ARDL Model.
JEL Classification: O40; Q56; Q58; O53; C32.

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1. Introduction

Climate change, which manifests in the emission of greenhouse gases that cause global warming, is one of the crises the world is currently facing. This problem affects both developing and developed countries equally. Therefore, it has become necessary to intensify coordinated international efforts and find common solutions to mitigate or reduce the impact of this phenomenon. All United Nations member states in New York in 2015 dedicated one of the 17 Sustainable Development Goals (SDGs) to combating climate change and reducing global warming, in response to the growing concern over this issue. The 2030 Agenda for Sustainable Development, which includes urgent action to address climate change and mitigate its negative effects, adopted this goal.

Among the greenhouse gases, carbon dioxide (CO2) accounts for about three-quarters of total greenhouse gas emissions, while methane contributes approximately one-sixth of these emissions. In 2023, global CO2 emissions from wildfires were above average (based on satellite records since 2003) due to an intense wildfire season in Canada, where emissions were 6 to 8 times higher than average. Scientists and policymakers have set a target to limit the increase in global temperature to no more than 2°C above pre-industrial levels, while continuing efforts to reduce warming to 1.5°C to avoid dangerous climate changes. Between 2013 and 2022, the Earth's surface temperature recorded an increase of 1.14°C above pre-industrial levels (1850-1900) (Global Climate Change, 2023).

For this reason, all countries and international organizations are advocating for sustainable development, environmental conservation, and climate improvement. However, human activities themselves are significant contributors to the emission of greenhouse gases, which in turn affect the climate (Mahfoudi et al., 2024). Heavy industries, such as the oil, mining, natural gas, petrochemical, and cement industries, often rely on fossil fuels for economic development and can contribute to environmental pollution through CO2 emissions. Land and ocean sinks absorb nearly half of the emitted CO2, while the remainder remains in the atmosphere, contributing to climate change. According to the Environmental Kuznets Curve (EKC), in the early stages of economic growth, CO2 emissions increase with rising income; however, after reaching a certain income level, CO2 emissions decrease while economic growth continues. Based on this, we raise the question: To what extent does economic growth impact CO2 emissions in East Asian and North African (MENA) countries?

The study provides insights into how economic development affects environmental sustainability by highlighting the relationship between CO2 emissions and economic growth in East Asian and North African nations. It offers useful information to help policymakers create plans that strike a balance between economic expansion and successful climate change mitigation. And the purpose of the study is to examine how economic expansion affects CO2 emissions in East Asian and North African nations over the long and short terms. To inform policy decisions for sustainable economic and environmental results, it aims to comprehend how economic development affects emissions and evaluate the significance of relevant variables. By using the CS-ARDL model to investigate how economic growth affects CO_2 emissions in several East Asian and North African nations, this work closes a gap in the literature. Its uniqueness comes from the way it combines sophisticated econometric tools with a regional focus to provide detailed insights into emissions dynamics and influence specific climate policy.

The study's conclusions highlight a strong and long-lasting correlation between CO_2 emissions and economic growth, indicating a long-term cointegrating relationship. Power consumption and CO_2 emissions rise in tandem with faster economic expansion. This association points to an important realization: while rising economic activity raises energy consumption, the long-term effects of rising CO_2 emissions are more noticeable and persistent. The idea that rising energy consumption and industrial expansion are the main causes of greenhouse gas emissions is supported by the high correlation observed between economic growth and CO_2 emissions. Growing economies usually result in increasing energy needs, which raise emissions if the energy sources continue to be based on fossil fuels. This research highlights the necessity of combining cleaner technologies with sustainable energy practices to lessen the negative environmental effects of economic development. Conversely, the research indicates that trade openness and population increase have a relatively smaller impact on CO_2 emissions. This shows that although these factors do have an effect, it is not as great as the direct correlation between emissions and economic development. This distinction is important because it shows politicians where to concentrate their efforts to get the biggest environmental benefits when addressing climate change. Comprehensive diagnostic tests that address potential problems including autocorrelation, heteroskedasticity, and model misspecification are used to confirm the study's robustness. These verifications confirm the stability of the long-run parameters and support the estimations made by the CS-ARDL model. The study's ability to overcome these empirical obstacles ensures that the conclusions are trustworthy and useful for creating climate policies that effectively address the interplay between economic growth and CO_2 emissions.

The format of the paper is as follows. Previous investigations and background on global CO_2 emissions are presented in Section 2, while data and methodological concerns are the focus of Section 3. In Section 4, the empirical results are discussed. Section 5 concludes with the study's limitations, policy recommendations, and most significant conclusions.

2. Literature Review and Background

The relationship between economic growth and CO_2 emissions is complex, as evidenced by literature evaluations, which show that while sustainable practices can balance growth and environmental impact, industrial expansion frequently causes emissions to rise.

2.1 Literature Review

Numerous studies have highlighted different facets of the intricate and complicated relationship between economic growth and CO_2 emissions. Growth in the economy frequently results in higher CO_2 emissions because of increasing energy use and industrial activity. But the link is not linear, and it can be impacted by things like policy, new technologies, and energy sources. Using information from several research, this response delves into the subtleties of this relationship.

Decoupling Economic Growth and CO2 Emissions:

Using the Tapio decoupling model, Ma and Zhuang's study investigates how economic growth and CO2 emissions are separated in Liaoning Province, China. It concludes that while some cities have succeeded in weak or strong decoupling, others still face major obstacles, showing that, with the right steps implemented, economic expansion need not always result in higher emissions (Hubacek et al., 2021).

Using the STAR model, Ganie and Ahmad's research in India points to a nonlinear relationship in which economic expansion first raises CO2 emissions until a particular threshold is achieved, at which point additional growth may result in a decrease in emissions. This demonstrates how economic expansion may eventually promote environmental sustainability by encouraging the use of renewable energy sources and greater efficiency (Ganie & Ahmad, 2024).

The Environmental Kuznets Curve (EKC) Hypothesis:

Several studies have provided evidence in Favor of the EKC hypothesis, which suggests an inverse U-shaped link between environmental deterioration and economic growth. While noting regional differences, Balza et al. affirm the EKC globally, noting that income and emissions exhibit a monotonic positive relationship across Latin America and the Caribbean (Balza et al., 2024).
The EKC is further supported by Shahbaz and Du's research on 30 high-emitting nations, which demonstrates the diminishing marginal effects of economic growth on emissions. To reduce emissions, they highlight the importance of resource management and green technologies (Shahbaz et al., 2024).

The Function of Technology and Energy Sources:

Shahbaz et al., (2024) research, which shows that renewable energy greatly lowers CO2 emissions, especially at lower quantiles, emphasizes the significance of energy sources. This emphasizes how crucial it is to switch to greener energy sources to lessen the negative effects of economic expansion on the environment.

Economic growth, energy consumption, and CO2 emissions are shown to be path-dependent in Zhou's analysis of the Yangtze River Economic Belt in China, indicating that historical growth patterns have an impact on present emissions. This demonstrates the necessity of technological innovation and strategic planning in energy consumption to end this reliance (Zhou, 2023).

Globalization, Financial Development, and Policy Implications:

Research on African economies reveals that while these factors could reduce CO2 emissions through green financing and sustainable practices, they can also make emissions worse (Teklie & Yağmur, 2024).

And discover that although globalization and economic growth might lead to an increase in emissions, other components of globalization, including Islamic finance, can lead to a decrease in emissions. This suggests that financial and policy interventions may be able to offset environmental impacts (Harahap, 2024).

Although there is a clear correlation between economic growth and rising CO2 emissions, there are other variables at play as well, including changes in energy sources, technology, and governmental regulations. Economic expansion may eventually result in better environmental conditions, according to the EKC theory, albeit this is not always the case. The influence of technology advancements, energy policy, and regional variations on CO2 emissions is significant. As a result, attaining sustainable economic growth necessitates a multidimensional strategy that involves putting supportive laws in place, increasing energy efficiency, and making the switch to renewable energy.

2.2 Background on global CO2 emissions

Due to deforestation, industrialization, and the use of fossil fuels, global CO2 emissions have increased dramatically. This has led to climate change and calls for immediate worldwide action to reduce emissions and promote sustainability.

Analysis of Carbon Dioxide (CO2) Emissions Worldwide:

The global average for CO2 emissions from 1990 to 2020 was roughly 4.26 tons per capita, whereas the average for East Asian and North African countries was 4.65 tons, based on numerical data from the same source as the global CO2 emissions image above. With 4.9 tons of CO2 emissions per person, the globe saw its greatest emissions between 2011 and 2013, sparking concerns about the effects on human life. This led to it being included as one of the 17 Sustainable Development Goals, which aim to decrease or limit emissions that explicitly threaten human life on Earth as well as that of other organizations, including member states of the United Nations. After that, emissions started to fall, reaching 4.7 tons in 2016 and then falling even lower to 4.5 tons in 2020—a level not seen since 2004 worldwide.

The countries with the largest per capita CO2 emissions, above 20 tons, are shown by the dark red color in the graphic above, which shows the CO2 emissions in 2022. These include Brunei Darussalam in Southeast Asia (24 tons), Trinidad and Tobago in North America (22.4 tons per capita), the United Arab Emirates (25.8 tons), Bahrain (25.7 tons), Kuwait (25.6 tons), and Qatar (37.6 tons), which will be the world's top emitter of CO2 in 2022.

Countries with per capita emissions ranging from 10 to 20 tons are represented by the color red. Saudi Arabia is the largest of these nations with 18.2 tons, followed by Australia with 15 tons, the United States with 14.9 tons, and Canada with 14.2 tons. Russia has eleven tons, while Kazakhstan has fourteen.

China, Japan, South Africa, Libya, New Zealand, Malaysia, the Czech Republic, Singapore, Iran, Turkey, Greece, Poland, Bulgaria, Austria, Germany, Finland, Norway, Italy, Ireland, Spain, Belgium, Slovakia, Serbia, the Seychelles, Suriname, and the Bahamas are among the nations whose per capita emissions fall between 5 and 10 tons, which is marginally higher than the world average of 4.7 tons. The per capita emissions in the remainder of the world are less than 5 tons.

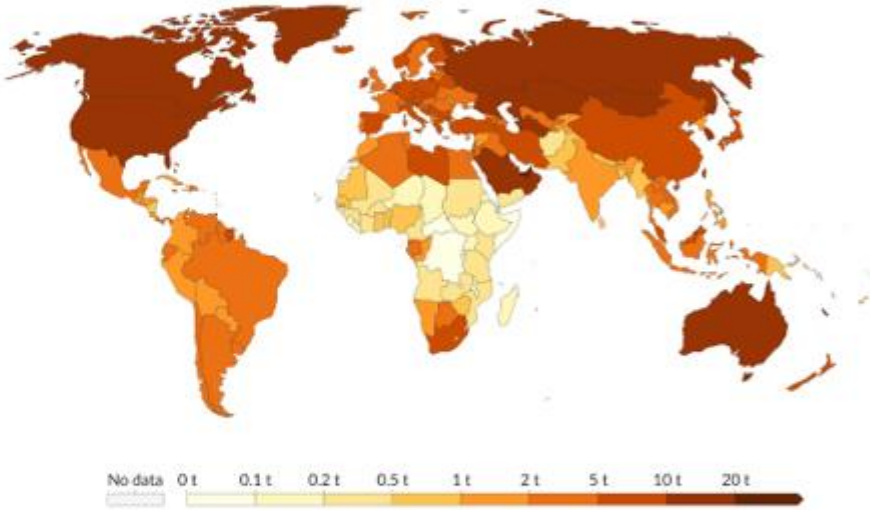

Figure 1. Map of CO2 Emissions Worldwide for 2022
Source: https://ourworldindata.org/.

The following graph illustrates the average per capita CO2 emissions, measured in metric tons, in the world, as well as in East Asian and North African countries from 1990 to 2022.

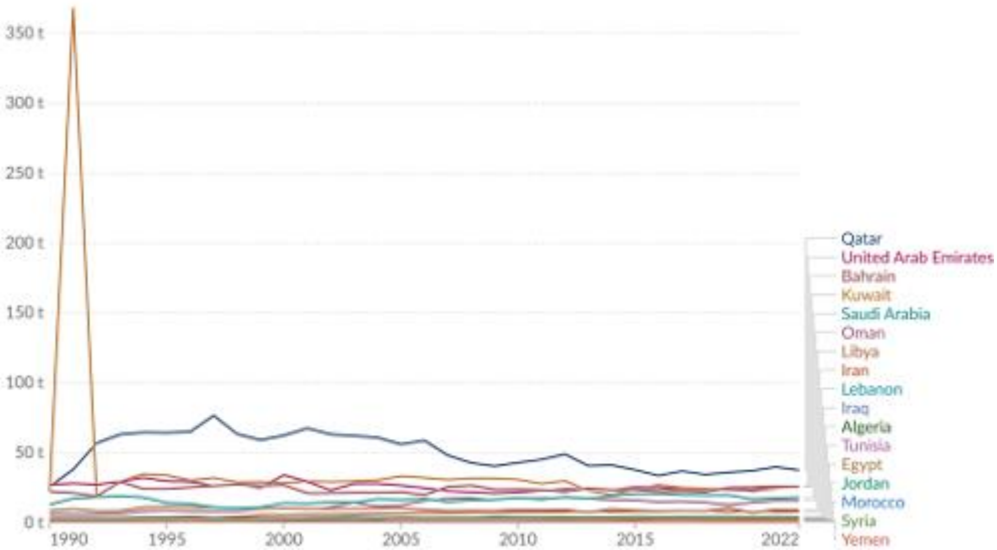

Figure 2. Graphical Representation of CO2 Emissions in MENA Countries
Source: https://ourworldindata.org/

3. Data and Methodology

3.1 Data:

The purpose of this study is to investigate how economic expansion affected CO2 emissions in MENA countries from 1990 to 2020. The time frame is determined by the availability of data, especially GDP. GHG emissions, which comprise carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), and fluorinated gases (F-gases), are the dependent variable. Additionally, the study's reliance on CO2 emissions stemmed from the countries' data availability. Furthermore, the World Development Indicators (WDI) supply the data on economic growth, the trade openness, the electricity consumption per capita and the population growth rate. The data utilized in this study are displayed in Table 1.

Table 1. Sources and definitions of variables

Variables	Definitions	Sources
LnCO2	Atmospheric release of carbon dioxide	Climate Watch
LnGDPpc	The national average of economic output per person.	WDI
LnELC	Electricity Consumption in a country.	WDI
LnOPEN	Trade openness of a country.	WDI
LnPOP	Population size of a country	WDI

3.2 Methodology

We constructed a model based on previous studies, such as those by [author names], to study and analyze the impact of economic growth and additional variables on CO2 emissions in East Asian and North African (MENA) countries, including the UAE, Bahrain, Algeria, Egypt, Iran, Iraq, Jordan, Kuwait, Lebanon, Morocco, Oman, Qatar, Saudi Arabia, Tunisia, and Yemen, during the period from 1990 to 2020. Since the study encompasses various variables across multiple countries to represent the relationship between different factors contributing to environmental impact (such as CO2 emissions), the data might involve different units of measurement, outliers, or missing values. We processed these to create a dataset that took the form of panel data. Accordingly, the model for the study takes the following form:

$$y_{it} = \beta_0 + \beta_1 X_{1it} + \beta_2 X_{2it} + \dots + \varepsilon_{it} \quad (1)$$

Therefore, based on the model structure above (1), and by applying the natural logarithm to both sides of the equation to homogenize the data, we obtain a linear logarithmic version as follows:

$$LnCO2_{it} = \beta_0 + \beta_1 LnGDPpc_{1it} + \beta_2 LnOPEN_{2it} + \beta_3 LnELC_{3it} + \beta_4 LnPOP_{4it} + \varepsilon_{it} \quad (2)$$

Where CO2, GDPpc, OPEN, ELC and POP represent CO2 emissions, per capita GDP, the trade openness, the electricity consumption per capita and the population growth rate, respectively.

3.3 Descriptive Statistics

The link between the variables being studied to determine the cross-sectional and dynamic differences across time between persons or units is shown in the following table 2.

Table 2. Descriptive Statistics

Variable		Mean	Std. dev	Min	Max	Observation
CO2	overall	10.7202	11.3844	0.3085	47.6569	N= 465
	between		11.4807	0.7354	38.3612	n = 15
	within		2.5138	-6.9615	20.016	T= 31
GDPPC	overall	15422.64	17899.46	1057.282	73493.27	N= 465
	between		17964.4	1995.167	55552.97	n = 15
	within		4305.42	-2081.782	33362.94	T= 31
ELC	overall	5.4086	6.11686	0.073	21.23	N= 465
	between		6.16845	0.1477	18.4376	n = 15
	within		1.351387	-1.8737	8.7557	T= 31
OPEN	overall	83.22	33.7705	0.0209	191.8726	N= 465
	between		29.0724	43.7614	145.451	n = 15
	within		18.7053	11.7599	165.9734	T= 31
POP	overall	2.9386	2.6537	-3.392	22.136	N= 465
	between		1.4278	1.2184	6.0114	n = 15
	within		2.2660	-3.9729	19.063	T= 31

It is noted that the standard deviation between years is 2.51, whereas the standard deviation between countries is 11.48. This suggests that there is a larger range in CO2 emissions between countries than there is within years. This indicates that CO2 emissions vary significantly across national boundaries. In the same way, there is more variance in per capita GDP across nations than there is within years. The same is true for trade openness and power usage, where there are more national variations than there are study-year variations. On the other hand, there is less fluctuation in the population growth rate between nations than there is year over year.

3.4 Correlation analysis

The relationships between the variables under investigation are displayed in Table 3's correlation matrix. LnCO2 and LnGDPPC have a substantial positive association (0.9543), suggesting that higher CO2 emissions are correlated with higher GDP per capita. Additionally, there is a substantial positive connection between LnELC and LnCO2 (0.9632) as well as LnGDPPC (0.9158), indicating that higher GDP per capita and CO2 emissions are associated with higher electricity consumption. With LnGDPPC (0.3702) and LnCO2 (0.2617), LnOPEN exhibits a moderately high link, although LnPOP has smaller correlations with the other variables and the least overall association.

Table 3. Correlation matrix between the variables under study

variable	LnCO2	LnGDPPC	LnOPEN	LnELC	LnPOP
LnCO2	1				
LnGDPPC	0.9543	1			
LnOPEN	0.2617	0.3702	1		
LnELC	0.9632	0.9158	0.2992	1	
LnPOP	0.3244	0.3681	0.0933	0.2552	1

4. Empirical Findings

4.1 Results of the Cross-Sectional Dependency Test

The existence of cross-sectional dependence between the research variables—such as CO_2 emissions, economic growth, and other variables—is ascertained by the CD Test. Ignoring this test could result in the model's estimates being skewed. There is no cross-sectional dependence between the cross-sectional units, according to the test's null hypothesis (Pesaran, 2015).

Table 4. Results of cross-sectional dependence analysis

Variable	CD-test	P-value	Average joint T
LnCO2	11.817	0.000	31.00
LnGDPPC	21.182	0.000	31.00
LnOPEN	14.442	0.000	31.00
LnELC	31.979	0.000	31.00
LnPOP	13.614	0.000	31.00

The preceding table's data indicate that the p-value is significantly less than 0.05. At the 5% significance level, this suggests that the null hypothesis is rejected and that there is cross-sectional dependence among the units for every research variable.

4.2 Panel Unit Root Tests

To determine whether the study variables are stationarity, the CIPS test must be run prior to the long-term comparison between variables. It should be noted that this test accounts for cross-sectional dependence more accurately than the IPS (Im-Pesaran-Shin) test, which does not.

Table 5. Results of unit root test

Variable	Level		1er difference	
	Const	Const+trend	Const	Const+trend
LnCO2	-2.245*	-1.975	-4.973***	-5.009***
LnGDPPC	-2.241*	-2.908***	-4.208***	-4.212***
LnELC	-1.857	-1.856	-5.094***	-5.009***
LnOPEN	-1.841	-2.471	-4.726***	-4.773***
LnPOP	-2.894***	-3.503***	-5.324***	-5.485***

** and *** are significant at 5% and 1% levels, respectively

Except for GDP per capita (LnGDP) and the population growth rate (LnPOP), which are stationary at level at the 5% significance level, all variables (LnCO2, LnELC, and LnOPEN) become stationary after taking the first difference at the 5% significance level, according to the results of the CIPS test in the above table. The Westerlund test is the proper test in this situation to see if there is cointegration among the research variables (Westerlund, 2007) as displayed in Table 6 below.

Table 6. Results of Westerlund test

Statistic	Value	Z-value	P-value
Gt	-2.937	-1.996	0.023
Ga	-12.790	0.084	0.533
Pt	-12.368	-3.736	0.000
Pa	-13.715	-2.252	0.012

The results of the Westerlund cointegration test clearly show cointegration among the research variables, suggesting a relationship of long-term equilibrium between the variables. Thus, we employ the CS-ARDL model to calculate the short- and long-term correlations in East Asia and North Africa between CO2 emissions, economic growth, and other explanatory factors (Chudik & Pesaran, 2015). Table 7 provides further information about this.

Table 7. Results of CS-ARDL analysis (long run)

Variables	Coefficients	Std.err	Significance Level
Long-Run Estimates			
LnGDPPC	0.3569**	0.1517	0.019
LnELC	0.3867***	0.1304	0.003
LnOPEN	0.0044	0.0641	0.945
LnPOP	0.0592**	0.0289	0.041
Short-Run Estimates			
LnCO2	0.1787**	0.0728	0.014
LnGDPPC	0.2342**	0.1036	0.024
LnELC	0.3302***	0.770	0.000
LnOPEN	0.0359	0.0374	0.337
LnPOP	0.0514*	0.0269	0.056
ECT	-0.8212***	0.0728	0.000

** and *** are significant at 5% and 1% levels, respectively

Apart from the trade openness indicator, which is not significant over the long or short terms, most of the estimates in the table above that displays the connections over the short and long terms are statistically significant at the 5% level. Conversely, most of the studies we previously studied and economic theory agree with the coefficients of the explanatory variables for CO_2 emissions. Furthermore, there is a negative and large error correction term at the 1% level, suggesting that the model has an error correcting mechanism. To restore to the long-term equilibrium state, about 82% of short-term errors can be fixed in a year.

We find that, at the 5% significance level, the per capita GDP coefficient is positive and significant (both in the short and long terms) based on our analysis of the data. Accordingly, a 1% rise in per capita GDP causes a short-term increase in CO_2 emissions of 0.23% and a long-term increase of 0.35%. According to some earlier research (Alkasasbeh et al., 2023; Espoir et al., 2023 and Khalfaoui et al., 2023) and economic theory, this result is consistent.

It is common knowledge that more economic expansion necessitates a greater demand for energy, which in turn drives up demand for vital sectors like mining, petrochemicals, cement, oil, and natural gas. These sectors may be more responsible for rising environmental pollution, particularly carbon dioxide emissions. We also find that, at the 1% significance level, the per capita electricity consumption coefficient is positive and significant (both in the short and long terms). Accordingly, a 1% increase in the average person's electricity consumption causes a short-term rise in CO_2 emissions of 0.33% and a long-term increase of 0.38%. This outcome is in line with most research. Notably, out of all the factors in the model, per capita energy usage had the biggest effect on CO_2 emissions. This makes sense because the production of electricity frequently uses fossil fuels that aren't renewable, such as coal, oil, and natural gas, all of which release significant amounts of CO_2 that contribute to global warming.

Due to numerous daily human activities, population increase also contributes to CO_2 emissions. The population growth rate coefficient in our analysis is positive and significant at the 5% long-term level and at the 10% short-term level, which supports this. In the short and medium run, respectively, CO_2 emissions rise by 0.051% and 0.059% with each increase in the population growth rate. Nonetheless, in comparison to other explanatory variables, its effect is quite minor. This results from the fact that human activities vary and that certain activities emit more CO_2 than others.

Trade openness, the final explanatory variable, has a positive but negligible coefficient at the 5% significance level. Its short- and long-term effects on CO_2 emissions are different, though. It seems to decline with time, indicating that trade openness might eventually make it easier for poorer nations to acquire cleaner, greener technologies (see Table 8).

Table 8. Dumitrescu and Hurlin (2012) test results

Null Hypothesis	W-stat	Zbar-stat	Prob
LnGDPPC does not homogeneously cause LnCO2	5.4707	12.2436	0.0000
LnELC does not homogeneously cause LnCO2	2.5491	4.2423	0.0000
LnOPEN does not homogeneously cause LnCO2	3.2943	6.2831	0.0000
LnPOP does not homogeneously cause LnCO2	1.7322	2.0051	0.0449

The null hypothesis, according to which GDP per capita does not Granger-cause CO2 emissions, was rejected based on the findings of the Granger causality test shown in the above table and the Granger non-causality test conducted by Dumitrescu and Hurlin (2012). This is since, at the 5% significance level, GDP per capita does Granger-cause CO2 emissions, as shown by the p-values for the Z-bar and W-statistics being less than 0.05. Similarly, at the 5% significance level, it was discovered that population growth rate, trade openness, and power use per capita all Granger-cause CO2 emissions.

5. Conclusion, Policy Implications and Limitations

The goal of this econometric study was to examine how economic expansion affected CO2 emissions in East Asia and North Africa between 1990 and 2020 (this time frame was chosen because data for many of the nations were available). The CD-test indicated that there was cross-sectional dependence among the variables under investigation, which led to the use of the CS-ARDL model to answer the research topic. The CIPS test was also used to assess the longitudinal data series' stability, and the results indicated that the series are stationary at both level and first difference. Westerlund (2007) test was used to confirm cointegration among the variables. Ultimately, the CS-ARDL model was acquired, and it was discovered that this model had an error correction mechanism that allows 82% of short-term errors to be repaired in less than a year to restore the long-term equilibrium. Additionally, the research demonstrated a positive correlation between the explanatory factors and North African and East Asian CO2 emissions, such First, there is a positive correlation between CO2 emissions and GDP per capita. This is because critical industries like mining, oil, natural gas, petrochemicals, and cement are necessary for economic growth in any nation over the long run and their effects do not diminish with time. It was also shown that there is a positive correlation between CO2 emissions and the amount of power consumed per person, given that electrical energy is produced from non-renewable fossil fuels. Thirdly, the study also discovered a significant correlation between CO2 emissions and the rate of population expansion, supporting the idea that a variety of growing human activities contribute to environmental damage. Lastly, albeit it is not statistically significant, there is a positive correlation between trade openness and CO2 emissions in the countries studied.

The findings demonstrate a robust long-term cointegrating relationship between economic expansion and CO2 emissions. Long-term increases in electricity consumption and CO2 emissions are positively correlated with increased economic growth, with the latter having a larger effect. There is less of a correlation between trade openness and population size and CO2 emissions. The results demonstrate robustness to several empirical challenges, including autocorrelation, heteroskedasticity, and model misspecification. Diagnostic tests confirm the stability of the long-run parameters and the accuracy of the CS-ARDL calculations. Which is consistent with the study of (Arouri et al., 2012; Farhani & Rejeb, 2012; Munir et al., 2020 and Batmaz et al., 2023). In addition, this study's findings are distinct from those of previous research that used a different tack when addressing the subject. The disparity results from the study countries' varied composition, with the Middle East and North Africa comprising a different group than the European Union, North America, and South America. As an illustration, we may discuss, but not be limited to, the research of (Hossain, 2011; Sebri & Ben-Salha, 2014 and You et al., 2022)

Policymakers in East Asian and North African nations can benefit greatly from the CS-ARDL model's investigation of the relationship between economic growth and CO2 emissions. The necessity of including environmental factors into economic planning is highlighted by the significant association found between GDP per capita and CO2 emissions. To separate economic growth from CO2 emissions, policymakers should prioritize supporting sustainable practices and green technologies. Enacting laws that encourage renewable energy and energy efficiency can help to both promote economic growth and lessen the impact on the environment. Furthermore, the power sector must switch to greener energy sources due to the close correlation between electricity usage and CO2 emissions. Governments might impose more stringent emission regulations and offer financial support for low-carbon technology.

Policies pertaining to climate change can also be made more successful by international collaboration and knowledge exchange between different regions. Collaborative research and development projects can hasten the implementation of cutting-edge techniques and creative fixes. Moreover, raising public knowledge of how economic activity affects the environment can help to promote a sustainable culture, which is crucial for long-term success.

The CS-ARDL model has drawbacks even if it provides insightful information. First, because the model relies heavily on historical data, it might not accurately reflect current technical developments or changes in the regulatory landscape, which could have an impact on the correlation between CO2 emissions and economic growth. Second, additional variables that could affect emissions independently of GDP growth are not considered by the model, such as modifications in the industrial makeup or advancements in technology. Furthermore, by concentrating only on aggregate data, the study may have missed regional differences across the nations it examined, which could have resulted in less customized policy suggestions. Finally, it should be noted that the CS-ARDL model relies on linear connections between variables, which might not account for the more nuanced dynamics of economic growth and emissions.

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