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The impact of energy consumption on climate change in MENA countries Using panel Cointegration Analysis During the period 2000-2023

تأثير استهلاك الطاقة على التغير المناخي لدول MENA التكامل المتزامن لمعيطات بانل خلال الفترة 2000-2023

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Abstract:
This study aims to measure the impact of energy consumption on climate change in the Middle East and North Africa (MENA) region. The study covers 18 countries using panel data techniques, with carbon dioxide (CO_2) emissions employed as the dependent variable, while energy consumption, gross domestic product (GDP), and foreign direct investment (FDI) serve as the independent variables. The study finds a positive relationship between energy consumption and CO_2 emissions, as well as a bidirectional causal relationship between these two variables. The most important recommendation is to promote the use of renewable energy sources in order to achieve sustainable development.

Keywords: Energy Consumption, Renewable Energy, Carbon Dioxide (CO_2), Panel Data

الملخص:

تهدف هذه الدراسة الى قياس تأثير استهلاك الطاقة على التغير المناخي في دول شمال افريقيا وشرق الأوسط ،وكانت الدراسة على 18 دولة باستخدام بيانات بانل باستخدام مؤشر انبعاثات ثاني أكسيد الكربون كمتغير تابع، وجاءت متغيرات استهلاك الطاقة والناتج الداخلي الخام والاستثمار الأجنبي المباشر كمتغيرات مستقلة.

وتوصلت الدراسة الى وجود علاقة موجبة بين استهلاك الطاقة و انبعاثات ثاني أكسيد الكربون، إضافة الى وجود علاقة سببية ذات اتجاهين بين المتغيرين السابقين. وأهم توصية هي العمل على استخدام الطاقات المتجددة من أجل تحقيق التنمية المستدامة.

الكلمات المفتاحية: استهلاك الطاقة ،الطاقات المتجددة ،ثاني اسيد الكربون ،بيانات بانل

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1.INTRODUCTION

The energy sector is considered the lifeblood of national economies and a fundamental pillar of economic development, particularly in the countries of the Middle East and North Africa (MENA) region. These countries are facing increasing carbon dioxide (CO_2) emissions resulting from the intensive use of fossil fuels. This situation is mainly due to the rentier nature of many MENA economies on the one hand, and the rapid population growth, urban expansion, and industrial development on the other. All these factors have contributed to a significant increase in carbon emissions, leading to climate change phenomena associated with global warming and air pollution.

In recent years, some countries in the region have sought to transition toward renewable energy sources despite facing numerous economic and geopolitical challenges. However, this transition remains difficult because of several constraints and obstacles.

Based on the above, the main research question can be formulated as follows:

What is the impact of energy consumption on climate change in the countries of the Middle East and North Africa (MENA)?

The following sub-questions can also be raised:

Is there a positive relationship between energy consumption and climate change?

Is there a causal relationship between energy consumption and climate change, and if so, in which direction?

Hypotheses

There is a positive relationship between energy consumption and climate change.

There is a unidirectional causal relationship between energy consumption and climate change.

Research Aims

To review previous theoretical and empirical studies that have directly or indirectly addressed the relationship between energy consumption and environmental pollution.

To understand the relationship between energy consumption and environmental pollution.

To measure the impact of energy consumption on environmental pollution in MENA countries using econometric methods.

The research was divided as follows:

2. Empirical Studies

This section presents and analyzes a number of previous studies and empirical research that have addressed the relationship between energy consumption and climate change across different regions and economic blocs around the world. The methodology and main findings of each study are summarized as follows:

Jana Chovancova et al (2025) examined the relationship between different energy sources and carbon dioxide (CO_2) emissions in the countries of the European Union. Specifically, the study analyzed the effects of natural gas, coal, oil, wind energy, biofuels, solar energy, hydropower, and nuclear energy on CO_2 emissions. The findings revealed significant differences in the impacts of various energy sources on carbon emissions across EU countries. The results also indicated that coal, oil, and natural gas have positive and statistically significant effects on CO_2 emissions, with coal exerting the largest impact. The study employed panel data models covering the period from 2011 to 2022.

Yongming Huang et al (2025) confirmed previous findings that fossil energy consumption contributes to an increase in carbon dioxide emissions. The study also found that forest area, human capital, and renewable energy have a negative and statistically significant effect on environmental pollution, implying that they contribute to reducing CO_2 emissions. The analysis covered the BRICS countries during the period 1990–2020 and utilized panel data models to provide policy recommendations aimed at supporting the achievement of sustainable development goals.

In the same context, a study by Jana Chovancova et al (2024) aimed to analyze the factors influencing CO_2 emissions in 22 European countries over the period (1992–2019). These factors included gross domestic product, total energy consumption, renewable energy, nuclear energy, urbanization, energy intensity, import dependence, and the share of industry in GDP. The study employed traditional panel models alongside advanced estimation techniques, such as the common correlated effects (CCE) approach, as well as two-stage instrumental variables estimation with common factors (2SIV – two-stage

instrumental variables approach). The results of this study indicated that a number of factors have a significant impact on CO_2 emissions. According to the 2SIV model, an increase in renewable energy production contributes to reducing CO_2 emissions, while the expansion of nuclear energy production also helps reduce CO_2 emissions, albeit to a lesser extent. The study results also showed that increased energy consumption is positively and strongly associated with CO_2 emissions. As for energy intensity, it has a slight effect on CO_2 emissions within the 2SIV framework, suggesting an improvement in energy efficiency. The same findings were reached by Hakan Altın (2024). Similarly, a study by Ayad Hicham et al (2023) aimed to examine and analyze the impact of economic uncertainty, economic growth, and energy consumption on environmental pollution in the Middle East and North Africa (MENA) region. This study reached several conclusions, the most important of which is the confirmation of the Environmental Kuznets Curve (EKC) hypothesis in all the countries studied. Additionally, both energy consumption and population growth contributed to increasing carbon dioxide emissions in all the countries examined over the study period. In the same context, a study by Mohammed Touitou (2021) was also conducted.

As indicated by a study by Hui Dai et al (2022), climate change is closely linked to economic output, as countries with higher GDP per capita are among the largest producers of carbon dioxide emissions. This was confirmed by a study by Richard Gardinera and Petr Hajekb (2020), which found, in the context of EU member states, a unidirectional causal relationship running from GDP to energy consumption and CO_2 emissions. Similarly, a study by Zeeshan Khan et al (2020) supported the above findings, showing that imports and income contribute to increasing consumption-based carbon emissions,

while exports, environmental innovation, and renewable energy consumption reduce such emissions. These results are consistent with those of BALOCH et al (2019), who identified an interactive relationship between natural resources and carbon dioxide emissions. Furthermore, a study by Festus Victor Bekun et al (2019) reinforced what some earlier research had found—namely, that heavy reliance on natural resource revenues adversely affects environmental sustainability. In addition, both non-renewable energy consumption and economic growth were found to increase CO_2 emissions, while renewable energy consumption tends to reduce them. The same conclusions were reached by other studies, such as those by Umer Jeelanie Banday and Ranjan Aneja (2019) and Muhammad Shahbaz et al (2018).

A study by Javeria Maryam et al (2017) also addressed the relationship between growth and climate change, and found that carbon dioxide emissions are positively correlated with GDP and energy consumption in the BRICS countries.

3. Evolution of carbon dioxide (CO2) emissions in the countries of the MENA region:

The following table presents the evolution of carbon dioxide (CO_2) emissions in the MENA region over the period 2000–2023, arising from various economic and industrial activities.

Table 1: Evolution of CO_2 emissions in the MENA region by sector, 2000–2023 (in Mt CO_2e).

Years	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**
CO_2 Emissions	969 ,60	1015,10	1035,30	1065,30	1138,50	1215,50	1281,00	1143
Years	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**

CO_2 Emissions	1385,00	1430,70	1456,70	1463,80	1532,40	1558,10	1602,60	1600
Years	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**
CO_2 Emissions	1645,00	1732,40	1739,60	1792,30	1801,20	1913,60	1946,80	1978

Source: World Bank Database.

As shown in the table, carbon dioxide (CO_2) emissions have risen markedly across MENA countries over the study period. This upward trend can be attributed to multiple factors, including rising emissions from energy use in buildings, the industrial sector, and transportation. Many countries in the region are experiencing sustained population growth, which has been accompanied by a significant expansion of the building sector and rapid urbanization. This has driven up energy demand for residential uses, particularly cooling and heating. Indeed, energy consumption in buildings recorded a steady increase from 163.6584 Mt CO_2e in 2000 to 296.2524 Mt CO_2e in 2023. This is largely due to the limited adoption of modern construction technologies that could improve energy efficiency, resulting in a persistent lack of energy performance standards across the sector. Regarding industrial emissions, they also showed continuous growth, rising from 211.5538 Mt CO_2e in 2000 to 435.0476 Mt CO_2e in 2023. This expansion is closely linked to the growth of industrial activities, particularly in petrochemicals, gas, and oil sectors in countries such as Saudi Arabia, Qatar, and the United Arab Emirates. For instance, CO_2 emissions in the UAE increased from 5.60 Mt CO_2e in 2000 to 19.60 Mt CO_2e in 2023, with a similar trajectory observed in Qatar, albeit at a lower scale in Algeria, Tunisia, and Morocco. This persistent rise highlights the region's limited success in implementing sustainable industrial policies aimed at curbing

emissions.

Another major factor contributing to rising emissions is the transport sector, which is a significant source of CO_2 emissions in the MENA region. This is largely due to a substantial increase in the use of both private cars and public transport. Emissions from this sector rose from 295.3025 Mt CO_2e in 2000 to 597.7662 Mt CO_2e in 2023. This remarkable increase reflects the expansion of transport infrastructure, urban sprawl, and the development of major road networks, all of which have driven up fuel demand. Although some countries—notably Qatar and the United Arab Emirates—have begun to adopt electric and hybrid vehicles, and to a lesser extent North African nations, the overall impact on emissions reduction remains limited so far.

In summary, the analysis of CO_2 emissions trends across the MENA region reveals that the transport sector is a major contributor to overall emissions, thereby aggravating the impacts of climate change. This underscores the responsibility of regional governments to enhance energy efficiency across all sectors, with particular emphasis on transport, while also promoting the use of natural gas and cleaner fuels. Furthermore, it calls for redirecting investments toward cleaner and more sustainable energy sources. However, this transition remains challenging, given that most countries in the region are heavily dependent on oil revenues and fossil fuel-based economies.

4- Econometric analysis of the impact of energy consumption on climate change:

4-1 Study Methodology and the Econometric Model Used

In order to conduct a standard empirical study, we will rely

on panel data for 18 countries from the Middle East and North Africa region (n=18) over the period from 2000 to 2023, where t=24. Thus, the total number of observations used in the analysis (t·n) will be 432. The panel cointegration analysis technique will be employed to verify the existence of a long-run equilibrium relationship among variables that are non-stationary over time, as well as to distinguish the genuine long-run relationship from spurious correlations arising from time trends.

The model for this study is formulated to analyze the impact of energy consumption on climate change in the MENA region countries, based on the economic background and with reference to similar previous studies. The general form of the model can be expressed as follows:

$$CO2_{it} = a_{0i} + b1iGDP_{it} + b2iFDI_{it} + b3iEC_{it} + \varepsilon_{it}$$

Where:

CO_2 : Carbon dioxide emissions per capita.

GDP : Gross Domestic Product (at constant 2010 US dollars).

FDI : Foreign Direct Investment.

EC : Total primary energy consumption.

(b_1, b_2, b_3) : Coefficients that measure the long-run relationship.

a_0 : The constant term in the long-run equation.

ε : The error term.

The above equation expresses a long-run equilibrium relationship between per capita CO_2 emissions (the dependent variable) and several other independent variables, namely GDP, foreign direct investment, and total primary energy consumption, provided that a cointegration relationship is found to exist among these variables. For this purpose, it is required that the data be integrated of the same order so that cointegration tests can be properly applied. Since the data used in our study

are in panel form, the application of unit root and cointegration tests requires a minimum level of homogeneity across the units—i.e., the countries included in the sample—in order to obtain reliable and generalizable results. To this end, we divided the study sample into 18 countries with similar economic characteristics, which allows for a reasonable degree of homogeneity. Furthermore, the data used in this study are sourced from the World Bank.

4-2 Unit root tests

In order to verify the stationarity of the time series, we conducted several panel unit root tests, including the LLC (Levin, Lin & Chu) test, the IPS (Im, Pesaran & Shin) test, the Breitung (BRT) test, and the Maddala & Wu (MW) test. The following table presents the results of these tests.

Table 2: Results of Unit Root Tests

Null: Unit Root							Null: NO Unit Root	
Methods	**Variables**	**Levin, Lin and Chu (LLC)**	**Breitung t-stat**	**Im, Pesaran And Shin (IPS) W-stat**	**MW–ADF Fisher Chi-square**	**MW–PP Fisher Chi-square**	**Hadri Z-stat**	**Heteroscedastic consistent Z-stat**
Level	***CO2***	**-1.24077 (0.1073)**	**-1.41899 (0.0780)**	**-1.75467 (0.0397)**	**19.6148 (0.0331)**	**14.5133 (0.1508)**	**3.00204 (0.0013)***	**2.02516 (0.0214)**
	EC	**-0.99791 (0.1592)**	**-2.55343 (0.0053)***	**-1.19868 (0.1153)**	**16.1654 (0.0950)**	**16.4948 (0.0863)**	**2.68161 (0.0037)***	**2.29885 (0.0108)**
	FDI	**-2.67727 (0.0037)***	**-1.08284 (0.1394)**	**-3.40404 (0.0003)***	**30.0389 (0.0008)***	**19.4475 (0.0349)**	**1.69570 (0.0450)**	**1.69455 (0.0451)**
	GDP	**-1.22666 (0.1100)**	**1.10374 (0.8651)**	**-1.58213 (0.0568)**	**15.0433 (0.1305)**	**8.43628 (0.5863)**	**3.56005 (0.0002*)**	**2.48824 (0.0064)***
First difference	**Δ*CO2***	**-6.70475 (0.0000)***	**-4.77474 (0.0000)***	**-7.02706 (0.0000)***	**55.6559 (0.0000)***	**180.345 (0.0000)***	**1.68828 (0.0457)**	**5.33730 (0.0000)***
	Δ*EC*	**-8.04939 (0.0000)***	**-7.98605 (0.0000)***	**-6.98314 (0.0000)***	**54.8273 (0.0000)***	**306.317 (0.0000)***	**-0.10007 (0.5399)**	**3.87356 (0.0001)***
	Δ*FDI*	**-4.96927 (0.0000)***	**-2.91911 (0.0018)***	**-6.40446 (0.0000)***	**50.3448 (0.0000)***	**59.6577 (0.0000)***	**1.44102 (0.0748)**	**0.68456 (0.2468)**
	Δ*GDP*	**-3.38372 (0.0004)***	**-2.69087 (0.0036)***	**-3.14411 (0.0008)***	**25.6583 (0.0042)***	**22.4400 (0.0130)**	**2.91169 (0.0018)***	**2.55392 (0.0053)***

* Significance at 1%. Δ is the first difference operator.

Source: Outputs generated by EViews 13.

The unit root test results, as reported in the table above, show that all variables for the MENA region countries are non-stationary at levels, indicating the presence of a unit root. However, after applying the first difference, all variables become stationary, as the p-values associated with the test statistics are below the 1%, 5%, and 10% significance levels. This confirms that all variables are integrated of order one, I(1). Consequently, we proceed to the next step, which involves testing for the existence of a long-run equilibrium relationship using panel cointegration tests.

4-3 Panel Cointegration Test

As shown in Table 4, the majority of Pedroni test statistics reject the null hypothesis of no cointegration at the 1% and 5% significance levels, indicating the presence of a long-run equilibrium relationship among the variables. This finding allows us to estimate the long-run coefficients using appropriate panel estimation techniques.

Table 3: Cointegration Tests

Methods	Within dimension (panel statistics)			Between dimension (individuals statistics)		
	Test	Statistics	Prob	Test	Statistics	Prob
Pedroni (1999)	Panel v-statistic	2.020319	0.1668	Group ρ-statistic	0.457190	0.6976
	Panel rho-statistic	-1.590889	0.2874	Group pp-statistic	-8.958542	0.0061
	Panel PP-statistic	-5.111237	0.0010	Group ADF-statistic	-6.469957	0.0000
	Panel ADF-statistic	-4.673604	0.0005			
Pedroni (2004) (Weighted statistic)	Panel v-statistic	0.987656	0.2844			

Panel rho-statistic	**-0.552836**	**0.3358**
Panel PP-statistic	**-4.724618**	**0.0000**
Panel ADF-statistic	**-3.848843**	**0.0000**

* Significance at 1%. Δ is the first difference operator.

Source: Outputs generated by EViews 13.

The above table summarizes the results of the Pedroni cointegration test according to seven different statistics. The results indicated strong statistical significance for four main statistics: the Panel PP-Statistic and Panel ADF-Statistic for the within-dimension tests, and the Group PP-Statistic and Group ADF-Statistic for the between-dimension tests. The probability values associated with these statistics were less than the 5% significance level, leading us to reject the null hypothesis H_0, and thus confirming the existence of a cointegration relationship among the variables in the model.

These results demonstrate the importance, power, and accuracy of panel cointegration tests compared to traditional time-series cointegration tests, especially in detecting long-run equilibrium relationships across different time and spatial units. Accordingly, we will estimate the long-run relationship using both the FMOLS and DOLS methods, as developed by Pedroni and Mark & Sul. The results show some variation in estimation between the two methods.

4-4 Estimation of the Long-Run Cointegration Relationship in Panel Data

The estimation results presented in Table 5 indicate that all explanatory variables are statistically significant and carry the expected signs. Specifically, both GDP and total primary energy consumption exert a positive and significant impact on CO_2 emissions per capita, while FDI shows a ... (negative/positive) effect. Furthermore, the FMOLS and DOLS estimates are largely consistent in terms of sign and significance, although

some differences in magnitude are observed. This variation may be attributed to the different correction mechanisms employed by each method for endogeneity and serial correlation. Overall, these findings confirm that economic growth and energy consumption are key drivers of environmental degradation in the MENA region, consistent with prior empirical literature.

Table 4: Long-Run Cointegration Relationship Estimation Using FMOLS and DOLS

Dependent Variable	FMOLS			DOLS		
"CO2"						
	Independent Variables			Independent Variables		
Variables	*EC*	*FDI*	*GDP*	*EC*	*FDI*	*GDP*
WithinResults	[0.647490	[0.420227	[0.378712	[-0.02903	[0.062989	[0.296869
	11.11854	7.013864	6.827410	-0.58922	7.478946	4.430288
	(0.0000)*	(0.0000)*	(0.0000)*	(0.5572)	(0.0000)*	(0.0000)*
BetweenResults	[0.447576	[0.045292	[0.162312	[0.788483	[0.031560	[0.135718
	6.458961	5.702576	4.930973	4.528072	1.559736	2.964775
	(0.0000)*	(0.0000)*	(0.0000)*	(0.0000)*	(0.1224)	(0.0039)*

* Significance at 1%. Δ is the first difference operator.

Source: Outputs generated by EViews 13.

The above table shows the long-run relationship between carbon dioxide (CO2) emissions and some other variables, namely energy consumption (EC), gross domestic product (GDP), and foreign direct investment (FDI). The results of the FMOLS method, with respect to within-dimension estimators, indicate a strong positive and statistically significant relationship at the 1% significance level between energy consumption and CO_2 emissions, where a 1% increase in energy consumption leads to a 0.647940% increase in CO_2 emissions. This has been confirmed by many studies, including the study by Sarikaya and Cetintas (2015), which was conducted in the United Kingdom and the United States, as well as the study by Rossazana Ab-

Rahim and Teoh Xin-Di (2016).

There is also a positive and statistically significant relationship at the 1% level between foreign direct investment and CO_2 emissions, where a 1% increase in FDI leads to a 0.420227% increase in carbon emissions, indicating that FDI flows may be directed toward emission-intensive sectors, consistent with the findings of Hongfeng Peng (2016).

Moreover, the results reveal a positive and statistically significant relationship at the 1% level between gross domestic product (GDP) and CO_2 emissions, whereby a 1% increase in GDP leads to a 0.378712% rise in CO_2 emissions. This finding is consistent with the results obtained by Petar Mitić (2017).

As for the between-dimension (between-groups) estimators, energy consumption has a positive and statistically significant effect at the 1% significance level on CO_2 emissions, where a 1% increase in energy consumption leads to a 0.447576% increase in emissions, supporting the hypothesis that energy consumption is among the main causes of environmental degradation.

Foreign direct investment has a limited effect, with a coefficient of 0.045292, and although it is relatively low, it remains noticeable.

Regarding gross domestic product, it has a positive and statistically significant effect at the 1% level, with a coefficient of 0.162312, meaning that it contributes to increasing emissions, but at a moderate level.

As for the DOLS method, the within-dimension (within-groups) results indicate that the energy consumption coefficient is negative (-0.02903) and insignificant ($p = 0.5572$), indicating the absence of a long-run relationship between energy consumption and carbon emissions at the within-dimension level according to this method. Foreign direct investment has a

positive and significant effect at the 1% significance level, but this effect remains limited as its coefficient is relatively low at 0.062989. Regarding gross domestic product, it has a strong positive relationship at the 1% significance level, where a 1% increase leads to a 0.296869% increase in emissions.

As for the between-dimension (between-groups) results, energy consumption is positively and significantly related to emissions at the 1% level, where a 1% increase in consumption leads to a 0.788483% increase in emissions, reflecting a significant direct impact of energy consumption on emissions. The FDI coefficient is insignificant at 0.031560 ($p = 0.1224$), indicating the absence of a long-run relationship at the between-dimension level for this method. Regarding GDP, it has a positive and statistically significant relationship at the 1% level, reflecting the continued positive relationship between economic growth and carbon emissions.

4-5. Granger Causality Test for Panel Data

Having confirmed the existence of a long-run cointegrating relationship between carbon dioxide emissions and the various other explanatory variables, we now proceed to analyze the causal relationships among these variables. The following table presents the results of the Granger causality tests, for which the optimal lag structure was determined using the Akaike Information Criterion (AIC) and the Schwarz Criterion (SC) to ensure estimation accuracy and robustness.

Table 5: Panel Granger Causality Test Results

Lags 3	CO2	EC	FDI	GDP
CO2		4.97552* (0.0007)	7.08599* (3.E-07)	4.65216* (0.0051)

EC	**10.14536*** **(0.0092)**		**5.70221*** **(3.E-09)** →	**7.69292** **(0.0154)**
FDI	**0.73872** **(0.6189)**	**1.84473** **(0.3477)**		**4.69552** **(0.0002)***
GDP	**1.68292** **(0.5684)**	**5.72757** **(0.0008)***	**3.58036** **(0.0983)**	

* Significance at 1%.

→ : denotes that there is causality.

▭ : Absence of causality sens.

✕ : means the relationship between each Variable and himself.

Source: Outputs generated by EViews 13.

The results of the Granger causality test in the above table show the directions of causal relationships between the variables (CO_2, EC, FDI, and GDP), which were estimated at the 1% significance level.

The results in the above table indicate a bidirectional causal relationship between CO_2 emissions and energy consumption (EC), as both null hypotheses—"energy consumption does not cause CO_2 emissions" and "CO_2 does not cause energy consumption"—are rejected for the MENA region countries. This supports the adoption of the feedback hypothesis, reflecting mutual influence, and this pattern of relationships is a clear indicator of the association between energy use and CO_2 emissions.

The results also show a unidirectional causal relationship running from foreign direct investment (FDI) to GDP, as the null hypothesis "FDI does not cause GDP" is rejected, while the reverse relationship remains insignificant, indicating that FDI contributes to enhancing economic growth.

A bidirectional causal relationship has also been observed

between energy consumption (EC) and GDP, reflecting the dependence of economic growth on energy demand and vice versa, as increased economic activity leads to higher energy consumption.

5. CONCLUSION

The study of the relationship between energy consumption and climate change is among the topics that have garnered significant attention from public policymakers. Countries are making concerted efforts to reduce their reliance on conventional energy sources, particularly fossil fuels, which constitute the overwhelming majority of energy use in the countries under study. Consequently, these countries must strive to improve energy efficiency and transition toward renewable energy sources, which offer greater sustainability.

In this research paper, we have attempted to review the most important empirical studies that have addressed the topic of energy consumption and climate change, in accordance with the economic philosophy of each country and each researcher. We have also conducted an applied econometric study on the impact of energy consumption on climate change in the Middle East and North Africa (MENA) region, relying on statistics from 18 countries, using panel data techniques.

The main findings of this study can be summarized as follows:

A strong positive and statistically significant relationship at the 1% level was found between energy consumption and CO_2 emissions, whereby a 1% increase in energy consumption leads to a 0.647940% rise in CO_2 emissions, according to the within-dimension FMOLS estimates.

A positive and statistically significant relationship at the 1% level was found between foreign direct investment and CO_2 emissions, whereby a 1% increase in FDI leads to a 0.420227%

increase in carbon emissions, based on the within-dimension FMOLS results.

A positive and statistically significant relationship at the 1% level was found between gross domestic product and CO_2 emissions, whereby a 1% increase in GDP leads to a 0.378712% rise in CO_2 emissions, according to the within-dimension FMOLS estimates.

A strong positive relationship was found between energy consumption and emissions at the 1% significance level, according to the between-dimension FMOLS results.

A positive but relatively modest effect of FDI on emissions was observed, while GDP was found to contribute more notably to carbon emissions, based on the between-dimension FMOLS estimates.

No long-run relationship was detected between energy consumption and carbon emissions at the within-dimension level according to the DOLS method.

A positive and statistically significant effect at the 1% level of FDI on carbon emissions was found according to the within-dimension DOLS estimates, while GDP exhibited a strong positive relationship with CO_2 emissions at the 1% significance level.

For the between-dimension DOLS estimates, both energy consumption and GDP exhibited a strong positive and statistically significant relationship with CO_2 emissions at the 1% level, whereas FDI showed no significant effect.

The Granger causality results revealed a bidirectional causal relationship between CO_2 emissions and energy consumption (EC).

A unidirectional causal relationship running from FDI to GDP was identified.

A bidirectional causal relationship was found between

energy consumption (EC) and GDP.

Based on the findings obtained, we proceed to test the following hypotheses:

Confirmation of the first hypothesis, which states that "there exists a long-run equilibrium relationship between total primary energy consumption and CO_2 emissions in the MENA region countries."

Rejection of the second hypothesis, which states that "there is a unidirectional causal relationship between energy consumption and climate change," as the results indicate a bidirectional causal relationship between primary energy consumption and carbon emissions.

Recommendations:

In light of the empirical findings, the following policy recommendations are proposed:

Learning from leading countries: MENA region countries should strive to benefit from the experiences of pioneering nations in energy transition and environmental policy.

Regional cooperation in renewable energy: Enhancing collaboration among MENA countries in the field of renewable energy is essential, including joint ventures in solar, wind, and other clean energy projects.

Encouraging investments and partnerships: Governments should actively encourage both domestic and foreign investments in renewable energy sectors, offering incentives to attract private sector participation.

Supporting infrastructure development: Policymakers should prioritize the development of energy infrastructure, including smart grids, storage facilities, and transmission networks, to facilitate the integration of renewable energy sources and ensure energy security.

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