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Trade Globalization, Remittance Inflows, and Environment Nexus in the Middle East and North Africa: Cross-Sectional Dependence Analysis

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ABSTRACT

Trade globalization and remittance inflows can support economic growth. However, these indicators might have environmental problems due to scale effects in any economy and could be a hurdle in achieving target numbers 8 and 13 of the sustainable development goals (SDGs). Thus, the effects of exports, imports, remittance inflows, and economic growth on CO_2 emissions are tested in 16 MENA economies by using the period 2001-2022 and by using cross-sectional dependence (CSD) econometric techniques. The results confirm the Environmental Kuznets curve (EKC) hypothesis with a threshold point of 13,181 US dollars. 6 out of 16 investigated economies are found in the second phase of the EKC and economic growth could have a pleasant effect in these economies. However, the effects of exports, imports, and remittance inflows on CO_2 emissions are found positive in the long run. Therefore, exports, imports, and remittance inflows have environmental problems in this region. Thus, the research proposes to impose taxes on exports, imports, and remittance inflows to mitigate their environmental effects.

Keywords: Carbon Dioxide Emissions, Sustainable Development Goals 13 and 8, The Environmental Kuznets Curve, Trade Globalization
JEL Classifications: F14, Q51

1. INTRODUCTION

Most Middle East and North Africa (MENA) economies are fossil fuel dependent in terms of their income, trade, and energy consumption. Particularly, some MENA economies are energy-export-driven. Moreover, most MENA nations are among the top polluted countries in the world as per their CO_2 emissions per capita (World Population Review, 2024), and environmental regulations are also weak in most MENA economies (Boulanouar and Essid, 2023), which are responsible for higher emissions. Thus, increasing trade globalization could cause environmental problems in this region. For instance, Saudi Arabia, the UAE, and Qatar are major exporters of oil and gas in the globe (Khatib, 2014) and higher export demand from these economies can contribute to emissions significantly from oil and gas extraction and refining processes. Particularly, the extraction of both oil and gas releases a significant amount of carbon emissions (Masnadi and Brandt, 2017), which are responsible for regional environmental degradation. Carbon emissions are also global emissions, which contribute to global warming. In addition, exports of oil and gas are responsible for carbon leakage from exporter to importer economies (Felder and Rutherford, 1993). Furthermore, other industrial exports may also give rise to carbon emissions due to industrial energy consumption, which is majorly sourced from fossil fuel sources in the MENA region. Some MENA economies are transitioning from fossil fuel dependence to renewable energy consumption (REC) (Gyau et al., 2024). But still, this transition is slow and minute to support the concept of clean economies.

The second major component of trade globalization is imports. Most MENA countries are importing energy-intensive consumer products like automobiles, electronics, and appliances (Mahmood et al., 2023). Particularly, the importation of automobiles might release significant emissions from the transport sector. Moreover, the imports of industrial machinery and other industrial inputs are also energy-intensive. Some MENA countries like Egypt and Morocco are importing a significant amount of natural gas for their electricity generation making their electricity sector emissions-intensive (Khatib, 2014). However, imports can also help to reduce emissions. For instance, Gulf countries and some other MENA countries are targeting for transition to renewable energy and are importing cleaner technologies and infrastructure (Gyau et al., 2024), which can help to reduce emissions from their energy sector. Moreover, the importation of electric vehicles and other energy-efficient products could also help in reducing emissions. In addition, the importation of advanced energy-efficient industrial machinery would help in reducing emissions from the industrial sector.

Remittance inflows can also be responsible for carbon emissions (Li and Yang, 2023). A large number of laborers and businessmen from low or middle-income MENA economies are working in the high-income MENA economies or other parts of the world (Naufal, 2011), who remit their incomes to their mother countries and shape the consumption pattern. For instance, remittance can be utilized for buying energy-intensive vehicles, appliances, and other luxury items (Chen et al., 2023) in the fossil fuel-dependent MENA economies. Moreover, remittance inflows can also promote urbanization, which can raise construction emissions from urban building and infrastructure development (Zhao and Qamruzzaman, 2022). Alternatively, remittance inflows can also help in promoting environmental sustainability. For instance, remittance inflows can be utilized to buy clean technologies (Yang et al., 2021). Likewise, remittances can be utilized for purchasing energy-efficient vehicles, domestic appliances, and industrial machinery (Rahaman and Islam, 2024), which could help in reducing emissions. Moreover, remittance inflows in rural areas can raise energy efficiency by importing sustainable agriculture technologies, which can reduce emissions from the agriculture sector.

The above discussions highlight the positive or negative environmental aspects of exports, imports, and remittance inflows. Therefore, the exact environmental effect of exports, imports, and remittance inflows are analyzed in the MENA region. The MENA literature scrutinized the relationship between exports, imports, and emissions (Mahmood et al., 2023; Al-Mulali and Sheau-Ting, 2014). Still, the nexus between remittance and emissions is ignored in the MENA region. Thus, we aim to probe the influence of exports, imports, and remittance inflows on emissions in 16 MENA economies. The past literature also ignores the possible cross-sectional dependence (CSD) in the model, which is expected due to some common trading and environmental policies and the geographical location of MENA countries. To ensure an empirical contribution to MENA literature, this research applies a CSD-based econometric approach.

2. LITERATURE REVIEW

The trade and emissions nexus has been intensively explored in literature. First, we focus on recent literature investigating the effects of trade on emissions in country-specific studies. For instance, Ehigiamusoe et al. (2024) investigated Malaysia from 1980 to 2021 and found that income, trade openness, and natural resources contributed to emissions. However, technological innovation alleviated these effects. Particularly, innovation moderated adverse environmental impacts of income and trade openness. However, innovation could not moderate adverse environmental impacts of natural resources. Furthermore, innovation had a U-shaped effect on emissions. Wiloso et al. (2024) investigated Indonesia's trade-related carbon emissions and found that the electrical and machinery sectors contributed to export-related emissions. Moreover, metal and chemical industries were also highly carbon-intensive. Aldegheishem (2024) examined Saudi Arabia from 1991 to 2023 and found that trade openness and income raised emissions. Moreover, the EKC was not validated in Saudi Arabia. Faria et al. (2023) scrutinized the environmental impact of Brazil's trade structures and found that exports' incentives and imports' tariff reductions raised emissions in Brazil due to increasing economic activity in energy-intensive sectors.

Yusuf (2023) investigated Nigeria from 1980 to 2020 and validated the EKC. Furthermore, imports and energy usage had adverse effects on environmental quality. However, exports and financial development reduced emissions. Kalaycı and Artekin (2024) examined Turkey and found that freight transport and trade openness raised environmental degradation. Mao et al. (2023) scrutinized China from 2001 to 2015 and found that exports helped reduce emissions. However, imports did not affect emissions. Li et al. (2023) analyzed carbon transfer and found that China's primary production exports to foreign construction sectors increased carbon transfers. Cai et al. (2025) investigated Chinese firms at a micro-level and analyzed the environmental impact of importing behavior. The authors found that importing intermediate goods enhanced environmental performance, which was due to technological efficiency and optimization in processing. Zhang et al. (2023) examined Chinese embodied emissions in the global value chain (GVC) and found that Chinese domestic embodied emissions were found in manufacturing and final goods' exports through GVC. However, Chinese imports reduced global emissions.

The literature also investigated the trade-emissions nexus in the panel analysis. For instance, Hermida et al. (2024) scrutinized 65 economies from 1995 to 2018 and found that GVC participation helped in the reduction of emissions from exports and imports in developed countries. However, backward participation increased emissions. Wang et al. (2024) investigated trade-related carbon emissions by incorporating tariffs into the analysis of 141 economies in 2017 and found that tariffs moderated the distribution of emissions among countries. The analysis suggested that raising carbon prices and adjusting trade tariffs could reduce exports of carbon-intensive goods. Li and Khan (2024) examined the belt and road initiative's (BRI) environmental impacts and found that BRI countries had an extensive share of global trade-related emissions. Developed countries transferred emissions to developing nations. However, technological adjustments in export sectors moderated emissions' responsibilities. Moreover, China's BRI-led investments had environmental benefits by promoting renewable energy in participating countries.

Mpeqa et al. (2023) explored 29 BRI countries from 2008 to 2019 and stated that exports and imports mitigated emissions. Nevertheless, energy inefficiency and population accelerated emissions, and innovation in green technologies helped reduce emissions by raising energy efficiency. Wu et al. (2023) examined the influence of Chinese trade intensity on emissions in 97 BRI nations from 2002 to 2017 and found that imports from China reduced emissions in BRI economies. However, exports to China raised emissions, and the effect was found more dominant in resource-rich countries. Li et al. (2022) analyzed the impact of imports and Chinese FDI on emissions in BRI nations from 2003 to 2018, which raised emissions. Conversely, green innovation and exports mitigated them. Ali and Wang et al. (2024) investigated BRI economies and found that GVC integration increased emissions through energy intensity and industrial structure.

Wang et al. (2024) investigated OECD and G20 countries from 1997 to 2019 and stated that trade openness accelerated emissions in lower quantiles. Nonetheless, it mitigated emissions in other quantiles. Moreover, trade diversification mitigated emissions. Particularly, import diversification had the strongest effect. Furthermore, the nexus between trade openness and emissions was mediated by industrial structure and technological progress. Zhang et al. (2024) scrutinized OECD nations from 1990 to 2021 and found that eco-innovation, exports, and REC reduced CO_2 emissions. However, imports and economic activity raised emissions. Saqib et al. (2024b) examined the largest ecological footprints' economies from 1990 to 2019 and found that innovations, green evolution, and REC enhanced environmental quality. However, financial growth and non-REC mitigated it. Dua et al. (2024) examined five South Asian economies and trade in environmentally friendly goods and cleaner technology transfer helped to mitigate emissions. Moreover, regional collaborations mitigated emissions. However, imports exacerbated emissions due to energy-intensive imported goods.

Wang et al. (2022) scrutinized the effect of energy efficiency on trade-related emissions in BRICS from 1990 to 2019 and found that exports reduced emissions. Nevertheless, affluence and imports raised them. Safi et al. (2023) analyzed BRICS from 1990 to 2020 and stated that imports and gross domestic product (GDP) growth increased emissions. Duodu and Mpuure (2023) assessed Sub-Saharan Africa from 1990 to 2020 and stated that total trade reduced pollution. Further, exports and imports also contributed to pollution reduction. Yu and Du (2025) assessed 11 RCEP nations from 2000 to 2020 and stated that exports initially raised emissions. Nevertheless, their impact turned out to be negative with technology adoption. However, imports exacerbated emissions. Mahmood (2023) explored Latin America from 1970 to 2019 and authenticated the EKC. Furthermore, exports accelerated emissions both domestically and regionally and imports mitigated emissions in neighboring economies. Moreover, financial development worsened environmental degradation. Saqib et al. (2024a) explored various economies from 1990 to 2020 and revealed that mineral exports influenced the transition to REC and financial sector growth acts as a barrier to this transition.

Wang and Kuusi (2024) investigated carbon leakage from the UN trading system and stated that it reduced the carbon intensity of exports. However, it increased the carbon intensity of imports. Demiral et al. (2022) scrutinized the trade-related carbon leakage in Europe from 1995 to 2018 and non-European imports increased emissions in Europe. Moreover, exports exacerbated global emissions. However, REC reduced carbon leakage. Jiang et al. (2022) explored the effects of R and D and political risk on emissions in G7 countries from 1990 to 2020 and found that both reduced emissions. In addition, exports mitigated emissions, and imports and income raised them. Besides, the EKC was also confirmed. Mahmood (2022) scrutinized the impact of trade and FDI on consumption-based emissions in GCC from 1990 to 2019 and confirmed the EKC. Moreover, exports reduced emissions because of negative spillover effects. However, imports increased emissions and FDI reduced emissions. Akif et al. (2025) examined 10 mineral-rich African countries from 2000 to 2020 and indicated that trade, affluence, and mineral rent raised mineral dependency. Conversely, international collaborations reduced it and strict regulations showed no direct impact. However, international collaborations and regulations were found to mitigate the dependency associated with trade.

The literature indicated the prominence of investigating the effect of exports and imports on emissions separately as both might have diverse effects on emissions. So, we examine the effects of exports, imports, and remittance inflows on CO_2 emissions in MENA economies. Moreover, the EKC is also tested in this region.

3. METHODS

The economic growth could pollute the MENA economies due to their heavy dependence on fossil fuels. Increasing economic growth could have scale effects by increasing aggregate demand and energy consumption, which can pollute MENA economies. However, economic growth at a later stage can realize the importance of environmental sustainability and can reduce pollution by adopting energy-efficient technologies and economic sectors, cleaner energy usage, and stricter environmental regulations, which can have technique and composition effects. Considering these arguments, Grossman and Krueger (1991) recommended testing the nonlinear effect of economic progress on pollution, which is an EKC hypothesis. Thus, the present research hypothesizes the quadratic effect of GDP per capita on CO_2 emissions in MENA economies. Trade and remittances would determine the EKC hypothesis. As, exports of MENA economies are majorly from the oil and gas products, which carry highly pollution-intensive extraction and production activities. Moreover, the income of the MENA region is dependent on the exports of oil and gas sectors (Khatib, 2014), which can raise aggregate demand and energy consumption. Thus, MENA's exports can have environmental problems. Conversely, revenues from exports could be invested in the purchasing of clean energy technologies and infrastructure, which could help reduce environmental problems. In another aspect of trade, imports of MENA economies are energy-intensive consumer items like automobiles, electronics, and appliances (Mahmood et al., 2023). Some MENA economies are also importing a significant amount of natural gas for electricity production (Khatib, 2014), which could significantly contribute to emissions. Moreover, MENA economies are importing energy-intensive machinery for their industries. However, imports can also support a cleaner environment by importing clean energy technologies and infrastructure (Gyau et al., 2024). Lastly, some MENA economies are highly dependent on remittance inflows, which can also determine emissions (Li and Yang, 2023). For instance, remittance inflows can raise the demand for energy-intensive vehicles, appliances, and other luxury items (Chen et al., 2023), which can contribute to emissions. Moreover, remittances can also give rise to urbanization, which can stimulate pollution-oriented construction and urban infrastructure development (Zhao and Qamruzzaman, 2022). However, remittance can be used to buy energy-efficient products and renewable energy technologies (Yang et al., 2021), which can reduce emissions. Thus, exports, imports, and remittance inflows can have both positive and adverse environmental consequences. To gauge the exact environmental effects of these indicators, the following model is hypothesized:

$$CO_{2it} = f(GDPC_{it}, GDPC_{it}^2, REM_{it}, EXP_{it}, IMP_{it}) \quad (1)$$

CO_{2it} is the natural logarithm of CO_2 emissions per capita. $GDPC_{it}$ is the natural logarithm of per capita GDP and $GDPC_{it}^2$ is a square term of $GDPC_{it}$. REM_{it}, EXP_{it}, and IMP_{it} are the natural logarithm of the percentages of the remittance inflows, exports, and imports in GDP, respectively. All data is collected from World Bank (2024) from 2001 to 2022 for Algeria, Bahrain, Egypt, Iran, Iraq, Israel, Jordan, Kuwait, Libya, Morocco, Oman, Qatar, Saudi Arabia, Syria, Tunisia, United Arab Emirates.

In the panel of MENA economies, CSD is expected due to their geographical location and common economic structures. Thus, the CSD test is applied to test this issue. First, we start with Breusch and Pagan (1980), which test the pairwise correlation among countries of the panel series in the following LM statistic:

$$LM = \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} tq_{ij}^2 \quad (2)$$

q_{ij}^2 is a coefficient between the cross-sectional series and the same procedure can be applied to the residual of regression in the equation. Afterward, another CSD test by Pesaran et al. (2008) can be utilized with the following CSD statistic:

$$CSD = \sqrt{\frac{2}{n(n-1)}} \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} q_{ij} \quad (3)$$

After testing equation 3, we applied another adjusted version of the CSD test proposed by Pesaran (2021) using the following statistics:

$$CSD_{adj} = \left[\sqrt{\frac{2}{N(N-1)}} \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} q_i j - p \right] / \sigma \quad (4)$$

Equation 4 takes the mean and standard deviation of the coefficient of the pairwise correlation, which is an adjusted version of the Pesaran et al. (2008) test. After confirming CSD, the slope heterogeneity (SH) can also be expected among the countries, which is tested using Pesaran and Yamagata's (2008) procedure in the following way:

$$\Delta = \sqrt{n}\left(\frac{S_n - k}{\sqrt{2k}}\right) \quad (5)$$

$$\Delta_{adj} = \sqrt{N}\left(\frac{S_n - E(S_n)}{\sqrt{Var(S_n)}}\right) \quad (6)$$

S_n captures the average slope of each country's relationship in both tests of Δ and Δ_{adj} later, we may shift our analyses to unit root testing as panel series could have this problem. We focus on the CSD-based tests for this purpose by following the methodology of Pasaran's (2007) CADF tests in the following way:

$$\Delta x_{it} = b_0 + b_{1i} x_{it-1} + b_{2i} \overline{x_{t-1}} + b_{3i} \overline{\Delta x_t} + \sum_{j=1}^{k} b_{4ij} \Delta x_{it-j} + e_{1it} \quad (7)$$

x_{it} is a panel series to be tested for unit root problems with a null hypothesis ($b_{1i}=1$). Alternatively, we can ensure a stationary series. Later, the results of CADF can be verified with the help of the following CIPS statistic:

$$CIPS = \frac{1}{n} \sum_{i=1}^{n} CADF_i \quad (8)$$

The CIPS statistic can be tested with a null hypothesis of all countries carrying a unit root and rejection of it would ensure the stationarity of the panel series. Later, we will test cointegration in the model of equation 1. First, we apply Kao's (1999) technique in the following way:

$$\Delta u_{it} = a e_{it-1} + \sum_{j=1}^{k} b_j \Delta u_{it-1} + v_{it} \quad (9)$$

Equation 9 will be applied to the residual of regressions in equation 1 and its stationarity will be evidence of cointegration in the model. Another residual base technique of Pedroni's (2004) can be utilized to verify Kao's (1999) results, which cares the SH in analysis with the help of the following seven test statistics:

$$T^2 n\sqrt{n} Z_{\hat{v}\,n,T} = T^2 n\sqrt{n} \Big/ \left(\sum_{i=1}^{n} \sum_{t-1}^{T} 1/\hat{L}_{11i}^2 \hat{u}_{i,t-1}^2\right) \quad (10)$$

$$T\sqrt{n} Z_{\hat{\rho}n,T-1} = T^2\sqrt{n}\left(\sum_{i=1}^{n}\sum_{t=1}^{T} 1/\hat{L}_{11i}^2 \hat{u}_{i,t-1} \Delta u_{i,t} - \hat{\lambda}_i\right) \Big/ \left(\sum_{i=1}^{n}\sum_{t=1}^{T} 1/\hat{L}_{11i}^2 u_{i,t-1}^2\right) \quad (11)$$

$$Z_{t\,n,T} = \left(\sum_{i=1}^{n}\sum_{t=1}^{T} 1/\hat{L}_{11i}^2 \hat{u}_{i,t-1} \Delta\hat{u}_{i,t} - \hat{\lambda}_i\right) \Big/ \sqrt{\left(\tilde{\sigma}_{N,T}^2 \sum_{i=1}^{n}\sum_{t=1}^{T} \hat{L}_{11i}^{-2} \hat{u}_{i,t-1}^2\right)} \quad (12)$$

$$Z_{t\,n,T}^{*} = \left(\sum_{i=1}^{n}\sum_{t=1}^{T} 1/\hat{L}_{11i}^2 \hat{u}_{i,t-1}^{*} \Delta\hat{e}_{i,t}^{*}\right) \Big/ \sqrt{\left(\tilde{s}_{N,T}^{*2} \sum_{i=1}^{n}\sum_{t=1}^{T} 1/\hat{L}_{11i}^2 \hat{u}_{i,t-1}^{*2}\right)} \quad (13)$$

$$T\sqrt{n}\tilde{Z}_{\hat{\rho}N,T-1} = T.1/\sqrt{n}\left(\sum_{t=1}^{T}\hat{u}_{i,t-1}\Delta\hat{u}_{i,t} - \hat{\lambda}_i\right)$$
$$\sum_{i=1}^{n}\left[\frac{1}{\sum_{t=1}^{T}\hat{u}_{i,t-1}^{2}}\right)] \quad (14)$$

$$1/\sqrt{n}\tilde{Z}_{t\,n,T} = \frac{1}{\sqrt{N}\left(\sum_{t=1}^{T}\hat{u}_{i,t-1}\Delta\hat{u}_{i,t} - \hat{\lambda}_i\right)}.$$
$$1/\left[\sum_{t=1}^{n}\left(\hat{\sigma}_i^2\sum_{t=1}^{T}\hat{u}_{i,t-1}^{2}\right)\right] \quad (15)$$

$$1/\sqrt{n}\tilde{Z}^{*}_{t\,n,T} = \frac{1}{\sqrt{n}\left(\sum_{t=1}^{T}\hat{u}^{*}_{i,t-1}\Delta\hat{u}^{*}_{i,t}\right)}.$$
$$1/\sqrt{\sum_{t=1}^{n}\left(\sum_{t=1}^{T}\hat{s}_i^{*2}\hat{u}_{i,t-1}^{*2}\right)} \quad (16)$$

Any statistically significant statistics in equations 10-16 can be evidence of cointegration in the model. The above equations care about the SH issue in the analysis and ignore the presence of CSD in the relationship. To care for CSD in cointegration, Westerlund's (2007) methodology offers another residual-based technique in the following way:

$$G_t = N^{-1}\sum_{i=1}^{N}\frac{\hat{\Omega}_i}{\hat{\sigma}_i} \quad (17)$$

$$G_a = N^{-1}\sum_{i=1}^{N}T\hat{\Omega}_i \quad (18)$$

$$P_t = \frac{\sum_{i=1}^{N}\hat{\Omega}_i}{\sqrt{\sum_{i=1}^{N}\hat{\sigma}_i^{\,2}}} \quad (19)$$

$$P_a = \sum_{i=1}^{N}T\hat{\Omega}_i \quad (20)$$

Any statistically significant statistics in equations 17-20 can corroborate cointegration in the model. After doing all of the above analyses, the long- and short-run results can be extracted from the CSD-based auto-regressive distributive lag (ARDL) methodology of Chudik et al. (2017) with the help of the following equation:

$$\Delta y_{it} = g_{1i}y_{it-1} + g_{2i}^{'}x_{it-1} + c_1\overline{y_{t-1}} + c_2\overline{x_{t-1}}$$
$$+\sum_{j=1}^{k}g_{3ij}\Delta y_{it-j} + \sum_{j=1}^{k}g_{4ij}^{'}\Delta X_{it-j} + e_{2it} \quad (21)$$

y_{it} represents CO_2 emissions per capita and x_{it} is a vector of independent variables hypothesized in equation 1. After regressing equation 21, we may find the long-run effects by following the normalizing procedure of Chudik et al. (2017). Besides, short-run effects can be assessed by adding an error correction term in equation 21.

4. EMPIRICAL RESULTS

The CSD and SH tests' results are provided in Table 1. All tests corroborate the presence of CSD in CO_{2it}, which reflects the interdependence of CO_2 emissions across MENA countries. For instance, CO_2 emissions are global emissions and are also interrelated due to some common environmental policies of the MENA region. Moreover, the energy structure of all MENA economies is fossil fuels-based and interconnected due to regional energy trade. The CSD is also proven in $GDPC_{it}$ and $GDPC_{it}^{\,2}$ in all CSD tests. The economic growth of the MENA economies can be interlinked due to their income dependence on the energy sector. Any fluctuation in the energy market can have the same effects on most MENA economies' incomes. Moreover, regional trade also affects the income of MENA economies in the same manner. All tests also validate the CSD in REM_{it}. It can be due to interregional migration of MENA labor as most of the low or middle-income countries' labor are working in the high-income MENA countries. EXP_{it} and IMP_{it} are also interconnected as per the results of all CSD tests. It can be claimed due to common export items. For instance, most MENA economies' exports are from the oil sector. Any oil price fluctuation affects most MENA exports in the same way. Moreover, some MENA economies have trade agreements, which interconnect the trade patterns of these MENA economies. Furthermore, MENA economies have almost the same trading markets in terms of exports and imports. Thus, the import items are also similar in most MENA economies. Similarly, the relationship between exports, imports, GDP per capita, remittance inflows, and CO_2 emissions have also CSD as per all results of CSD tests. Moreover, the SH is also corroborated across the MENA countries' regressions as per both tests of Pesaran and Yamagata (2008).

Table 2 shows panel unit root results of CADF and CIPS tests. All variables carry unit roots, due to positive or low negative values from the estimated statistics, at their level in the results of both tests. However, the test statistics are lower than their critical values after differencing all series. Thus, all series are first-differenced stationary and the integration level is exposed to be one in the model.

The Kao test supports cointegration in the model with a highly significant ADF statistic in Table 3. Thus, the residual of equation 1 is stationary. Panel v and ADF and group rho statistics of the Pedroni test are also significant, which again corroborate cointegration. However, the Kao test ignores the SH and CSD in the analysis and the Pedroni test ignores the CSD in cointegration analysis. Table 1 shows that the hypothesized model carries both issues of the SH and CSD. Thus, the Westerlund test is applied, which cares about the SH and CSD in analysis. The Gt, Pt, and Pa statistics are significant in this test, which strongly corroborates the presence of cointegration in the hypothesized model. Thus, we move to estimate the long and short effects.

The long- and short-run estimates are shown in Table 4. In the long run, economic growth captured by $GDPC_{it}$ raises CO_2

Table 1: CSD and SH tests

Series	CSD tests			Pesaran and Yamagata's (2008) SH test	
	Breusch and Pagan (1980)	Pesaran et al. (2008)	Pesaran (2021)	Δ	Δadj
CO_{2it}	69.524 (0.000)	36.854 (0.000)	29.824 (0.000)		
$GDPC_{it}$	258.518 (0.000)	70.652 (0.000)	62.574 (0.000)		
$GDPC_{it2}$	263.854 (0.000)	42.592 (0.000)	38.574 (0.000)		
REM_{it}	156.352 (0.000)	58.579 (0.000)	47.689 (0.000)		
EXP_{it}	296.826 (0.000)	45.687 (0.000)	36.852 (0.000)		
IMP_{it}	384.395 (0.000)	29.854 (0.000)	21.584 (0.000)		
Residual	436.591 (0.000)	86.519 (0.000)	36.186 (0.000)	21.328 (0.000)	20.324 (0.000)

CSD: Cross-sectional dependence, SH: Slope heterogeneity

Table 2: Panel unit root analyses

Series	Leveled series		Differenced series	
	C	C and T	C	C and T
CADF test				
CO_{2it}	0.269	0.965	−2.953***	−3.256***
$GDPC_{it}$	0.632	0.354	−3.295***	−3.329***
REM_{it}	−0.511	−0.359	−3.269***	−3.433***
EXP_{it}	−0.254	−0.628	−3.002***	−3.254***
IMP_{it}	0.396	0.012	−2.963***	−3.249***
CIPS test				
CO_{2it}	0.351	0.624	−3.542***	−3.928***
$GDPC_{it}$	0.541	0.219	−3.539***	−3.829***
REM_{it}	−0.629	−0.511	−3.972***	−4.022***
EXP_{it}	−0.196	−0.455	−4.596***	−4.962***
IMP_{it}	−0.615	−0.957	−4.864***	−5.649***

***stationarity at 1%. C and T are intercept and trend, respectively

Table 3: Panel cointegration

Cointegration test	Statistics	P-value	Weighed statistics	P-value
Pedroni (2004)				
Panel statistics				
v	−4.587	0.000	−3.964	0.000
rho	−0.587	0.384	−0.687	0.319
PP	−0.754	0.296	−0.667	0.302
ADF	−4.569	0.000	−4.287	0.000
Group statistics				
rho	−3.628	0.000		
PP	−0.874	0.186		
ADF	−0.524	0.349		
Kao et al. (1999)				
ADF	−5.698	0.000		
Residual variance	0.003			
Westerlund (2007)				
Statistic	Value	P-value		
Gt	−4.957	0.000		
Ga	−2.547	0.322		
Pt	−5.526	0.000		
Pa	−6.596	0.000		

emissions with a coefficient of 17.654 and its square term $GDPC_{it}^2$ mitigates emissions with a coefficient of −0.896. Thus, the EKC hypothesis is validated in the MENA panel with a threshold of 13,181 US dollars. Thus, after 13,181 dollars per capita GDP, MENA economies could have pleasant environmental effects. However, per capita GDP below 13,181 dollars could have adverse environmental effects in MENA economies. 6 out of 16 investigated economies are found in the second phase of the EKC. Moreover, REM_{it}, EXP_{it}, and IMP_{it} raise CO_2 emissions

Table 4: CSD-ARDL estimates

Regressor	Parameter	S.E.	t-value	P-value
Long run				
$GDPC_{it}$	17.654	5.948	2.968	0.000
$GDPC_{it2}$	−0.896	0.403	−2.222	0.025
REM_{it}	0.596	0.209	2.845	0.000
EXP_{it}	0.915	0.202	4.521	0.000
IMP_{it}	0.455	0.129	3.524	0.000
Short run				
$GDPC_{it}$	16.352	4.059	4.029	0.000
$GDPC_{it2}$	−0.759	0.281	−2.698	0.000
REM_{it}	0.499	0.139	3.588	0.000
EXP_{it}	0.822	0.232	3.541	0.000
IMP_{it}	0.259	0.166	1.556	0.196
ECT_{t-1}	−0.452	0.069	−6.521	0.000

CSD: Cross-sectional dependence

with coefficients of 0.596, 0.915, and 0.455, respectively. Thus, the increasing exports, imports, and remittance inflows can have environmental problems in MENA economies.

The coefficient of ECT_{t-1} is negative, which upholds the short-run connection with a speed of adjustment of 0.452% in the model. $GDPC_{it}$ raises emissions with a parameter of 16.352 and $GDPC_{it}^2$ mitigates emissions with a coefficient of −0.759. Therefore, the EKC hypothesis is also corroborated in the short run. Moreover, REM_{it} and EXP_{it} have positive and significant effects on CO_2 emissions with coefficients of 0.499 and 0.822, respectively. Thus, the increasing exports and remittance inflows are responsible for increasing CO_2 emissions. However, IMP_{it} has an insignificant effect in the short run.

5. DISCUSSION

The results of the CSD-based ARDL show that the EKC is corroborated in MENA economies with a threshold point of 13,181 dollars. Thus, this threshold point corroborates that the economic growth of any investigated MENA economy after the GDP per capita of 13,181 dollars is mature enough to transit toward cleaner technologies and environmental awareness to support the concept of sustainable growth. 6 out of 16 investigated MENA economies have a GDP per capita of more than 13,181. However, the rest 10 investigated economies are not mature enough to apply sustainable practices in their economies. Thus, the rising economic growth of these economies could damage the environment by releasing CO_2 emissions.

Remittance inflows increase emissions. This result exposes that additional income from remittances in fossil fuel-based MENA economies raises the usage of energy-intensive products like private vehicles and household appliances. Moreover, remittances can be invested in pollution-oriented businesses. Furthermore, remittance inflows could increase housing sector development, which can be responsible for CO_2 emissions. In addition, most MENA economies are giving subsidies for local fossil fuel consumption (Boulanouar and Essid, 2023), and increasing remittance inflows can increase economic activities and fossil fuel consumption, which may lead to energy inefficiency in the region. To reduce the ecological impact of remittances, policymakers should tax households with fossil fuel consumption and the revenue from these taxes should be used for subsidizing REC. Moreover, energy subsidies should be removed for fossil fuel consumption.

Exports also contribute to emissions. This result corroborates that MENA exports are majorly from crude oil, natural gas, and petroleum products. The extraction, refinement, and transportation of these products are highly energy-intensive and pollution-oriented. Moreover, energy subsidies in the MENA region are helping industries to remain competitive in the international market. But it is increasing the industrial fossil fuel consumption, which is accelerating CO_2 emissions in the region. To reduce the emissions associated with exports, the MENA governments should invest in renewable energy infrastructure to provide renewable energy to exporting industries. Moreover, energy subsidies should be removed from industrial fossil fuel consumption and these subsidies should be introduced for REC in these industries. In addition, exports' dependence on oil, gas, and petroleum products should be reduced by diversifying the exports from cleaner sectors.

Imports increase emissions in the long run results, which corroborates that MENA imports include pollution-oriented machinery, vehicles, and consumer products. Moreover, some MENA economies are involved in the processing of imported inputs in pollution-oriented industries like petrochemicals, steel, and cement. Some MENA economies are also importing fossil fuels to generate electricity, which contributes to CO_2 emissions. To reduce the adverse environmental effects of imports, the MENA government should impose heavy taxes on energy-intensive imports and subsidies should be provided to import renewable energy technologies and energy-efficient industrial and consumable items.

6. CONCLUSION

Exports, imports, and remittance inflows have a great potential to contribute to CO_2 emissions in fossil fuel-dependent MENA economies. Thus, the present research investigates their environmental effects in the EKC framework of 16 MENA economies from 2001 to 2022. For this purpose, CSD-based econometrics is applied for data analyses. The CSD is expected due to geographical location and economic similarities in the MENA economies. The results expose that CSD is presented in all investigated series and the hypothesized relationship. Moreover, the EKC is corroborated with a threshold point of GDP per capita of 13,181$. 6 out of 16 investigated MENA economies have a GDP per capita more than this point. Thus, 10 MENA economies have adverse environmental consequences of economic growth. Moreover, remittance inflows raise emissions in the long- and short-run. This finding reflects that additional income from remittance inflows in fossil-based MENA economies is increasing energy-intensive economic activities. Furthermore, exports raise emissions in the long and short run in MENA economies. This finding empirically corroborates that MENA exports are majorly reliant on crude oil, natural gas, and petroleum products. The extraction, refinement, transportation, and production of the resource sector are polluted-oriented activities. Lastly, imports raise emissions in the long run but have an insignificant impact in the short-run. This finding reflects that MENA imports include energy-intensive machinery, vehicles, and consumer products.

To reduce the ecological problems of remittance inflows, exports, and imports, the MENA governments should impose heavy taxes on energy-intensive imports, production of exportable items, and household consumption. Particularly, the import tariff should be revised as per the energy intensity of the imported items. Moreover, energy subsidies should be removed from fossil fuel consumption and these subsidies should be provided for REC in the region. Besides, MENA governments would invest in renewable energy infrastructure to increase renewable energy transformation in the MENA region. This renewable energy should be provided to exporting industries and households at concessional rates to improve the concept of energy efficiency in the region. Further, public-private partnerships should be enhanced in the renewable energy sector to promote sustainable growth as per the targets of SDGs.

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