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Analyzing the Threshold Effect in the Relationship Between Income and Environmental Degradation in the Middle East and North Africa Region

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Abstract

This study empirically explores the legitimacy of the Environmental Kuznets Curve (EKC) hypothesis for four economies from the Middle East and North Africa (MENA) region, considering the environmental quality measured by carbon dioxide emissions and national income proxied by real GDP per capita from 1980 to 2018, and employed the ARDL approach. The cointegration results reveal that there persist long-run associations among the series of interest and for each country. Results of ARDL show the validity of the EKC hypothesis for Turkey and unconventionality for the UAE in the long run, while reject its validity for Algeria, Egypt, and the UAE in the short run, and for Turkiya and UAE in the long run, while it is not valid for Algeria. Overall, the empirical estimates on the validity of the EKC hypothesis are found mixed. These empirical findings suggest to design efficient, prudent, and economically feasible environmental protection policies, whereas to start public awareness projects to improve environmental quality in order to achieve sustainable development in the region.

Keywords Carbon dioxide emissions · EKC · Income · MENA region

JEL Classification O4 · N55

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Introduction

Achieving sustainable economic development is a top priority of every nation which requires effective and prudent policy implementation in true sense (Azam et al., 2022). In a study by WCED (1987), it was established that "Sustainable development is that type of growth that meets the requirements of the present without compromising the welfare of coming generations to meet their specific needs." Today, the world is facing major problems in all three extents of sustainable development, i.e., social, economic, and environmental. The statistics show that more than one billion individuals are still living in high poverty and inequality; hence, unjustifiable production of goods and consumption pattern have caused enormous economic and social costs. In several cities of developing and underdeveloped economies, people do not have access to the basic necessities of life, like electricity, health care, sanitation, and water. Attaining sustainable economic development requires worldwide efforts to carry on the genuine ambition in the direction of more economic and social development, requiring economic growth and employment, with improved environmental shield. Overall, sustainable development is to be comprehensive and requires special attention to the needs of the poorest and most helpless people (United Nations, 2013). Sustainable development is only achieved by increasing the income level without damaging the environment quality of the world.

The income elasticity of demand for environmental quality is the proportional change is the demand for environmental quality per the proportional change in the level of income. The people willing to pay more for a cleaner environment are those with an increase in income and higher living standard. At higher level of income, people prefer quality instead of quantity and like clean environment (Baldwin, 1995). The demand for environmental services will bring the structural change in the economy, thus causing a reduction in the carbon emission. In Environmental Kuznets Curve (EKC), a higher level of income is gradually apt to alter lifestyle and behavioral patterns towards to energy- and carbon-intensive products. Consumer behavior of wealthy people inclines towards energy-efficient services and products (Edenhofer et al., 2011; Girod et al., 2014; Selden & Song, 1994). Other behaviors such as contributions to organization working for clean environment and defensive outlay become a characteristic of the wealthy people (Dinda, 2004).

Several erstwhile studies investigate the relationship between economic growth and CO_2 emissions, but the link between economic growth and environmental quality is yet not clear and needs further inquiry. In this regard, Kågeson (1997) and Meadows et al. (1992) viewed that economic growth and environmental degradation followed the same trend, as increasing economic activities lead to environmental degradation. On the other hand, Radetzki (1990) and Beckerman (1992) claimed that the link between growth rate in national income and environmental quality was not at odds with each other and sustainable growth can be achieved without any harm to the environment. These counter-arguments render economic, environmental, and energy-saving initiatives to be contradictory (Acheampong, 2018).

It is observed that CO_2 emissions are the leading atmospheric gas as compared to other gasses like monoxide and sulfur dioxide which contribute to global warming. Human health is at risk as many diseases like heart disease, respiratory disease, and lung cancer are caused by air pollution, and in 2012, nearly 7 million people died due to air pollution. Similarly, 88% of premature deaths in the less developed countries happened due to climate pollutants. Moreover, the highest number of premature deaths was recorded in Southeast Asia and the Western Pacific region. For a sustainable society, both economic activities and ecological health should be in balance. Production of goods relies on environmental resources as by utilizing these resources people dumped back the wastes into the environment in the form of industrial wastes, etc. (World Health Organization, 2018). Most of the researchers and policymakers aimed to find out ways on how sustainable economic growth can be achieved without harming the environment. For this purpose, one of the widely used hypotheses for economies regarding the environment is the EKC hypothesis which states that environmental degradation increases up to a certain level with an increase in income, but after a threshold level pollution decreased with an increase in per capita income (Azam & Khan, 2016).

The Middle East and North Africa (MENA) region is considered in the current study due to many reasons. The World Bank (2008) reports "a number of countries in the region remain on an unsustainable path, consuming profits on natural resource exploitation rather than investing these profits to ensure long-term economic sustainability." Furthermore, "the Middle East & North Africa region has increased its carbon dioxide emissions, faces diminishing critical per capita water resources, and is at risk on several fronts from climate variability." Furthermore, the population of the region is around 6% of the world's population and it emits 7% of overall greenhouse gasses of the world. From 1990 to 2004 in this region, residual discharges rose by 88%, which was the third-fastest upsurge worldwide. In 2000, the total estimated environmental cost in the MENA was projected at US$ 9 billion per annum, which is almost 2.1 to 7.4 of the GDP (Hussein, 2008).

The Environmental Performance Index (EPI) (2012) report disclosed that the MENA region countries are ranked quite low as compared to other countries which showed their poor environmental performance. According to the EPI report, Algeria is ranked on the 42nd place followed by Morocco which is placed on 52nd, whereas Saudi Arabia is ranked on 99th and the United Arab Emirates (UAE) is placed on 152nd. The EPI classified MENA countries into two groups; the first one comprised of those nations which are doing well in terms of environmental performance as compare to other countries in a cluster like Algeria, Egypt, Morocco, Tunisia, Lebanon, Syria, Iran, and Jordan, while the second group includes fossil fuel–producing countries like Bahrain, Libya, Kuwait, Qatar, Oman, UAE, Saudi Arabia, Sudan, and Yemen, and these countries are ranked in lowest environmental performance ranking with the highest greenhouse gas emission of all the clusters. Previous literature estimated EKC relationship for the region as a whole by utilizing panel data techniques, while this study selected the top four highest CO_2 emitter countries from the region as indicated by the Statista Research Department (2020), which includes Egypt, Algeria, Turkey, and the UAE. Furthermore, these four countries are also doing well in terms of economic growth, so these are the most suitable countries from the region to analyze association between economic growth and CO_2 emissions.

It has also been observed that there is a deficiency of apprehension in developing as well as underdeveloped nations about environmental quality and the focus is to raise now and clean up later. The developing countries are focusing on increasing their income and production capacity in order to get desired growth; however, they are totally ignoring other associated costs like environmental degradation. This not only ruins the environmental quality of the country and health of their citizens but also becomes a threat to the world. Sustainable development requires an orderly investigation of whether the EKC hypothesis grips the selected MENA region countries. From the finding of this study, policymakers will be able to formulate a better policy option in terms of mitigating CO_2 emissions in the MENA region through adopting different clean technological techniques. This study will analyze the scenario on how MENA region countries can reduce CO_2 emissions without imposing long-term adverse effects on economic growth. Additionally, most of the studies have studied the EKC for MENA nations by using panel data analysis whereas this study has differently used country-level data for achieving the said objective.

The motivation of the study is based on the significance of achieving sustainable development in the MENA region. Though there are a few related empirical studies, we have not come across any study which analyzes the link between the national income and carbon emissions for the MENA region, while many of the extant studies employed the panel data approach to find an overall result for a panel/group of countries (Al-Rawashdeh et al., 2014) and overlooked individual country analysis. The individual country analysis is much important and mandatory because each country has unique economic and demographic characteristics, and panel data findings might not provide an accurate and applicable conclusion. Furthermore, the majority of prior studies did not find the evidence of threshold value (Koirala et al., 2011; Li et al., 2016), even Sanchez and Stern (2016) used 129 countries' data and Fernández-Amador et al. (2017) for world level. Moreover, López-Menéndez et al. (2014) just confirmed the EKC in four out of 27 EU countries. Therefore, the central aim of the study is also to detect the threshold level of the EKC hypothesis in the MENA region.

Similarly, the EKC hypothesis discovered by panel or cross-country data evaluations would simply reveal the coincidence of a positive link between the national income and carbon emission in developing economies while a negative link for the developed economies, and no link that concerns both categories (Afsah & Vincent, 2017). This claim does apply not only to cross-regional but also to cross-country studies, because they assumed the same development track in all countries (M'henni et al., 2011). Generally, the studies regarding EKC are mostly criticized on the basis that they lack comparability and coherence in the turning points and forms of the income-pollution link (Ekins, 1997; Stern & Common, 2001). Moreover, Selden and Song (1994) considered that it should be simpler to get an inverted U curve for attentiveness for emission indicators. Furthermore, there are many estimation issues in the studies regarding EKC; for example, Stern et al. (1996) indicated the problem of heteroskedasticity is too important in the framework of regressions of grouped data. Similarly, Schmalensee et al. (1998) revealed that the residuals obtain from the OLS technique were heteroskedastic with minor residuals link with countries with higher population and total GDP. Moreover, Holtz-Eakin and Selden (1995) employed Hausman tests for regressor and exogeneity to promptly address the simultaneity problem, but nothing was found. Stern (2004) concluded that a major portion of EKC literature is statistically weak; therefore, to overcome these statistical problems there is a need to use appropriate techniques for estimation. Therefore, the current study employs the ARDL model[1] to test the threshold effect between income and carbon emission for selected countries from the MENA region.

The central aim of this study is to test the validity of the EKC hypothesis for the selected four countries from the MENA region. The countries are selected for analysis that have the highest CO_2 emissions and highest income among the cluster because it will give a clear view about the EKC hypothesis, and the sample countries will represent the situation for the whole cluster in a better manner. Most importantly, the UAE and Turkey economies are a business hub and tourists' places where large number of people frequently visit for tourism and business activities from all over the world. It is therefore more important for them to keep a check on their environmental quality. So, this study will contribute by giving direction to the policymakers on how they can boosts up economic activities without harming the environment for the considered countries. This study evaluates the correlation between GDP per capita income representing economic growth and CO_2 emissions representing environmental quality. The threshold effect (turning point) for the sample countries is also estimated. That is also ignored by prior studies, like Katircioğlu and Katircioğlu (2018) and Verbič et al. (2021).

The remainder of the paper is ordered as below. "Literature Review" presents related literature. Empirical methodology and data are described in "Data and Empirical Methodology." "Results and Discussion" deals with the results and discussion, while finally, "Summary and Conclusion" concludes the study.

Literature Review

Examining the soundness of the EKC hypothesis is the principal concern of this study; therefore, this section reviews the empirical and theoretical literature relating to the EKC hypothesis. Although the EKC depicts the inverted U-shaped link between carbon emission and income level, there has been presence of opposing evidence (Beyene & Kotosz, 2020). For example, many studies have endorsed the EKC (Saboori et al., 2012; Shahbaz et al., 2013), but some have not (Zambrano-Monserrate et al., 2018). Furthermore, several studies have mixed outcomes about EKC, like supporting for some countries but not for others.

Theoretical Literature

Dinda (2004) noted that "The Environmental Kuznets Curve (EKC) hypothesis postulates an inverted U-shaped relationship between different pollutants and

[1] "The major advantage of this approach lies in its identification of the cointegrating vectors where there are multiple cointegrating vectors" (Nkoro & Uko, 2016).

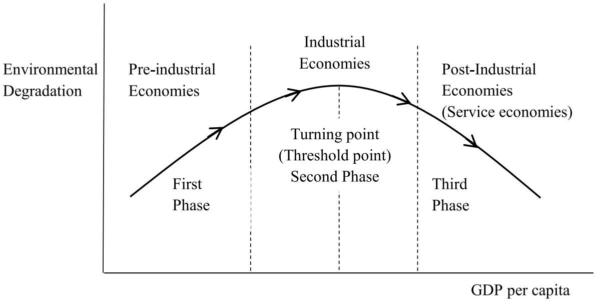

Fig. 1 Phases of EKC. Source: Authors construction

per capita income, i.e., environmental pressure increases up to a certain level as income goes up; after that, it decreases. The EKC reveals how a technically specified measurement of environmental quality changes as the fortunes of a country change" (p. 431). The query relating to the importance of the environment and economy can be found in many prior studies. Ricardo supposed that supply of poor-quality land resulted in diminishing returns in farm production (Salvatore, 2019). Similarly, theoretical literature regarding the EKC hypothesis is primarily found in the seminal work done by Simon "Simon Kuznets" entitled "Economic Growth and Income Inequality," which discovered the link between growth and income inequality. The author suggested that at the first stage income inequality upsurges with growth in income, but after a turning point income inequality declines with an increase in income. The same kind of relationship is detected between growth and environmental pollution; as the production upsurges, per capita income upsurges at the first stage, and it also leads to increase in environmental pollution (Kuznets, 1955). However, in the microeconomic point of view, environmental cleanliness becomes the priority of the people as they earn more (Weil, 2014).

The EKC hypothesis provides the theoretical foundation for income per capita and environmental degradation association; it suggests that at the beginning environmental pollution rises with the upsurge in economic growth but after a certain stage growth in economic figures leads to improve the environmental quality and this trend is clearly explained in Fig. 1, which clearly shows that at first phase both environmental degradation and GDP per capita share have the same upward trend, indicating that at this stage countries generally do not care about the negative environmental externalities. However, they take care of the environmental negative externalities once they reach stage two where their GDP per capita is on its peak and then falls. Once they achieved the desired GDP per capita, then extensive policies are developed to further fix the negative environmental externalities in the last stage (Beckerman, 1992; Khanna & Plassmann, 2004; Mao et al., 2013). The existing literature reveals the concept of the EKC hypothesis got popularity in 1992 that accelerating economic activity has bad implications for environmental quality (World Bank, 1992).

Moreover, in their study, Kaika and Zervas (2013) explained that according to the EKC hypothesis, the process of national economic development is likely to perimeter the environmental dilapidation created in the initial stages of development. The EKC concept leads several scientists from the early 1990s to adopt that each country should emphasize on its development, and any environmental issues can be ultimately abolished by the procedure of economic expansion. However, the literature on the EKC theory is rather huge, but empirical fallouts are yet mixed, and no pure inference can be found. Many other studies expounded about the bond between national income and environmental degradation within the framework of the EKC theory (Apergis, 2016; Azam, 2016, 2019; Dogan & Inglesi-Lotz, 2020; Özcan & Öztürk, 2019).

Empirical Literature

When it comes to the empirical work related to the affiliation between economic progress and environmental quality, Grossman and Krueger's (1991) study is viewed as a pioneer study on the perception of the EKC hypothesis. So far, abundant literature is available on this issue with contradictory conclusions (Al Sayed & Sek, 2013; López-Menéndez et al., 2014; Panayotou, 1993; Shafik & Bandyopadhyay, 1992).The human activities are responsible for drastic climatic change. Human activities and climatic change are directly related to each other. Even the agriculture sector which is an environmental friendly sector contributes 75% of the global nitrous oxide emission (Duxbury et al., 1993; Isermann, 1994). Grossman and Krueger (1995) concluded that the environmental consequences of human actions can be positive as well as negative. The economic modernization theory suggests that there have been different phases in every economy and the environmental consequences of economic activities vary at different phases. Most of the developing countries pass through the traditional phase where people are highly dependent on the agriculture sector. At this stage, the income level of the people is very low, and they highly depend on the natural resources for survival. Narayan and Narayan (2010) in their study for the Middle Eastern panel concluded that, in the long run, the income elasticity is smaller than that in the short run, which means that carbon dioxide emission has dropped with an upsurge in income.

How an economy can be grown without harming the environment is a hot debated issue, and researchers carried out different studies for different regions to come up with cost-effective solutions for the problem such as M'henni et al. (2011) who examined the EKC for 12 MENA countries over 1981–2005 and found poor evidence for the EKC hypothesis. Al-Rawashdeh et al. (2014) found evidence to support U-shaped EKC at the country level, while at regional level, it did not showed EKC for two environmental proxies SO_2 and CO_2 emissions in 22 MENA countries. Azam and Khan (2016) observed that environmental degradation had a negative and significant impact on economic growth for 11 Asian countries from 1975 to 2014. Zafeiriou and Azam (2017) provided strong evidence for the validity of EKC during 1992–2014 in the cases of France, Portugal, and Spain.

However, Acar et al. (2018) found the N-shaped relationship for all the countries which suggested that at a certain point environmental degradation upsurged as income increased for OECD, Middle East, and OPEC countries over 1970–2016. Beyene and Kotosz (2020) found a bell-shaped curve and concluded that economic activities in East Africa did not led to environmental degradation for 12 East African countries from 1990 to 2013. Similarly, Aruga (2019) concluded on the Energy-Environmental Kuznets Curve for 19 Asian pacific countries. Ike et al. (2020) instituted the inverted U-shaped curve and supported the pollution halo hypothesis in 15 oil-producing countries over 1980–2010. Dogan and Inglesi-Lotz (2020) observed the validity of EKC for seven European countries by using the data set 1980 to 2014. Similarly, Tenaw and Beyene (2021) used the data from 1990 to 2015 of twenty sub-Saharan African countries and CCE-PMG for estimation and confirmed the existence of the EKC hypothesis. However, Pata and Samour (2022) did not found the inverted U-shaped association between carbon emission and income by using the data from 1977 to 2017 of France and employed cointegration analysis. However, Jahanger et al. (2023) employed the Dynamic Common Correlation Effect Approach and used the data from 1990 to 2018 of top nuclear energy–producing economies and confirmed the validity of the N-shaped EKC hypothesis. Some more related empirical studies on the validity of the EKC hypothesis are given in Table 1.

Data and Empirical Methodology

Empirical Model

The EKC hypothesis assumes that:

$$\mathrm{ED}_{i,t} = f\left(Y_{i,t}\right) \tag{1}$$

where ED_t is the per capita CO_2 emissions (kilo tons) and $Y_{i,\,t}$ stands for per capita income (GDP per capita in constant US$).

The following multivariable regression model of the Kuznets curve hypothesis is used, which is also used by many prior studies (including M'henni et al., 2011; Al-Rawashdeh et al., 2014; Acar et al., 2018; Alharthi et al., 2021; Aruga, 2019; Awan et al., 2020; Beyene & Kotosz, 2020; Cheikh & Zaied, 2021; Haseeb & Azam, 2021; Awan & Azam, 2022). It is used to estimate association among income level and environmental quality, and thereby test the EKC for the MENA region, and can be expressed as follows:

$$\mathrm{ED}_t = \beta_0 + \beta_1 Y_t + \beta_2 Y_t^2 + \epsilon_t \tag{2}$$

where Y^2 is the per capita income squares, while β_{1-2} are the coefficients to be estimated, ε_t is the residual term with zero mean and constant variance, and lastly the subscript t refers to time period. As the broad intention of this work is to check the soundness of EKC, it is necessary for β_1 to be positive while $\beta_2$is anticipated to be having a negative sign (Orubu & Omotor, 2011).

The most important issue which arises in analyzing the environmental aspects of developing economics is that most of developing countries do not have environmental quality proxy, whereas some of the developed countries have introduced pollution taxes and other proxies. Therefore, when it comes to comparing the group of regions or countries, then it is hard to find the same proxy available for all countries. As the data on environmental quality measure does not exist for most of the countries, this study used of CO_2 emissions as a proxy for environmental degradation for the MENA region (Asghari, 2012; Hassaballa, 2014; Ratnayake & Wydeveld, 1998; Sarmidi et al., 2015; Yoon & Heshmati, 2017).

Table 1 Summary of literature review on the EKC validity

Author(s)	Time periods, country(s), and methodology	Response variable	Explanatory variables	Findings
Beyene and Kotosz (2020)	1990–2013, 12 East African countries, PMG	CO_2 emissions	GDP per capita and its square	Found U-shaped bell curve relationship
Koilo (2019)	1990–2014, Eastern European and Central Asian countries, OLS	CO_2 emissions	GDP, GDP^2, foreign direct investment, trade openness, and energy intensity	Confirmed existence of EKC hypothesis
Fang et al. (2020)	2004–2013, China, GMM	Per capita industrial wastewater and per capita SO_2	GDP and its square, trade, per capita industrial electricity use, population per square kilometer, manufacturing, and service	EKC does hold for China
Javaid and Zulfiqar (2017)	1971–2010, Pakistan ARDL and VECM	CO_2 emissions	GDP, and its square term, trade openness and urban population	Results authenticate environmental degradation and economic growth relationship is as per EKC hypothesized.
Kalchev (2016)	1970–2008, Bulgaria Newey-West, regression	CO_2, SO_2, CH4, NH3, and N20	GDP and its square	Results support the statement that EKC does hold.
Elgin and Öztunali (2014)	1950–2009. Turkey Johansen Test	CO2 and SO_2	Tax revenue as a percentage of GDP	EKC hypothesis holds true.
Ahmed and Long (2012)	1971–2008, Pakistan ARDL	CO_2 emissions	Economic growth, energy use, trade liberalization, population density	Study confirms the existence of EKC both in short run and in long run.
Shahbaz et al. (2010)	1971–2008, Portugal ARDL	CO_2 emissions	GDP per capita and its square, energy use, trade openness, and urbanization	EKC hypothesis does exist for Portugal.
Granda et al. (2008)	1980–2000, 46 countries, random and fixed-effect	Biochemical oxygen demand	GDP Per capita and foreign trade intensity	Results are in favor of ECK hypothesis.

Table 1 (continued)

Author(s)	Time periods, country(s), and methodology	Response variable	Explanatory variables	Findings
Aldy (2005)	1960–1999, United States , FGLS	CO_2 emissions	Income and trade	Found results that income-emissions relation varies among the states.
Andreoni and Levinson (2001)	1977–1994, United States, OLS	Abetment cost index	Gross state product and its squares	Study provides empirical evidence in the support of EKC.

Source: Authors' compilation

Table 2 Variables' description

Variables	Description
ED	CO_2 emission metric ton per capita is taken into account as a proxy of environmental quality; high levels of CO_2 emissions represent the worse environmental conditions and lower CO_2 emissions indicate better environmental conditions.
Y	GDP per capita is used to measure the level of economic activities, the well-being of the country, and market size.

This study will calculate the EKC turning point by following Shahid et al. (2014) and Stern (2004), and Y_t refers to a turning point in the equations given below. The income level where carbon emissions are at their highest levels is tagged as "turning point." The turning point provides us the supplementary information about the carbon emission and income nexus (Jalil & Mahmud, 2009; Stern, 2004). The turning point of the income, where the carbon emission level is maximized (Ozatac et al., 2017), can be calculated from the quadratic function as follows:

$$\frac{d\,\text{ED}}{d\,Y} = \frac{d}{d\,Y}\left(Y\beta_1 + \beta_2 Y^2\right)$$

$$\frac{d\,\text{ED}}{d\,Y} = \beta_1 + 2\beta_2 Y$$

$$0 = \beta_1 + 2\beta_2 Y$$

$$Y_t = -\frac{\beta_1}{2\beta_2} \tag{3}$$

Data and Its Sources

Annual time series data from 1980 to 2018 is taken from the WDI (World Development Indicators, 2021), the World Bank publication and CO_2 emissions, and the Global Carbon Atlas (2021). All the variables have been converted into log form to avoid non-linearity problems in the data. Data descriptions are given in Table 2.

Estimation Strategy

It is mandatory to check stationarity properties of the time series to sidestep any econometric problem resulting in biased, inconsistent, or spurious results. We, therefore, implement the extensively used unit root test, namely the ADF test, which is one of the widely used test developed by Dickey and Fuller (1979). Another important method for examination of the unit root properties of time series is the PP methodology formulated by Phillips and Perron (1988). The ADF method is used for checking the stationarity of time series, as it is observed that some series are stationary at a level while others are on first difference, so the ARDL approach developed by Pesaran and Shin (1995) of cointegration is to be applied. The ARDL technique is more beneficial than other techniques due to many reasons, like the use of variables having mixed order of integration for regression mean loss of appropriate long-run properties or evidence of the equilibrium link among the variables included in the model. The cointegration analysis makes it possible to retain the relevant information that had been missing due to differencing, specifically, the convergences from short-run dynamics to long-run equilibrium, like ECM. The conventional Engle and Granger (1987) and Granger (1981) cointegration analysis is not appropriate in the case of mixed order of integration; ARDL and Johansen and Juselius (1990) cointegration procedure is applicable (Nkoro & Uko, 2016). However, the ARDL techniques edge the Johansen and Juselius (1990) cointegration because the ARDL techniques establish the direction of causation among the variables (Duasa, 2007).

Results and Discussion

This finding includes summary statistics of the series for each country of the study which are given in Table 3. The total numbers of observations are 39, from 1980 to 2018. The Jarque-Bera normality test illustrates that residuals are normally distributed for each series except the residual of CO_2 emissions of Algeria.

Table 4 shows the fallouts of the correlation matrix among all variables for each concerned country. Results outlined that there is no perfect multi-collinearity among the variables, and the correlation values between Y_t and Y_t^2 are high just because of the reason that we have derived Y_t^2 by squaring Y_t values.

Table 5 reports the outcomes of unit root for each series and each country under the study. The outcome of the unit root illustrates that some variables are integrated at a level, and some are integrated at first order. This information has useful insight in terms of estimating procedures.

Regression Results

The short- and long-run elasticities for each country are reported in Table 6. These regression results confirmed that there are U-shaped links between the income and carbon emission both in the long and short run, in the case of Algeria. Furthermore, there are U-shaped links in the long run, while an inverted U-shaped relationship in the short run between the income and carbon emission, in the case of Egypt. Moreover, there are inverted U-shaped links in the long run, while a U-shaped relationship in the short run between the income and carbon emission, in the case of Türkiye. However, there are inverted U-shaped relationships between the income and carbon emission both in the long and short run, in the case of the UAE. The error correction term is negative and highly

Table 3 Descriptive statistics

Statistics/countries		Algeria		Egypt, Arab Rep.			Turkey			UAE		
	ED_t	Y_t	Y_t^2	ED_t	Y_t	Y_t^2	ED_t	Y_t	Y_t^2	ED_t	Y_t	Y_t^2
Mean	1.1352	8.2624	68.283	0.5625	7.5203	56.62	1.1167	8.9942	80.9843	3.3132	10.9747	120.54
Median	1.1633	8.2355	67.815	0.5762	7.5097	56.39	1.1502	8.9673	80.4134	3.3592	11.0199	121.43
Maximum	1.3494	8.4820	71.9521	0.9447	7.9234	62.78	1.5410	9.5512	91.2270	3.5985	11.6633	136.03
Minimum	0.6528	8.0653	65.0543	0.0436	7.0051	49.07	0.5439	8.5145	72.4971	2.9206	10.4309	108.80
Std. Dev.	0.1361	0.1242	2.05501	0.280532	0.2714	4.078	0.2826	0.2991	5.401869	0.1795	0.3171	6.9728
Skewness	− 1.3470	0.2403	0.25710	0.0058	− 0.0528	− 0.007	− 0.3742	0.2324	0.28265	− 0.3766	0.1039	0.1782
Kurtosis	5.7081	1.8090	1.8130	1.5936	1.8545	1.826	2.2376	2.0784	2.1004	2.3534	2.7418	2.8064
Jarque-Bera	22.5132	2.5424	2.5784	3.0491	2.0398	2.122	1.7596	1.6424	1.7400	1.5191	0.1693	0.2537
Probability	0.0001	0.280	0.2753	0.2177	0.3606	0.345	0.4148	0.4398	0.4189	0.4678	0.9187	0.8808

Source: Authors' calculation

Table 4 Correlation matrix analysis

	Countries														
	Algeria				Egypt, Arab Rep.				Turkey				UAE		
Variables	ED_t	Y_t	Y_t^2		ED_t	Y_t	Y_t^2		ED_t	Y_t	Y_t^2		ED_t	Y_t	Y_t^2
ED_t	1.00			Y_t	1.00			ED_t	1.00			ED_t	1.00		
Y_t	0.40	1.00		Y_t^2	0.97	1.00		Y_t	0.71	1.00		Y_t	0.84	1.00	
Y_t^2	0.43	0.90	1.00	ED_t	0.97	0.99	1.00	Y_t^2	0.75	0.99	1.00	Y_t^2	0.83	0.99	1.00

Source: Authors' calculation

Table 5 Unit root test analysis

Variables	Algeria		Egypt, Arab Rep.		Türkiye		UAE	
	ADF	PP	ADF	PP	ADF	PP	ADF	PP
ED_t	– 2.742*** (0.0769)	– 2.973** (0.0471)	– 1.118 (0.697)	– 1.369 (0.586)	– 2.216 (0.204)	– 2.199 (0.2098)	– 2.078 (0.2541)	– 1.879 (0.3381)
Y_t	– 0.7835 (0.8107)	– 0.1266 (0.9388)	– 0.942 (0.761)	– 1.671 (0.436)	– 4.522* (0.000)	– 4.292* (0.0017)	– 2.182 (0.2160)	– 1.969 (0.2983)
Y_t^2	– 0.7546 (0.8187)	– 0.1002 (0.9419)	– 0.8067 (0.804)	– 1.422 (0.560)	– 4.621* (0.000)	– 4.377* (0.0014)	– 2.263 (0.1890)	– 2.055 (0.2631)
ΔED_t	– 6.5398* (0.0000)	– 6.9852* (0.0000)	– 8.179* (0.000)	– 8.200* (0.000)	– 6.614* (0.000)	– 6.621* (0.0000)	– 7.287* (0.0000)	– 18.67* (0.0001)
ΔY_t	– 3.1987** (0.0285)	– 3.262** (0.0246)	– 3.036** (0.041)	– 3.59** (0.011)	– 4.135* (0.002)	– 4.156* (0.0026)	– 3.662* (0.0092)	– 3.652* (0.0095)
ΔY_t^2	– 3.1908** (0.0291)	– 3.254** (0.0251)	– 3.146** (0.0327)	– 3.56** (0.012)	– 4.058* (0.003)	– 4.068* (0.0032)	– 3.695* (0.0085)	– 3.678* (0.0089)

Source: Authors' calculation

() is p-value

*, **, and *** indicated the significance level at 1%, 5%, and 10%

significant which strengthens the existence of long-run affiliation among the variables with the speed of a marginally high rate of 57% in the case of Algeria, 73% in the case of Egypt, 33% in the case of Turkey, and 78% in the case of the UAE, alteration from previous year's imbalance to the current year's balance. The outcomes of bound test for testing long-run association between the variables of interest and under the study. The outcomes of cointegration test disclosed that the F-statistics exceed the upper bound and thus, there exists a long-run relationship among variables of interest and under the study for each country. The diagnostic test results show that there is no autocorrelation, heteroskedasticity, and specification error issue in the data.

Estimates of Environmental Kuznets Equation

Table 6 is presented to check the possibility that either EKC is valid for selected MENA region countries or not and for calculating its turning point. The coefficient of Eq. (2) is

Table 6 Regression results

Variables		Algeria	Egypt, Arab Rep.	Turkey	UAE
Y_t		– 45.252*** [24.6090] (0.0752)	– 1.2769* [0.0216] (0.0000)	8.142** [3.8277] (0.0415)	5.1697** [2.3789] (0.0373)
Y_t^2		2.752*** [1.4877] (0.0736)	0.0563*** [0.0326] (0.0941)	– 0.374*** [0.1884] (0.0561)	– 0.2186** [0.1071] (0.0497)
C		186.64*** [101.826] (0.0761)	– 2.0956 [1.8620] (0.2690)	– 40.701** [19.328] (0.0434)	– 27.800** [12.9550] (0.0396)
ARDL-bound test		3.8581***	4.2992**	3.7129***	5.1387*
ΔY_t		– 45.565** [20.471] (0.0334)	6.2058* [1.7918] (0.0015)	– 2.202*** [1.2841] (0.0958)	2.2164** [0.9689] (0.0291)
ΔY_t^2		2.793** [1.2394] (0.0314)	– 0.3507* [0.1239] (0.0078)	0.135** [0.0624] (0.0382)	– 0.0778*** [0.0444] (0.0899)
ECM_{t-1}		– 0.5689* [0.1385] (0.0003)	– 0.7298* [0.1680] (0.0001)	– 0.3316** [0.1226] (0.0110)	– 0.7819* [0.1649] (0.0000)
Long-run turning point (TP)		62.2668	0.0359	1.5226	0.5651
Long-run EKC		Not exist	Not exist	Exist	Exist
Short-run turning point (TP)		63.6315	1.0882	0.1486	0.0862
Short-run EKC		Not exist	Exist	Not Exist	Exist
Breusch-Godfrey serial correlation LM test (F-Stat)		1.8999 (0.1089)	0.2375 (0.7901)	0.7334 (0.4889)	1.8431 (0.1758)
Heteroskedasticity test: Breusch-Pagan-Godfrey (F-Stat)		1.3576 (0.2733)	1.5509 (0.2121)	0.8556 (0.5013)	0.6976 (0.5604)
Ramsey RESET test	t-stat	0.8404 (0.4071)	0.2949 (0.7700)	0.3922 (0.6976)	1.1256 (0.2690)
	F-stat	0.7063 (0.4071)	0.0870 (0.7700)	0.1539 (0.6976)	1.2671 (0.2690)

Source: Authors' calculation

The value inside [] is standard deviation and () is p-value

*, **, and *** indicated the significance level at 1%, 5%, and 10%

The critical values of the bound test are 2.63–3.35 at 10%, 3.1–3.87 at 5%, and 4.13–5 at 1%

estimated using ARDL whereas the turning point for EKC is calculated using Eq. (3). It is anticipated that the coefficient of Y_t is to be positively associated with ED_t and Y_t^2 to be negatively associated with ED_t.

The empirical estimates for environmental Kuznets equations are reported in Table 6. The coefficient of Y_t and Y_t^2 shows the pattern of association between ED_t and Y_t, and ED_t and Y_t^2. Since the signs of coefficients in terms of Algeria of Y_t and Y_t^2 are not the same as expected but both are statistically significant, the EKC hypothesis is not validated for

Algeria; it supports the U-shaped bell curve relationship. In the case of Egypt, Arab Rep, the coefficients are not statistically significant; thus, EKC is not validated for Egypt, Arab Rep.

The estimated coefficients of Y_t and Y_t^2 are statistically significant as well as signs are the same as anticipated. Thus, EKC is validated in terms of Turkey, while the signs are according to the EKC hypothesis but the value of Y_t^2 is not statistically significant so the EKC is unconventional for the UAE. The results confirmed the validity of EKC in Egypt in the short run with tuning point (TP) of 1.0882, Türkiye in long run with TP of 1.5223, and the UAE in both long and short run with 0.5651 and 0.0862 respectively.

Overall, the results obtained for Algeria are similar to the work of Beyene and Kotosz (2020). In the case of Egypt, Arab Rep, the estimated coefficients are not statistically significant; thus, EKC hypothesis is not validated for Egypt, Arab Rep as well; these outcomes are the same as the work of M'henni et al. (2011). In the cases of Turkey and the UAE, the findings are consistent with the findings by Al-Rawashdeh et al. (2014), Azam and Khan (2016), Shahid et al. (2014), Azam et al. (2021), and Bah et al. (2020).

Stability Dialogistic CUSUM Test

The study incorporates the plot of the CUSUM stability test to examine that the parameters persist steady over the sample period. The cumulative sum (CUSUM) of the recursive residuals test is engaged to evaluate the parameter stability Pesaran and Pesaran (1997) and pinpoints systematic fluctuations in the regression parameters. Figure 2 plots the fallouts for the CUSUM test where the outcomes point out the nonappearance of any uncertainty and volatility of the parameters because the scheme of the CUSUM statistics plunges exclusively the critical 5% bands for the parameter stability. Thus, there subsists constancy in the parameters over the time 1980 to 2018 for Algeria, Egypt Arab Republic, Turkey, and the UAE.

Summary and Conclusion

The broad aim of this study is to empirically explore the threshold effect and validity of the EKC hypothesis for selected nations from the MENA region. This study chooses "The Middle East & North Africa region" for testing the validity of the EKC hypothesis because this region faces an increasing rate of carbon dioxide emissions and quick natural resource depletion. We study selected four highest CO_2 emitter countries from the region according to the Statista Research Development (2020) which includes Egypt, Algeria, Turkey, and the UAE over the period ranging from 1980 to 2018. The most relevant estimation technique, namely ARDL, is implemented based on the order of integration of data.

The empirical estimates of the ARDL approach exhibit that there are U-shaped relationships between the income and carbon emission both in the long run, in the case of Algeria and Egypt while in Algeria and Türkiye in the short run. Furthermore, there is an inverted U-shaped relationship between the income and carbon emission in the long run in Türkiye and the UAE while in Egypt and the UAE in

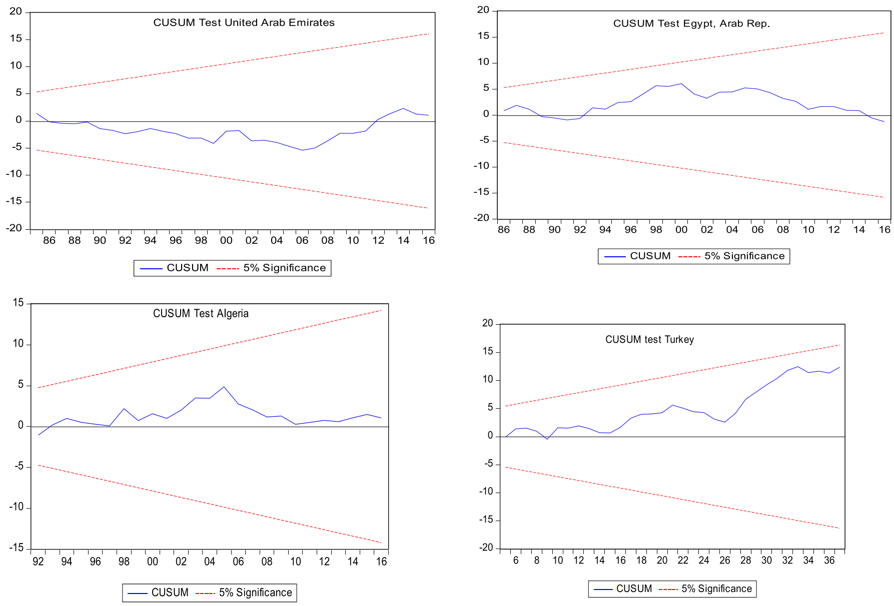

Fig. 2 CUSUM stability test

the short run. The results further confirmed the validity of EKC in Egypt in the short run with tuning point (TP) of 1.0882, equal to $297 per capita, Türkiye in long run with TP of 1.5223, equal to $458 per capita, and the UAE in both long and short run with 0.5651 and 0.0862, equal to $176 and 109 per capita respectively. Moreover, the EKC is not valid for Algeria and Egypt and overall fallouts are in line with the conclusions by Al-Rawashdeh et al. (2014) and Azam and Khan (2016). These empirical outcomes support the validity of the EKC hypothesis for Turkey, and unconventionality for the UAE, while the study is unable to discover any support for the validity of the EKC hypothesis for Algeria and Egypt.

These empirical findings suggest that countries, where the EKC hypothesis does not exist, need to speed up economic activities, though keeping in mind that economic development shall be on sustainable basis. Overall, policymakers of the MENA region need to design strict and economically feasible environmental protection policies and start public awareness projects for improving environmental quality because the economic activities are important for a better standard of living; however, this must not be on the cost of environmental degradation. Moreover, individuals should also play their due role being as a virtuous national to achieve the desired level of sustainable development in the region.

Declarations

Ethics Approval and Consent to Participate This study follows all ethical practices during writing and interpretations. Consent to participate is not applicable.

Conflict of Interest The authors declare no competing interests.

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