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Environmental Kuznets Curve Revisited, With Reference to the Middle East and North Africa (MENA)

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ABSTRACT

Using an up-to-date panel dataset that covers 88 countries over a 38-year period (1991–2018), this paper revisits the Environmental Kuznets Curve (EKC) to measure environmental degradation (CO_2, methane, nitrous Oxide, PM 2.5, HFC, PFC and SF6) in relation to GDP per capita. This study confirms the inverted-U relation for CO_2 emissions, with the estimated turning point at $13,233, but also identifies a U relation in the case of PM 2.5. Furthermore, in a regional analysis of both CO_2 and PM 2.5, with special reference to the MENA region, it finds gaps between actual CO_2 emissions and their fitted values. We observe that Libya, Iran, Iraq, Jordan, Lebanon, and Algeria show average ratios higher than 1, meaning the actual values are higher than the fitted ones and therefore these countries face more serious pollution problems. Based on this finding, we recommend the implementation of policies in this region that aim to reach energy efficiency as well as the development of eco-friendly and sustainable technologies.

Keywords: EKC, MENA, CO_2 emissions, PM 2.5 emissions

INTRODUCTION

The Environmental Kuznets Curve (EKC, hereafter) is based on the hypothesis that an inverted U relationship exists between environmental degradation and economic growth. This non-monotonicity, depicted in Figure 1, is based on Kuznets (1955) hypothesis, which posits a quadratic relationship between a country's inequality and income levels. Like the Kuznets Curve, the EKC hypothesizes that, while economic growth in early stages exacerbates environmental degradation, this effect fades and even turns into a negative once an economy exceeds a certain tipping point (Grossman & Krueger, 1991).

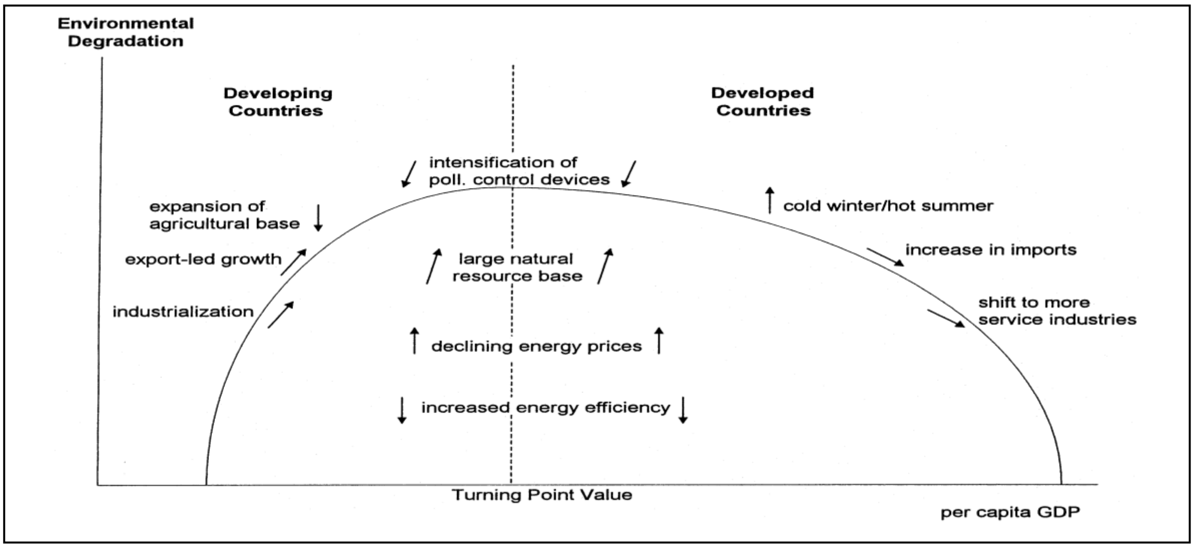
Most empirical studies have successfully tested this hypothesis. Grossman & Krueger (1992) focused on SO_2 and Suspended Particulate Matter (SPM) emissions, with GDP per capita, population density and trade as independent variables. Later, they added other pollution-dependent variables including dissolved oxygen, biological oxygen, nitrates, arsenic, and mercury, among others (Grossman & Krueger, 1995). Panayotou (2003) investigated deforestation, nitrogen pollution, and SO_2. Selden and Song (1994) examined SO_2, SPM, Nitrogen, and CO_2, and Holtz-Eakin and Selden (1995) focused on CO_2. All of these studies have successfully shown inverted-U relationships between per capita GDP and pollution materials. Shafik and Bandyopadhyay (1992) extended this line of research by considering non-economic factors, such as political rights, trade, debt, and civil liberties. In a similar vein, Torras and Boyce (1998) found that literacy, civil liberties, and political rights exert substantial impacts on environmental quality in low-income countries. Furthermore, Leitao (2010) found a positive relationship between a country's degree of corruption and turning points in per capita income, and Oh Jinhwan and Yun ChiHyun (2014) found a negative correlation between democracy and CO_2 emissions.

Other studies, however, have not been successful in proving the U-inverted relation of the EKC. Jha & Bhanu (2003) research develops an environmental degradation index composed by several indicators of environmental degradation focusing on the 174 countries represented in the Human Development Index. Their results highlight the inadequacy of the EKC to understand the relation between economic growth and environmental degradation, observing a negative relation between both. Özokcu and Özdemir (2017) performed a research examining 26 high-income OECD countries followed by a model with 52 emerging countries, but none reflected the EKC. EKC tends to reflect consistent results in empirical research with air pollutants, but less with other forms of pollution. Hettige et al. (2000) research focuses on industrial water pollution in developed and developing countries. Their research results show that industrial water pollution does not follow the EKC pattern, but their results propose that there is a declining relationship between pollution and income increase.

Recognizing that higher pollution is often associated with increased export levels and lower pollution is often correlated with increased imports in manufacturing goods, some studies have explored trade variables (Agras & Chapman, 1999; Grossman & Krueger, 1992; Shafik & Bandyopadhyay, 1992; Stern, 2004; Suri & Chapman, 1998; Wycoff & Roop, 1994). Stern (2004) and Lucas et al. (1991) combined this approach with the Hecksher-Ohlin trade theory to show that, in free trade situations, developing countries are expected to focus on producing labor- and natural resource-intensive goods (given that they have them in abundance), while developed countries tend to specialize in capital-intensive products. Following this narrative, Meng et al. (2018) explores the relationship between the participation of developing countries in Global Value Chain (GVC) and CO_2 emissions, noticing that the GVC provides a way to shift pollution to other countries as "when a country uses more foreign intermediate inputs to substitute for domestic inputs, relatively less CO_2 emissions will be generated domestically" (Meng et al., 2018, p. 31). In that sense, developed countries that have already shifted towards the service sector are able to place a share of their environmental degradation into developing countries whose economies are export-focused.

Figure 1

Environmental Kuznets Curve with conflicting dynamics (Agras and Chapman, 1999)



Using an up-to-date panel dataset that covers 88 developing countries over a 38-year period (1991–2008), this study revisits the EKC Hypothesis and examines the non-monotonic relationship between environmental degradation and GDP per capita. Unlike previous studies, this study broadens the dataset by including more recent years and a variety of environmental degradation (air pollutants) as dependent variables (CO_2, methane, nitrous oxide, PM 2.5, HFC, PFC and SF6 emissions) and conducting region-specific analyses. In particular, this study pays extra attention to the Middle East and North Africa (MENA, hereafter) region, given the significant amount of natural and human resources as well as steadily increasing levels of pollution in the region. The region accounts for 57% of the world's oil reserves as well as 41% of its gas reserves (Farzanegan & Markwardt, 2012, p. 2), which explains its intensified dependence on energy, gas, and oil production relative to other developed nations (Babiker & Fehaid, 2011; Farhani et al., 2014; Goel et al., 2013).

Regardless of the role gas and oil production play in the region's economic growth, they are considered the main causes of CO_2 and SO_2 emissions (Alrawashdeh et al., 2015). In addition, the current underpricing of these products results in a greater demand and, by extension, increases pollution. Even though the MENA region relies heavily on fossil fuels, academic debates have surprisingly neglected the potential risk of environmental degradation in the region, as Arouri et al. (2012) correctly pointed out.

Against this backdrop, this study pays extra attention to the MENA region, particularly for environmental issues and not for geo-political, ethnical, or religious ones. To state the conclusion up front, this study supports and reinforces the previous findings of an inverted U shape for CO_2 emissions with the estimated turning point at \$13,233,[1] but not for PM2.5, which shows the existence of a U-shaped relationship. Furthermore, in a regional analysis of both CO_2 and PM 2.5, with special reference to the MENA region, this study finds gaps between actual CO_2 emissions and their fitted values. We observe that Libya, Iran, Iraq, Jordan, Lebanon, and Algeria show average ratios higher than 1, meaning that the actual values for these countries are higher than the fitted ones, indicating that they face more serious pollution problems. Based on this finding, we recommend the implementation of policies in the region that aim to reach energy efficiency and develop eco-friendly and sustainable technologies.

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[1] When $y = ax^2 + bx + c$ and when a<0 and b>0, this function is concave upward and the value of x that reaches the maximum of y is $dy/dx = 2ax + b = 0$ and $x = -b/2a$. Based on Table 1, x=0.794/0.00003=\$13,233

The remaining sections are constructed as follows: section 2 explains the data and methods employed in this study; section 3 presents our major findings, particularly regarding CO_2 emissions and PM 2.5 air pollution, with special reference to the MENA region; and section 4 concludes the paper.

DATA AND METHODOLOGY

In this study, we employ a panel dataset that covers 88 lower-middle (US$ 1,026 – 4,035) and upper-middle (US$ 4,036–12,475) income countries (based on the World Bank 2011 gross national income per capita criteria) for a 38-year period (1991–2018). We systematically exclude low-income and high-income countries from the analysis as they do not properly capture the non-monotonic relationship of the inverted U shape. For the region-specific analyses, the dataset is broken into six parts: Europe and Central Asia (ECA), Sub-Saharan Africa (SSA), Latin America and the Caribbean (LAC), the Middle East and North Africa (MENA), East Asia and the Pacific (EAP) and South Asia (SA), after which this paper mainly focus on the MENA region.

In addition to CO_2 emissions (in metric tons per capita), which is the most frequently used dependent variable, this study includes methane emissions (in kt of CO_2 equivalent), nitrous oxide emissions (in thousand metric tons of CO_2 equivalent), PM 2.5 air pollution, and other greenhouse gas emission including HFC, PFC and SF6 (in thousand metric tons of CO_2 equivalent). Regarding explanatory variables, not only GDP per capita (and its quadratic term), population density (people per square kilometer of land area), and the primacy index (population in the largest city divided by urban population), but also ores and metals as well as final manufactures due to the fact that these are the ones that might be harmful for the environment. The regression equation is as follows:

$$m_{it} = \beta_0 + \beta_1 y_{it} + \beta_2 y^2_{it} + \beta_3 X_{it} + \varepsilon_i$$

where m is a variety of pollution materials, y is per capita GDP (with its square term), and X entails all other explanatory variables. The CO_2 emissions and PM 2.5 air pollution have been multiplied by 1,000 to facilitate the calculation of the turning points and avoid the digit gap with the other variables. After performing a Hausman Test that generated significant results (p value = 0.0014), this study uses the fixed effects model, and repeats it with logged and lagged independent variables, together with region-specific analyses to figure out each region's turning points. Finally, this study examines the discrepancies between fitted and actual values, especially for the MENA region to derive policy implications. All the data was obtained from the World Bank's World Development indicator.

ANALYSES AND RESULTS

All emissions in the fixed effects model

Table 1 shows the results for all emissions based on the fixed effect analyses and Figure 2 visually illustrates the fitted plots and the turning points, which are derived from the results in Table 1. Only the CO_2 emission results follow the pattern of the EKC Hypothesis (positive coefficient for GDP per capita and negative for its quadratic term, all with statistical significance). According to Table 1, the turning point for CO_2 emissions is determined at $13,233. This is consistent with the findings of previous studies including Grossman and Krueger (1995), Holtz-Eakin and Selden (1995), Oh Jinhwan and Yun ChiHyun (2014), Selden and Song (1994). Our analysis shows that methane and nitrous oxide emissions also follow the EKC Hypothesis, but the results lack statistical significance.

Interestingly, PM 2.5 air pollution and HFC, PFC, and SF6 emissions show U shape relationships with per capita GDP; these pollutants may become more serious as a country's income level rises and higher income countries also seem to be ineffectively tackling these issues. However, this result should be interpreted with caution because, as shown in Table 2, the signs for the coefficients turn out to be opposite when the variables are log-transformed.

Table 1

Estimation results for all emissions

	Co_2	Methane	Nitrous Oxide	PM 2.5	HFC, PFC and SF6
GDP per capita	0.794***	33.806	10.291	-0.799***	-27.604*
	(0.199)	(30.699)	(10.330)	(0.249)	(15.213)
(GDP per capita)^2	-0.00003***	-0.002	-0.001	0.00002*	0.002
	(0.000)	(0.002)	(0.001)	(0.000)	(0.001)

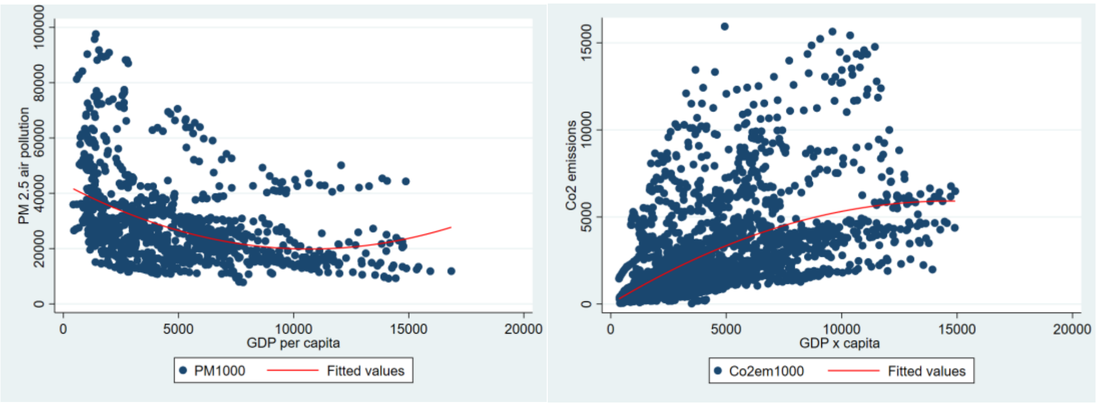
Note. *** $p<0.01$, ** $p<0.05$, * $p<0.1$. White heteroskedasticity-consistent errors are provided in parentheses. CO_2 emissions and PM 2.5 air pollution are measured in metric tons x 1,000 per capita to adjust for the use of per capita GDP. This table does not include results for all the other explanatory variables, denoted as *X* in Equation (1), as all of them turn out to be insignificant, and this table emphasizes deriving the turning points illustrated in Figure 1. Table 2 shows the results for all X variables with log and lag transformations.

To check the robustness of the original results, this study conducts another series of analyses with the same variables, but all log-transformed and lagged by one year to avoid any potential endogeneity. Table 2 presents the results. This analysis confirms the inverted U pattern for CO_2, although the quadratic term of GDP per capita loses its significance. As mentioned above, however, PM2.5 turns out to follow an inverted U pattern; the U pattern in the previous table is not robust and the relationship appears spurious.

Regarding other variables, the primacy index still shows statistically insignificant results, while population density gains significance for CO_2, methane, and nitrous oxide emissions.

Figure 2

Scatter plots and quadratic fit plots for CO_2 emissions and PM2.5 emissions



Graph 1. CO_2 emissions

Graph 2. PM 2.5 air pollution

Table 2

Estimation results for all emissions in the fixed effect model with logged variables

	Co2 emissions	**Methane emissions**	**Nitrous Oxide emissions**	**PM 2.5 air pollution**	**HFC, PFC and SF6 emissions**
Log GDP per capita	1.078*	0.033	0.842	0.549**	-0.809
	(0.555)	(0.643)	(0.690)	(0.253)	(3,569)
Log (GDP per capita)^2	-0.028	0.008	-0.045	-0.040***	0.078
	(0.034)	(0.040)	(0.043)	(0.015)	(0.221)
Log Population density	0.269**	0.610***	0.455***	0.005	0.921
	(0.121)	(0.101)	(0.107)	(0.038)	(1.019)
Log Primacy index	-0.190	-0.117	-0.220	0.073	-0.540
	(0.183)	(0.234)	(0.202)	(0.058)	(1.685)
Log Lag Ores and metal trade	0.010	-0.042**	-0.010	0.011	-0.189
	(0.024)	(0.018)	(0.024)	(0.011)	(0.170)
Log Lag Manufactures trade	0.077	-0.010	-0.018	-0.043	-0.403
	(0.048)	(0.046)	(0.050)	(0.040)	(0.271)
Constant	-7.966***	6.643***	3.165	1.731	8.149
	(2.267)	(2.383)	(2.764)	(1.094)	(13.500)

Note. *** p<0.01, ** p<0.05, * p<0.1 White heteroskedasticity-consistent errors are provided in parentheses.

Region-specific approach

To look further into these results, this study conducts region-specific analyses. Table 3 shows the estimation results for CO_2 emissions and PM 2.5 air pollution in the fixed effect model by region. Given that the results for most of the independent variables lack significance, this table focuses on the estimation results for CO_2 emissions and PM 2.5 air pollution with only GDP per capita and its quadratic term as independent variables. When looking at CO_2 emissions, the Latin America and Caribbean region well captures the EKC, with strong significance levels, setting the turning point at $23,900. South Asia also gains statistical significance and is consistent with the EKC with a turning point of $13,137. The results for the MENA region are not as distinctive as for the other regions but still reveal the inverted U shape with a turning point of $18,250 (see Figure 3). South Asia's turning point is closer to the global turning point for CO_2 captured in table 1 (13, 233$), while both Latin America and the Caribbean and MENA region are higher. The PM 2.5 air pollution results in this table show that only South Asia gains statistical significance and follows the EKC's inverted-U pattern. Things turn out to be the opposite for other regions. Further research needs to be conducted in order to establish the reason behind the inconsistency of PM 2.5 air pollution results.

Table 3

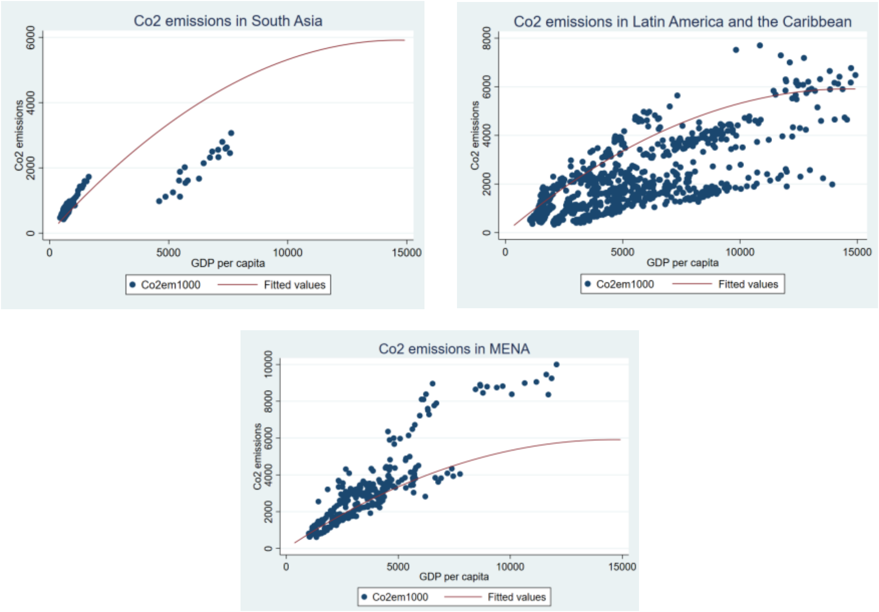
Estimation results for CO_2 emissions and PM 2.5 air pollution in the fixed effect model by region

	CO_2 emissions					
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
GDP per capita	0.360	-0.098	0.478***	0.730***	1.046***	1.051***
	(0.298)	(0.142)	(0.080)	(0.262)	(0.224)	(0.025)
GDP per capita)^2	-0.00001	0.00005***	-0.00001***	-0.00002	-0.00001	-0.00004***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Constant	3750.117***	942.204***	131.977	776.697	-711.581	-732.089***
	(956.711)	(200.199)	(255.263)	(763.224)	(433.147)	(32.417)
	PM 2.5 Air Pollution					
GDP per capita	-0.955***	-2.524*	-1.369***	0.955	-0.052	7.356***
	(0.224)	(1.372)	(0.361)	(0.924)	(0.698)	(1.666)
GDP per capita)^2	0.00003**	0.0002*	0.00005***	-0.00007	-0.00004	-0.001***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Constant	27886.875***	43023.371***	26987.486***	41964.844***	25097.931***	43848.654***
	(706.350)	(2874.332)	(1256.356)	(2505.972)	(1309.740)	(2736.041)

Note. *** $p<0.01$, ** $p<0.05$, * $p<0.1$ White heteroskedasticity-consistent errors are provided in parentheses. Also, Co2 emissions are multiply by 1000 in order to provide the turning point; otherwise, the unit gap between GDP per capita and Co_2 emissions is too big to be calculated. (1) Europe & Central Asia, (2) Sub-Saharan Africa, (3) Latin America & the Caribbean, (4) the Middle East & North Africa, (5) East Asia & the Pacific, and (6) South Asia.

Figure 3

Scatter plots and quadratic fits of CO2 emissions by region



CO_2 emissions in the Middle East and North Africa

The EKC Hypothesis posits that "economic growth and energy consumption may generate considerable pressure on the environment" (Farhani et al., 2014, p. 270) until a turning point is reached. In fact, one of the main policy implications of the EKC on developing countries is the "prioritization of economic prosperity as a potential solution to environmental concerns" (Sehid & Aslan, 2019, p. 260). However, it is important to note that "pollution is closely related to energy consumption since more energy consumption leads to higher economic development via productivity enhancement but it also leads to higher pollutant gases" (Farhani et al., 2014, p. 272).

As noted in the introduction, the MENA region accounts for a large share of natural resources, accounting for approximately half of the world's gas and oil reserves. Oil and gas production, therefore, is responsible for the region's economic growth and, subsequently, for a big share of CO_2 emissions. Oil and gas production, composed by the extraction and refining of these natural resources, are significant contaminating activities. In 2017, the MENA region provided 37% of the world's oil production and 22% of the world's gas production (Tagliapietra, 2019). Our analysis, however, does not include some of the highest contributors of the region, such as Saudi Arabia, Qatar, the United Arab Emirates or Kuwait. Osabuohien et al. (2014) and Yusuf et al. (2020) provide some examples of research done with oil-producing African countries to show the relationship between environmental degradation and economic development. Both concluded that oil-based economies tend to have contaminate largely due to the nature of their activities. Therefore, economic growth followed by a great amount of energy consumption, without a diversification of the energy sources, directly impacts CO_2 emissions in the region.

This study focuses on the CO_2 emissions in the Middle East and North Africa (MENA) region and seeks to determine the gap between actual CO_2 emissions and their fitted values. Identifying the cases where actual pollution levels exceed the model's predicted values from the model helps us pinpoint the countries in the region that face more serious pollution problems. Croitoru and Sarraf (2010) noted that, since the 1990s, countries in the MENA region have been developing environmental planning policies and building environmental legal frameworks.

Table 4 shows the discrepancies between actual and fitted values. To produce these results, this study runs two tests - a fixed effect model with all the explanatory variables and another model with only GDP per capita - and compute the average values. Values higher than 1 indicate that the actual values exceed the estimated values, revealing a serious degree of pollution (See Table 4 for the ratios). Libya, Iran, Iraq, Jordan, Lebanon, and Algeria all show average ratios higher than one.

These countries should consider implementing policies focused on energy efficiency and the development of environmentally friendly technologies in the sector of energy production and natural resources extraction and refining to minimize the negative effects of economic growth on CO_2 emissions. As Özokcu and Özdemir (2017) point out, pollution causes damages, especially CO_2 emissions, that are in nature irreversible, meaning that a reduction on environmental degradation means not an increase of pollution, not a decrease on the already caused damaged. The damaged caused by the efforts to reach the turning point will remain permanent. To mitigate air pollution and environmental degradation, the government can implement policies that increase the prices of energy and hydrocarbon products. One example would be adopting carbon taxes (Farid et al., 2016; Parry et al., 2015; The Climate Leadership Council, 2019) which increases the prices of the final products and thereby encourages the shift toward cleaner fuels, and has proven to be among the most effective policies for tackling environmental degradation.

Table 4

Discrepancies between actual versus fitted values for CO_2 emissions in the MENA region

	Frequency	Ratio Average
Algeria	31/34	1.233
Egypt	15/34	0.981
Iran	34/34	1.754
Iraq	31/34	1.458
Jordan	34/34	1.343
Lebanon	25/27	1.180
Libya	16/16	1.962
Morocco	0/34	0.643
Tunisia	0/34	0.898
Yemen	0/25	0.554

Note. These results are based on a fixed effect model. Frequency = the number of years where the ratio is higher than 1/the total years; the numbers differ country by country due to the lack of data on CO_2 emissions. Ratio average= average values of actual/predicted data. Djibouti and Syria belong to this region but do not show up in this table due to data unavailability.

CONCLUSION

Our findings regarding CO_2 emissions show consistent results based on the EKC Hypothesis, which are robust with both logged and actual variables. This contrasts with our findings for other emissions such as methane and nitrous oxide that still follow the EKC pattern but lack statistical significance. PM 2.5 air pollution shows an interesting case with a U pattern, but the pattern is not robust as the coefficients show opposite signs when they are lagged with log transformation. However, given the growing interest regarding PM 2.5, this area warrants further research. Adding other variables, like HDI, can also be considered. Last, but not the least, cubed terms can be used on top of quadratic ones (Lorente & Álvarez-Herranz, 2016; Sarkodie & Strezov, 2018; Sarkodie & Strezov, 2019), all of which will be reserved for further research.

Regarding other variables, primacy index, manufactures trade and ores and metal trade did not show statistically significant results. Only population density gained statistical significance when the variables were logged. The lack of consistency and statistical significance in trade variables might reflect the complexity of the relationship between trade and environmental degradation; Correa (2004) pointed out that high levels of manufactured goods exports translate into increased energy consumption (which would mean an increase of CO_2 emissions) as evidence for the “offshoring” argument, but this argument is not confirmed in this study.

Regarding the MENA region, one of the problems this study identifies as contributing to the region’s environmental degradation is the underpricing of energy products. These types of policies should be complemented with increased support for greener technology-related research and development (IMF, 2019) as a plan of action to boost research in the field. Policies following this approach can help countries overcome dependence on fossil fuels for energy production and shift towards environmental-friendly sources of energy. The government should not need to provide constant support for research and development, but it should not withdraw such support until the newer technologies are fully deployed.

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APPENDIX

Country list

1	Albania	13	Cameroon	25	Egypt, Arab Rep.	37	Iran, Islamic Rep.
2	Algeria	14	Chile	26	El Salvador	38	Iraq
3	Angola	15	China	27	Fiji	39	Jamaica
4	Argentina	16	Colombia	28	Gabon	40	Jordan
5	Armenia	17	Congo, Rep.	29	Georgia	41	Kazakhstan
6	Azerbaijan	18	Costa Rica	30	Ghana	42	Lao PDR
7	Belarus	19	Cote d'Ivoire	31	Grenada	43	Latvia
8	Bolivia	20	Cuba	32	Guatemala	44	Lebanon
9	Bosnia and Herzegovina	21	Djibouti	33	Guyana	45	Libya
10	Botswana	22	Dominica	34	Honduras	46	Lithuania