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The GDP–CO_2 Emissions Nexus in Arab Countries

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Abstract

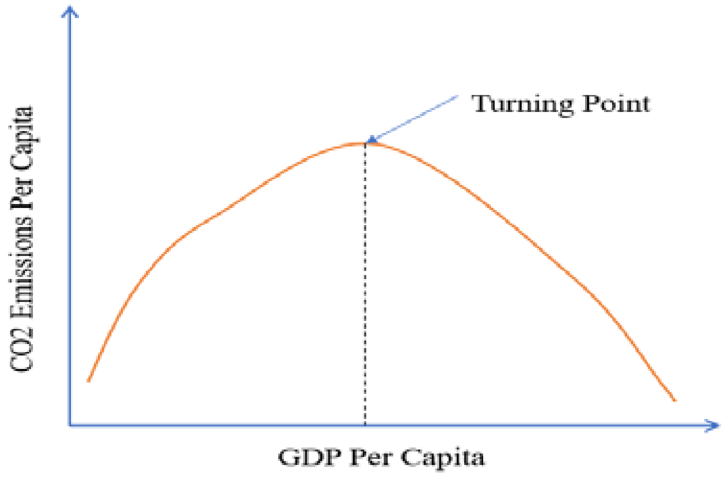
This research investigates the environmental Kuznets curve (EKC) paradigm by assessing the link between real GDP per capita, renewable energy, energy prices, and carbon dioxide (CO_2) emissions in selected Arab nations. In order to determine the extent of the association between the variables, the pooled mean group model is applied. According to the findings, real GDP per capita has a long-term positive effect on CO_2 emissions, but quadratic GDP has a negative impact on CO_2 emissions. The results suggest a non-linear relationship between the real GDP per capita and CO_2 emissions; hence, the EKC hypothesis can be true when heterogeneity in the sample is controlled for. The study found that higher GDP contributed to higher CO_2 emissions below the turning point. Still, higher GDP contributed to lower CO_2 emissions beyond the income turning point in high-income and non-high-income Arab countries. In addition, the findings indicate that the use of renewable energy is inversely related to carbon dioxide emissions. In a similar vein, fluctuations in energy prices have been shown to have a detrimental impact on CO_2 emissions, particularly in middle- and low-income Arab nations.

1. Introduction

The relationship between diverse economic activities and environmental deterioration has become a central issue for policymakers, practitioners and academicians. Evidence suggests that CO_2 emissions are among the most critical factors causing global warming. CO_2 accounts for approximately 74.4% of the total greenhouse gas emissions, followed by methane, which accounts for about 17.3%, and nitrous oxide, which accounts for 6.2% (Ritchie et al., 2020). The EKC hypothesis is crucial for comprehending the connection between economic development and greenhouse gas emissions. According to the EKC hypothesis, GDP may initially result in more significant greenhouse gas emissions, mainly when nations are in their early phases of economic development. However, the GDP could also be the main factor helping to mitigate artificial pollutants when countries achieve a certain threshold income level. This situation implies a non-linear association between economic output and CO_2 emissions.

In many countries, increased economic activity has been accompanied by the expansion of the manufacturing sector on account of the agricultural sector, the progress of the transportation sector, and other uses of primary energy sources for production and consumption. When income reaches a certain threshold level, as in many of today's advanced economies that have started to rely more on the services sector, countries begin to formulate rules and procedures regulating economic-environmental intersections, which change the behaviour of economic agents towards the environment and reduce emissions. At comparable phases, economic progress can be vital in enhancing environmental quality. Implementing carbon taxes by fiscal authorities in many developed countries has helped address some emissions-related concerns. Also, investment in green activities due to changes in consumer preferences toward environmentally friendly products may improve environmental outcomes and reduce CO_2 emissions. However, the ecological impact of economic activities in many developing countries remains to the left of the EKC curve (see Figure 1). This situation may indicate that many developing countries are still below an appropriate development level where solid environmental regulations have yet to be introduced, and fundamental changes in consumption and investment occur. In other words, at an early stage of industrialisation, greenhouse gas emissions rapidly increase because of the focus on improving physical output, and individuals concentrate more on improving their income status rather than the quality of the environment (see Lau *et al.*, 2014).

Figure 1. EKC hypothesis



Source: Grossman and Krueger (1993)

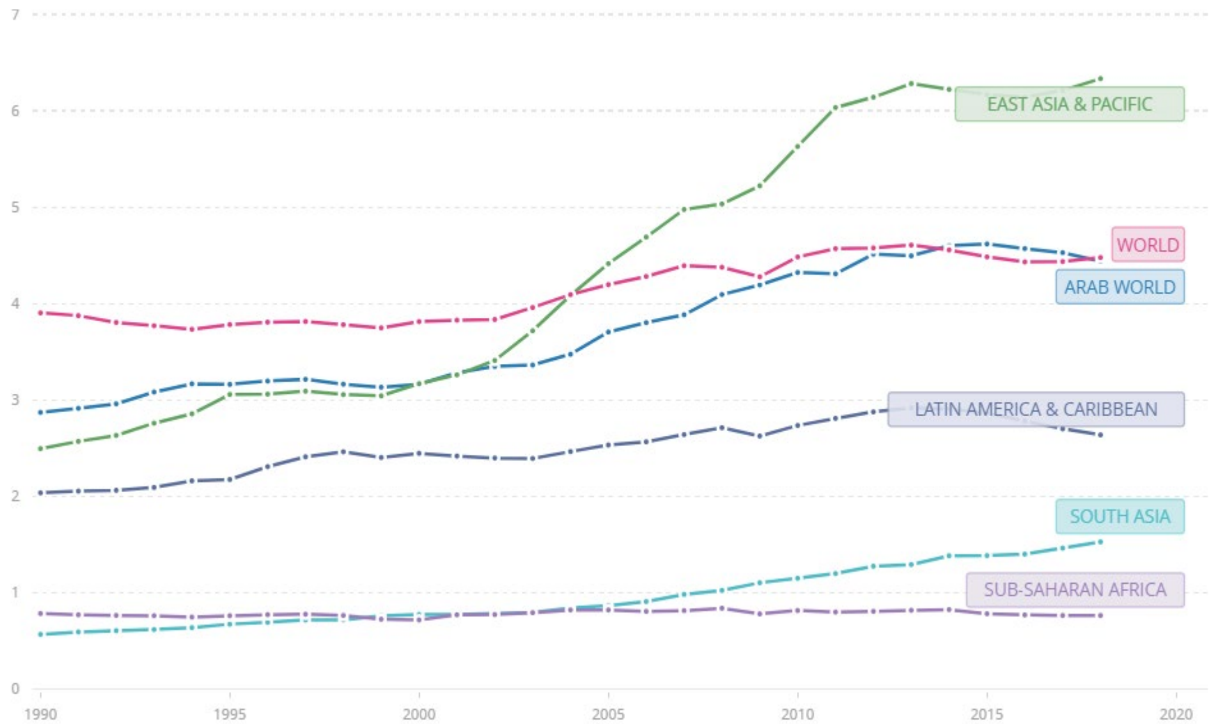
In recent years, there has been increasing interest in the issue of climate change among economists and policymakers. The growing volume of human activity has been the main driver of global warming, mainly attributable to the heavy use of primary fossil fuel products (e.g., coal, oil, and gas), and their emissions have draped the earth leading to climate change. This situation may also cause capital stock erosion and harm the supply side of the labour market, thus reducing labour productivity as economies adapt to higher temperatures. Another potential impact occurs when climate change affects domestic prices through rising commodity and energy costs, causing inflationary pressures. For these reasons, governments have carefully begun formulating policies that consider production-led climate change by imposing rational sectoral policies to mitigate swings in climate change.

According to the World Bank income classification, there are four low-income nations, twelve middle-income countries, and six high-income countries in the Arab world. In 2019, the region contributed to the world economy by approximately US$2.7 trillion[1]. However, this number does not explicitly describe the heterogeneity of the GDP per capita among the Arab countries. Specifically, the region's high-income countries[2] had far higher GDP per capita than emerging market economies and the other Arab countries.

[1] The World Bank (2022). The value is on real terms.
[2] "Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, and the United Arab Emirates".

Arab countries have witnessed remarkable progress in their economic performance. However, this has been at the cost of considerably high emission levels. The average level of CO_2 emissions for the world, East Asia and the Pacific, Latin America and the Caribbean, sub-Saharan Africa, and the Arab area are shown in Figure (2). The data shows that CO_2 emissions per capita increased sharply in Arab countries from 1990 to 2020[3]. Prior to surpassing the global average in 2014, the emissions in the Arab area were more significant than those in South Asia, sub-Saharan Africa, Latin America & the Caribbean, and the rest of the globe. Nonetheless, emissions of CO_2 started to fall slightly after 2015, going below the world's average in 2018, before they rose again. Figure (3) shows the level of CO_2 emissions of twenty Arab countries compared to the world's average from 1980 to 2020. Eight countries emitted CO_2 higher than the world's average, whereas the others had considerably lower emissions. Although higher-income states tended to contribute more to global CO_2 emissions than lower-income economies, they have declined, especially after 2005.

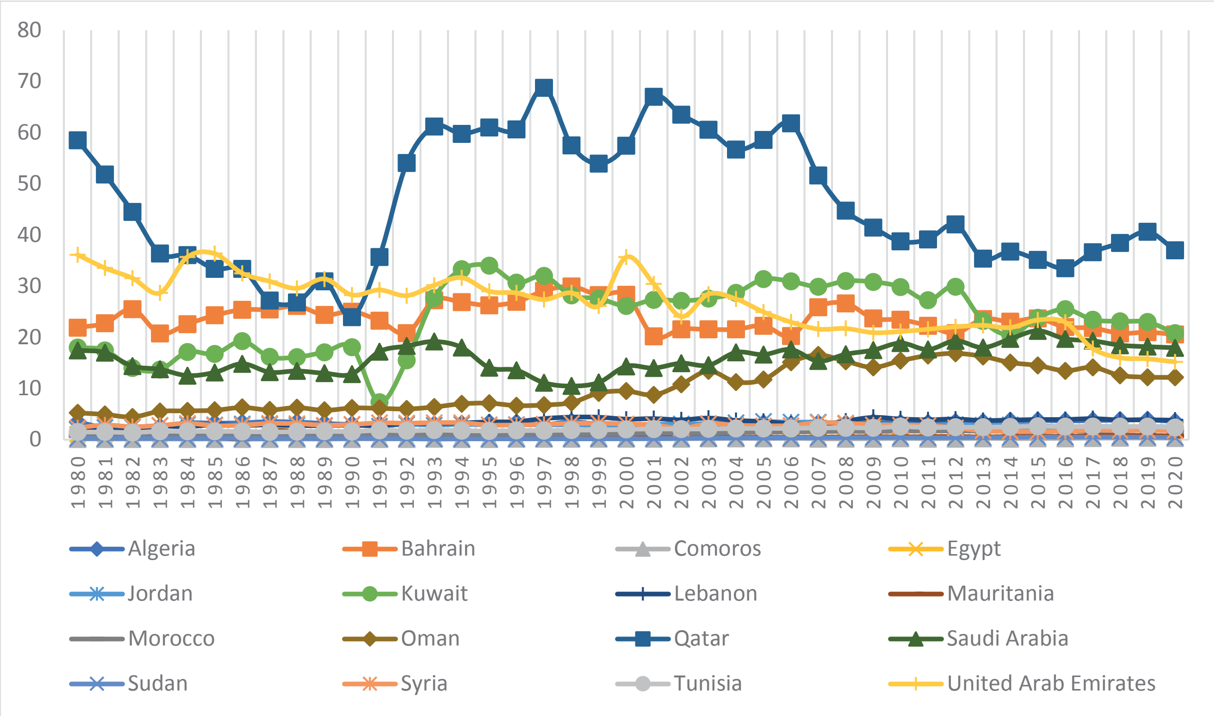
Figure 2. Carbon dioxide Emissions Per Capita (metric tons), Regions



Source: World Bank (2022).

[3] CO_2 emissions from the burning of fossil fuels and industries. Fossil CO_2 emissions do not include land use change, deforestation, soils, or vegetation.

Figure 3 . Carbon dioxide Emissions Per Capita, Arab Countries



Source: Our World in Data, Based on the Global Carbon Project (2022).

The impact of climate change encompasses the entire world. A substantial percentage of the world's population—roughly 77%[4]—makes Asia and Africa more sensitive to climate change than other continents, as Asia is home to most of the world's population. Furthermore, despite the modest contribution of Africa to global warming, it continues to be a highly vulnerable continent to climate change alongside Asia (Duenwald *et al*., 2022). To combat climate change, many nations, including most Arab states, have engaged with the United Nations Framework Convention on Climate Change (UNFCCC). More importantly, significant efforts have been made by Arab states, as explained by their Nationally Determined Contributions (NDCs). Various endowed countries have set up initiatives, strategies, and policies to address the consequences of climate change. Moreover, numerous projects and plans aimed at reducing the emissions of greenhouse gases by million tons of CO_2 equivalent by 2030 have been established by Arab countries.

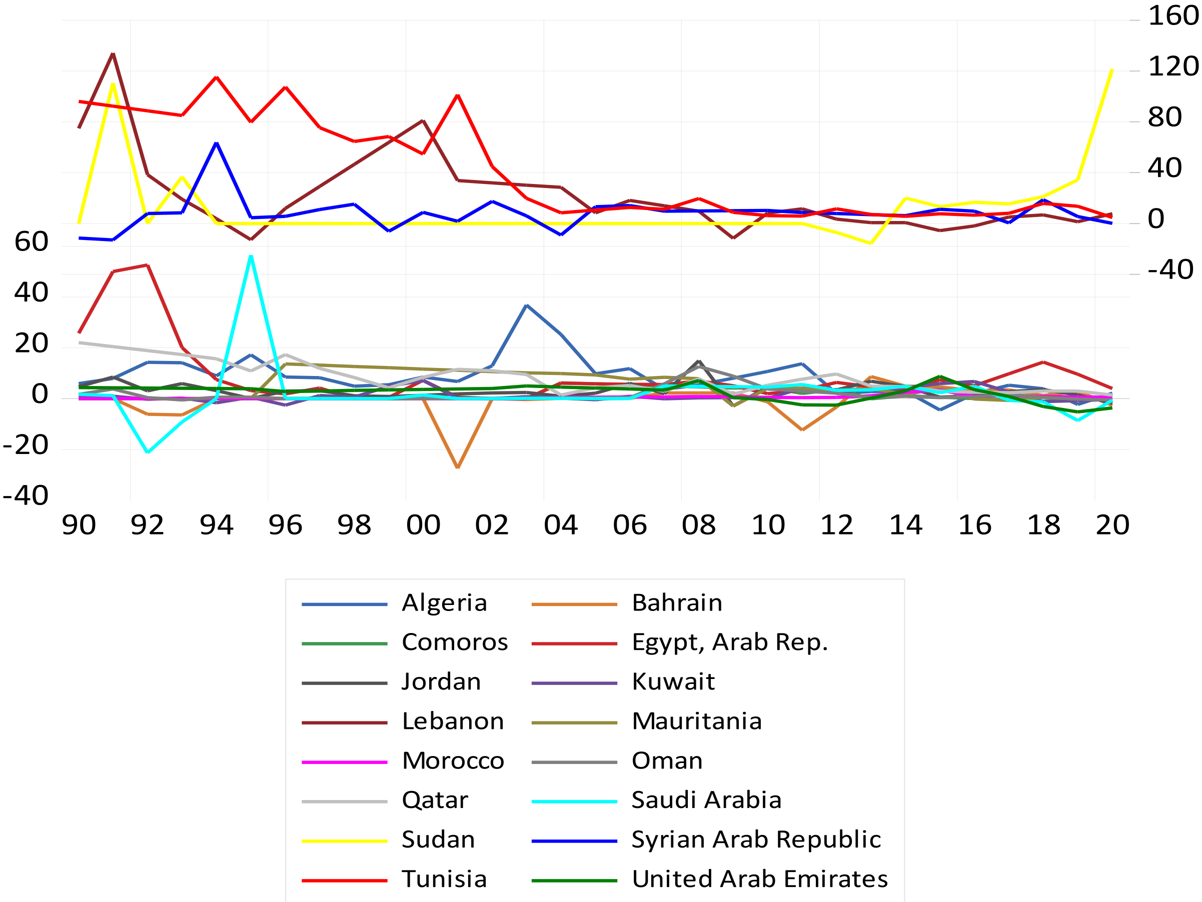
Energy and fossil fuel subsidy reform and elimination policies, which most likely result in high prices, are necessary to achieve Paris Agreement targets and alleviate greenhouse gas emissions (Chepeliev and van der Mensbrugghe, 2020). Fuel and energy subsidies are commonly used in the Arab region due to various economic and societal considerations. In the last decade, some Arab countries began to eliminate energy subsidies leading to higher oil prices, for instance. Figure (4) shows the changes in energy prices in most Arab countries from 2002 to 2020. It could be helpful to examine how the CO_2 emissions respond to the changes in energy prices, assuming that policy reforms that eliminate subsidies would result in higher prices.

The study uses the EKC hypothesis framework to examine the relationship between GDP per capita and CO_2 emissions in Arab nations. Also, the study investigates the effect of other important variables, namely renewable energy consumption, energy prices, and trade openness

[4] Source: https://www.worldometers.info/world-population/population-by-region/

on CO_2 emissions in the region. Estimating panel data containing heterogeneous countries concerning income levels could result in unrealistic estimates of the turning point (Dijkgraaf and Vollebergh 2005). Therefore, this study further investigates the EKC hypothesis by considering income differences.

Figure 4. Changes in Energy Prices



Source: Ha *et al.* (2021), A Global Database of Inflation.

The following are some ways this study adds to the body of knowledge on output-CO_2 emissions. First, following Pesaran *et al.* (1999), this study uses the pooled mean group (PMG) estimator to assess the validity of the EKC hypothesis in 16 chosen Arab countries. Although the PMG estimator permits short-run coefficients to vary among countries, it maintains long-run slope parameter homogeneity. Earlier research on the EKC hypothesis integrated a sample of nations with various characteristics. In this study, the sample is split into two groups based on the classification of their income level: high-income and middle- and low-income (hereafter non-high-income). Notably, the analysis accounts for the potential impact of renewable energy and energy prices on CO_2 emissions.

The rest of this study is divided into the following sections: Section 2 discusses pertinent earlier research. The data and techniques utilised in the current research are explained in Section 3.

The study's results are presented in Section 4. The findings are summarised in Section 5, along with suggested policy recommendations.

2. Literature Review

A considerable number of studies have been done on the relationship between CO_2 emissions and economic development, demonstrating the EKC hypothesis, which was developed in the World Bank's World Development Report, 1992 (IBRD1992) and promoted by Grossman and Krueger (1993). Existing empirical studies have recognised the critical role played by the GDP in shaping environmental depletion at early developmental stages (see Ibrahim and Law, 2014; Apergis and Ozturk, 2015; Al-mulali *et al.*, 2015; Sirag *et al.*, 2018; Destek and Sarkodie, 2019). Figure (1) explains the EKC hypothesis that suggests the relationship between GDP and CO_2 emissions is not linear. First, GDP per capita increases CO_2 emissions. Beyond a certain threshold level of income, the impact on CO_2 emissions becomes negative as income per capita increases.

In testing the EKC hypothesis Apergis and Ozturk (2015) found that the coefficients had the correct sign and statistically significant supporting the EKC hypothesis. In addition, Shahbaz *et al.* (2013) reviewed the EKC for a single economy, assessing the association between CO_2 emissions and economic development in Turkey using data from 1970 to 2010. Their results validated the EKC hypothesis in Turkey. In the same context, Al-Mulali *et al.* (2015) examined the EKC assumption for Latin American countries. They investigated the influence of income, renewable energy, and other factors on CO_2 emissions. They found an inverted U-shaped relationship between CO_2 and GDP, thus suggesting the existence of the EKC hypothesis. Additionally, Akram (2013) examined the consequences of climatic change on the economic growth of several Asian governments. The author found that economic growth is negatively affected by changes in temperature and precipitation.

Theoretically, the association between climate change and GDP growth is negative. Several empirical findings have supported this argument, e.g. (Akram, 2013; Shahbaz *et al.*, 2013; Bernard *et al.*, 2015; Kadanali and Yalcinkaya, 2020). However, although these studies reached the same result, they each used different proxies for climate change. For instance, Akram (2012) used temperature changes as a proxy for climate change, while others (Kadanali and Yalcinkaya, 2020) used greenhouse gas emissions.

Similarly, Stern (2004) found that environmental degradation increased initially but eventually fell when income per capita rose. Cohen *et al.* (2019) found that the EKC's elasticity was much lower in China's states over the last three decades, pointing to a long-term decoupling pattern between the CO_2 emissions and GDP. In 2014, the OECD published a report addressing the effectiveness of climate change on economic growth. The report showed that the effect was expected to rise over time, leading to a 0.7% to a 2.5% loss in global GDP by 2060 (Dellink *et al.*, 2014). Another study also found that environmental rules boosted the chances for growth if environmental quality increased productivity or efficiency (Ricci, 2007). Empirical studies have suggested various approaches to examine climate change's impact on economic growth.

To investigate the EKC hypothesis, Apergis and Ozturk (2015) used panel data and the GMM approach in a multivariate context to find evidence of the EKC hypothesis. Using the VECM method, Shahbaz *et al.* (2013) examined the relationship between income and CO_2 emissions. Their research confirmed the long-term association between GDP and CO2 emissions using the Fully Modified OLS (FMOLS) from 1980 to 2010 and the EKC. Akram (2013) incorporated temperature and precipitation as climate change measures in a fixed-effect model.

Although Bouznit and Pablo-Romero (2016) claimed a non-linear relationship between income and CO2 emissions, the turning point was higher than the income level. In the same vein, the estimated threshold of the GDP per capita reported by some previous studies was relatively unrealistic because it was higher than the income levels of those countries. This situation suggests that continuous increases in income lead to further carbon dioxide emissions (Bouznit and Pablo-Romero, 2016; Amri *et al.*, 2019). An unrealistic threshold could be due to methodological limitations (see Stern, 2004; Narayan and Narayan, 2010; Sirag *et al.*, 2018), sampling, and data measurement issues. Notwithstanding that, few studies have found evidence supporting the EKC hypothesis (see Kharbach and Chfadi, 2017; Bouyghrissi *et al.*, 2022).

Empirical evidence indicated discrepancies in verifying the EKC hypothesis on the ground. Some studies showed that reality matches the relationship hypothesis between output and environmental performance indicators, while others stated the opposite; the assumption was incorrect in some countries. By surveying the previous literature, we found insufficient studies linking output and environmental degradation on the one hand and climatic changes and carbon dioxide emissions on the other. This is an excellent opportunity to cover this gap and verify the EKC hypothesis in Arab countries.

3. Methodology

3.1. Model Specification

This study followed Sirag *et al.* (2018) and Destek and Sarkodie (2019) to investigate the EKC in 16 Arab countries and specified the following econometric model:

$$CO_{2\,it} = \alpha_0 + \alpha_1 GDP_{it} + \alpha_2 GDP_{it}^2 + Z_{it}\rho_i + \varepsilon_{it} \tag{1}$$

where CO_2 is carbon dioxide in per metric tons per capita, GDP is the real gross domestic product per capita, GDP^2 is GDP per capita squared, Z is a vector of other explanatory variables, such as renewable energy consumption as a percentage of total final energy consumption (RE), trade openness as a percentage of the GDP (TO), and energy prices measured as the percentage change of energy consumer price index (EP), $i = 1, 2, \dots, N$, $t = 1, 2, \dots, T$, and ε refers to the error term that is independently and identically distributed ($\varepsilon \sim$ *iid*). All the variables are transferred to natural logarithms.

For the EKC hypothesis to hold, both α_1 and α_2 are expected to be statistically significant, but with positive and negative signs for the former and the latter, respectively. The concern of a high degree of collinearity between the (GDP) series and its quadratic term (GDP^2) in testing for the EKC hypothesis is mitigated by de-meaning the logarithmic form of the real GDP per capita (see Brown and McDonough, 2016). The de-meaned covariate is then used to construct the quadratic term. Following Brown and McDonough (2016), the empirical model is written in the following form:

$$lnCO_{2\,it} = \beta_0 + \beta_1(lnGDP_{it} - ln\overline{GDP}) + \beta_2(lnGDP_{it} - ln\overline{GDP})^2 + Z_{it}\beta_{3i} + u_{it} \qquad (2)$$

Where $(lnGDP_t - ln\overline{GDP})$ and $(lnGDP_t - ln\overline{GDP})^2$ refer to the de-meaned values of the GDP and its quadratic form, β_1, β_2, β_{3i}, are the long-run elasticities. It is argued that the closer $(lnGDP_t - ln\overline{GDP})$ is to zero, in absolute terms, the less linear the relationship between $(lnGDP_t - ln\overline{GDP})$ and $(lnGDP_t - ln\overline{GDP})^2$, and the opposite is true (see Brown and McDonough, 2016). To judge whether the EKC existed or not, the joint significance of $\hat{\beta}_1$ and $\hat{\beta}_2$ is used. According to Brown and McDonough (2016), the GDP turning point is calculated as

$$\widetilde{GDP} = \rho = e^{-\frac{\hat{\beta}_1}{2\hat{\beta}_2} + ln\overline{GDP}}$$

Where ρ is the income turning point, e signifies the exponential function, and $\overline{GDP}$ is the mean of the GDP per capita. It is worth mentioning that the estimated turning point is meaningful only when the coefficients of the GDP and its quadratic term are significant.

3.2. Method of Estimation

3.2.1. Panel Unit Root Test

Using the panel unit root test in analysing macro panel data is a preliminary step to assess the stationarity of the data. Applying a unit root test in panel data has become increasingly important, especially with large T. A series whose integrated order zero is stationary I(0), while one's integrated of order one and order two I(1) and I(2) are non-stationary, respectively. Specifically, the main idea is to avoid using non-stationary I(2) variables in the regression model since it may lead to meaningless findings. Unit root tests typically include two generations. The independence of cross-sectional units is an assumption made by the first-generation unit root tests like LLC and IPS[5]. In contrast, cross-sectional dependence is supported by Pesaran's (2007) second-generation unit root test (CIPS). The CIPS test was employed in this investigation because it is preferable to the first-generation panel unit root test since it accounts for cross-sectional dependence (see Pesaran, 2007).

3.2.2. Panel Cointegration Test

In the next step, the panel cointegration assessment was conducted to verify the equilibrium connection among the variables. The significance of the cointegration testing procedure stems from concerns about the nonsense regression in the non-stationary data. Spurious regression is more likely for panel data with large T and small N, and the inferences based on the test statistics are misleading (Baltagi, 2012). The Pedroni (2004) cointegration test that permits heterogeneity among countries is used in this preliminary step. Pedroni suggested several tests under the H_0 of no cointegration and classified them into two categories. The first category involves averaging test statistics for the time series cointegration across individual countries.

[5] LLC and IPS refer to Levin, Lin and Chu (2002) and IM, Pesaran and Shin (2003) panel unit root tests, respectively.

At the same time, the second category takes the average in the sample. The two types are used for three tests: rho-statistic, PP-statistic, and ADF-statistic. If H_0 is rejected for at least two tests, the PP and ADF statistics, the cointegration relationship is valid.

3.2.3. Pooled Mean Group

After the cointegration test, the following step is estimating the model. Following Pesaran et al. (1999), the PMG estimator is utilised in this study. The PMG approach assumes the homogeneity of the parameters in the long run but allows for the short-run coefficients to differ across countries. The PMG estimator concurrently estimates the long-run and short-run dynamics, in contrast to cointegration regression approaches like dynamic least squares and fully-modified least squares. The error correction model demonstrates the long- and short-term dynamics adjustment processes. The ability to handle a mixed order of integration is another benefit of utilising the PMG estimator. Also, the PMG estimator assumes that disturbances are independent of one another across cross-sectional units. In order for the PMG estimation to be accurate, the cross-sectional dependency test, as suggested by Pesaran (2004), is essential. Other estimators, such as the common correlated effect PMG (CCEPMG) estimator, might be employed if cross-sectional dependency exists.

3.3. The Data

In order to examine the impact of GDP per capita on CO_2 emissions in the EKC hypothesis framework in chosen sixteen Arab nations from 1980 to 2020, this study employed CO_2 emissions per capita as its dependent variable. Environmental deterioration has frequently been measured using CO_2 emissions per capita. Metric tons per capita are used to measure CO_2 emissions. Also, CO_2 emissions data was the only available series with a longer timescale among total greenhouse gas emissions. Therefore, the present study used CO_2 emissions as its mean dependent variable. Data on CO_2 emissions are also obtained at the same time from the Global Carbon Project.[6]

The independent variable, the GDP per capita, was measured at constant prices (2015 US$). Another important explanatory variable we included in the model is renewable energy consumption as a percentage of total final energy consumption (RE). It is suggested that as renewable energy consumption increases, CO_2 emissions decline. Additionally, the proportion of exports to imports to GDP served as a measure of trade openness (TO), which may have an ambiguous impact on CO_2 emissions. Also, energy prices (EP) are used to see the effect of energy subsidies on CO_2 emissions since the prices reflect subsidies in some countries in the sample. The energy subsidy will likely result in higher emissions and vis versa. Thus, a negative relationship is expected between EP and CO_2 emissions. Another explanatory factor is trade openness[7]. The data used in this study are obtained from the World Bank database (World Development Indicators). The energy consumer price index is used to reflect energy

[6] The Global Carbon Project can be found in Our World in Data. The link: https://ourworldindata.org/co2-emissions

[7] According to the Hecksher–Ohlin theory, trade openness positively affects environmental pollution. The theory suggests that environmental degradation due to the consumption, processing and manufacturing of goods and services rises with more trade openness.

prices (EP), and the data are obtained from A Global Database of Inflation developed by the World Bank (Ha *et al*., 2021).

Economic growth is an essential factor impacting the EKC hypothesis. The fundamental explanatory element of environmental degradation is the development level. As income rises, economic activity increases, leading to more CO_2 emissions. However, when income reaches a certain level, additional increases in income tend to improve environmental quality. An inverted U-shaped relationship postulates the relationship between the GDP per capita and the environment.

Table (1) presents the descriptive statistics of the variables used in this study. Overall, the total number of observations was about 404. Also, we found that RE have the highest variation among the variable, whereas TO and GDP have the lowest standard deviations. Table (2) shows the correlation results. A strong positive correlation existed between CO_2 and GDP per capita and CO_2 and RE, whereas a weak negative correlation between CO_2 and EP is observed. Notably, there was no high correlation between the independent variables. It is worth noting that the correlation between GDP and GDP^2 was about 0.66, which is not a concern since it is not a high correlation.

Table 1. Descriptive statistics

Variable	Obs.	Mean	Std. Dev.	Min.	Max.
CO_2	404	0.955	1.532	-2.105	4.205
GDP	404	-1.259	1.334	-2.906	2.389
GDP^2	404	3.363	2.417	0.0009	8.447
RE	404	0.905	2.698	-4.707	4.450
TO	404	4.135	0.692	-0.243	5.175
EP	404	9.101	20.219	-21.30	134.10

Note: columns refer to observations, standard deviation, minimum, and maximum.

Table 2. Correlation Matrix

	CO_2	GDP	GDP^2	RE	TO	EP
CO_2	1					
GDP	0.906	1				
GDP^2	-0.720	-0.664	1			
RE	-0.900	-0. 801	0.634	1		
TO	0.522	0.452	-0.504	-0.409	1	
EP	-0.062	-0.104	-0.002	0.154	-0.099	1

Note: the diagonal elements represent the correlation of the series with itself, which is normally equals 1.

4. Results and Discussion

This study began with a preliminary analysis examining the selected countries' EKC hypothesis. Table (3) presents the findings of the CIPS unit root test. The variables GDP, GDP^2, RE, and TO were non-stationary I(1), while EP was stationary I(0). None of the variables was

I(2), meaning that they could be used without concern regarding the possibility of spurious regression. The following preliminary step was to run the Pedroni test to verify the existence of an equilibrium relationship between the variables. Table (4) displays the summary of the cointegration test. Table (4) shows that the H_0 of no cointegration was rejected for the ADF-statistic and PP-statistic; however, it was partially rejected in the case of the rho-statistic (Group). The conclusion from the test was the existence of an equilibrium relationship since the ADF and PP statistics had more power than the rho-statistic.

Table 3. CIPS unit root test results

	Level	First-difference
Variable	Intercept & Trend	Intercept
CO_2	-2.513	-5.745***
GDP	-2.254	-4.027***
GDP^2	-2.202	-3.720***
RE	-1.844	-4.436***
TO	-2.613	-5.029***
EP	-3.509***	-5.594***

Notes: The critical values are -2.85 (1%), -2.71 (5%) and -2.63 (10%) for the model with intercept & trend, and -2.38 (1%), -2.2 (5%) and -2.11 (10%) for the model with intercept. *** and ** stands for 1% and 5% significance levels, respectively.

Table 4. Pedroni panel cointegration test

	Panel	Group
rho-Statistic	0.3617	1.513*
PP-Statistic	-2.989**	-3.136**
ADF-Statistic	-2.218**	-2.722**

Note: *** signifies the rejection of the H_0 of no cointegration relationship at the 1% significance level.

Equation (2) was estimated using the PMG estimation technique for three models. Model (1) included the full sample of countries, model (2) comprised high-income Arab countries, and model (3) contained non-high-income countries. Table (5) provides the findings obtained from the PMG analysis. Model 1's (full sample) results show that the GDP per capita significantly impacted CO_2 emissions. There was a positive association between the GDP per capita and CO_2 emissions in the long run. However, CO_2 emissions appeared unaffected by the GDP per capita squared in the long run since the coefficient was statistically insignificant. These findings suggested the absence of a non-linear association between the GDP per capita and CO_2 emissions.

On the other hand, a negative relationship between renewable energy consumption and CO_2 emissions was found in the long run. An increase in renewable energy consumption by 1% led to an average decline in CO2 emissions by approximately 0.18%. This situation indicated that the transition towards using renewable and clean energy improves environmental quality and reduces CO_2 emissions. In contrast, the effect of trade openness appeared to be insignificantly related to CO_2 emissions, indicating the absence of a long-run relationship between the two variables. Notably, the energy prices seemed to be negative and statistically significant, meaning that higher prices (unsubsidised) lead to reduce emissions of CO_2. Indeed, a 10% increase in energy prices would result in an average of 0.008% decrease in CO2 emissions.

Model 2 (high-income Arab countries[8]) showed that the GDP per capita was positive and significantly related to CO_2 emissions. The squared term of the GDP per capita was negatively linked to the dependent variable (CO_2). The income turning point was US$ 58,151.32.[9] These results supported the non-linear relationship between output per capita and CO_2 emissions, which implied the validity of the EKC hypothesis for high-income Arab countries. The results indicated that any increase in the GDP per capita below the turning point would be translated into higher emissions. However, when income exceeds the threshold level, a further increase in the GDP per capita lowers pollution emissions and improves environmental quality.

More importantly, the effect of renewable energy consumption on CO_2 emissions was negative and statistically significant, indicating clean energy's contribution to diminishing CO_2 emissions. A 1% increase in renewable energy consumption was translated into a decrease in CO_2 emissions by roughly 0.7%. In addition, there was a negative relationship between trade openness and CO_2 emissions in high-income Arab countries. In particular, an increase in trade openness by 1% led to lower CO_2 emissions by 0.25% in high-income countries. The exports and imports of various goods and services inversely impacted CO_2 emissions over the long term. Nonetheless, there was a negative but insignificant relationship between energy prices and CO_2 emissions.

Model 3 (non-high-income countries) revealed that the GDP per capita was positively and significantly correlated to CO_2 emissions in the long run. Additionally, the dependent variable was negatively affected by the GDP per capita squared term, and the coefficient was statistically significant. These outcomes suggested the existence of a valid EKC hypothesis between income and CO_2 emissions in the non-high-income group. The results showed that the income turning point was approximately US$ 9,685. These findings indicated an inverted U-shaped relationship between output per capita and CO_2 emissions, which implied the validity of the EKC hypothesis for non-high-income Arab countries. Also, the results revealed a negative relationship between renewable energy consumption and CO_2 emissions in the long run, indicating that reducing pollution can be done through utilising clean and renewable energies. Indeed, increasing renewable energy consumption by 1% reduces CO_2 emissions by 0.14%. However, trade openness's effect was positive and significantly related to CO_2 emissions in non-high-income Arab countries. An increase in trade openness by 1% led to a rise in CO_2 emissions by 0.09%. Nonetheless, there was a negative relationship between energy prices and CO_2 emissions; the coefficient was significant at 10%. This indicated that higher prices lead to lower CO_2 emissions.

Regarding the short-run dynamic, the results in Table (5) showed that Models 1–3's error correction terms were negative and statistically significant at the 1% level. These findings were consistent with the earlier results of panel cointegration. In particular, the speed of adjustment coefficients suggested that the disequilibrium in Models 1–3 was corrected by 26.9%, 36.2%,

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[8] Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, and United Arab Emirates.

[9] This was calculated as $\rho = e^{-\frac{\hat{\beta}_1}{2\hat{\beta}_2} + ln\overline{GDP}}$, (see Brown and McDonough, 2016).

and 32.4% annually, and thereby took around 3.7 years, 2.8 years, and 3.1 years, respectively, for the total adjustment to take place. Models 1–3's results showed an insignificant effect of the GDP per capita, GDP squared term, and trade openness on CO_2 emissions in the short run, implying that these variables did not affect emission levels in the Arab countries. Renewable energy consumption was negative and significantly related to CO_2 emissions in the short run, only in non-high-income Arab countries. Unlike the long-run results, there was a positive and significant impact for energy prices on CO_2 emissions in the short-run, except in high-income countries, suggesting that higher energy prices in the short-run lead to increased emissions. This could be due to the inelastic nature of energy sources and the shifting process toward renewable energy over a more extended period.

Table 5. The results of the Pooled Mean Group (PMG) Model

Variables	Model 1	Model 2 (High)	Model 3 (Non-High)
Long-run			
GDP	0.454*** (0.073)	0.406*** (0.080)	0.431*** (0.090)
GDP^2	0.021 (0.026)	-0.448*** (0.061)	-0.174** (0.088)
RE	-0.177*** (0.028)	-0.699*** (0.213)	-0.136*** (0.019)
TO	-0.050 (0.040)	-0.253*** (0.062)	0.087*** (0.032)
EP	-0.0008*** (0.0003)	0.002 (0.005)	-0.0006* (0.0003)
Short-run			
ECT	-0.269*** (0.067)	-0.362*** (0.099)	-0.324*** (0.111)
ΔGDP	-4.057 (5.099)	2.499 (2.729)	-2.420 (2.572)
ΔGDP^2	0.042 (1.326)	2.039 (2.071)	0.997 (1.634)
ΔRE	-0.279 (0.256)	0.193 (0.401)	-0.517* (0.279)
ΔTO	0.110 (0.080)	0.174 (0.131)	0.044 (0.103)
ΔEP	0.002 (0.0009)	0.005** (0.002)	0.0002 (0.0006)
Intercept	0.621*** (0.157)	1.657*** (0.438)	0.213** (0.089)
No. Obs	476	176	300
No. Groups	16	6	10
Log-Likelihood	677.242	204.149	488.105
CD p-value	0.527	0.667	0.762

Note: ***, **, * denote significant at the 1%, 5%, and 10%, respectively. The standard errors are within ( )."Δ" stands for the first difference. CD is the test for the cross-sectional dependence test.

As mentioned in the literature review, income per capita has played a vital role in raising CO_2 emissions at the initial stage of development and eventually reducing them after exceeding a certain threshold level of income. Previous studies evaluating the impact of the GDP on pollution emissions have observed inconsistent results concerning whether there was evidence of an income turning point (see Saboori and Sulaiman, 2013; Onafowora and Owoye, 2014; Ozturk and Al-Mulali, 2015; Lacheheb *et al.*, 2015; Sirag *et al.*, 2018). The study showed that the EKC hypothesis was absent when the whole sample was used. However, the high-income and non-high-income groups (Models 2–3) indicated an inverted U-shaped association between income and CO_2. This finding supported evidence from previous observations of Arab countries (e.g. Shahbaz *et al.*, 2014; Salahuddin *et al.*, 2015; Charfeddine and Khediri, 2016; Mrabet and Alsamara, 2017; Salahuddin *et al.*, 2018; Mahmood *et al.*, 2019). These findings contradicted several studies that have suggested the non-validity of the EKC hypothesis for high-income countries (e.g. Jebli and Youssef, 2015; Lecheheb *et al.*, 2015; Ibrahiem, 2016; Samargandi, 2017; Raggad, 2018; Mohamed, 2018; Amri *et al.*, 2019; Bese and Kalayci, 2019). The inverted U-shaped curve estimated the income turning point for the high-income countries to be about US$ 58,151 and around US$ 9,685 for non-high-income countries. Other empirical studies estimated the income threshold level at approximately US$ 20,000 in Saudi Arabia (see Mahmood *et al.*, 2018; Mahmood *et al.*, 2019; Omri *et al.*, 2019).

Renewable energy sources are among the major contributors to reducing the emissions of greenhouse gases. In general, prosperous economies tend to consume more energy than developing countries. Unsurprisingly, all models had a negative and significant long-run relationship between renewable energy consumption and CO2 emissions. This finding has been well-documented in the literature; emissions will decline as the share of renewable energy consumption out of the total energy consumption increases. Similarly, we found energy prices, which include subsidies, were negatively linked to CO_2 emissions. This could imply more stable prices (subsidised) increase emissions, whereas volatile prices (unsubsidised) tend to reduce them. This suggests that removing energy subsidies may lead to higher prices, thereby lowering fossil fuel consumption, leading to less emissions in the long run. Finally, the analysis outcomes showed a negative link between trade openness and CO_2 emissions in high-income countries, while it was positive in non-high-income countries. Caution is required when interpreting the results since the existing studies have suggested that the impact of trade on the environment could be positive or negative depending on certain factors, such as institutional arrangements regarding international trade (Ibrahim and Law, 2016).

5. Conclusion and Policy Implications

The current study examined the effect of GDP per capita on CO_2 emissions in Arab countries. The EKC hypothesis framework was adopted to validate the existence of a non-linear association between GDP and CO_2 emissions. The mentioned hypothesis suggests that income initially works as an emissions-stimulating factor but lowers emissions after exceeding a certain threshold level. Thus, estimating the GDP turning point beyond which the progression of GDP per capita improves environmental quality is vital. Another critical objective of this study was to determine the effect of renewable energy consumption on CO_2 emissions in the region. Given the available panel data, the PMG estimation procedure was used to address potential discrepancies in the sample. Further, this research divided the sample into two categories based on income level: high-income and non-high-income, to control for heterogeneity in the sample.

The study's findings showed that the EKC hypothesis was not present when the whole sample was used in the long run. When heterogeneity was controlled for in the sample, the results showed that the GDP had a positive effect on CO_2 emissions, whereas GDP squared had a negative impact on CO_2 emissions in both high-income and non-high-income Arab countries. These outcomes signified the existence of the EKC hypothesis in Arab countries. A significant finding from this study was the valid income turning point for high-income countries to be about US$ 58,151, and about US$ 9,685 in non-high-income countries.

Regarding the long-run effect of renewable energy consumption as a share of total energy consumption on CO_2 emissions, a significant negative impact was observed due to the increase in renewable energy in the selected Arab countries. These results are supported by the idea that many Arab countries started to respond to climate change with policies and strategies aimed at controlling the emissions of greenhouse gases, such as CO_2, and increasing reliance on renewable energy sources. Some examples of policy efforts are the Saudi Green Initiative, the Middle East Green Initiative, and the UAE 2050 Net Zero Initiative. Energy prices emerged as a reliable factor inversely related to CO_2 emissions in the analysis of the whole sample and the non-high-income group. Still, it was statistically insignificant in the case of high-income countries in the long run. The absence of energy subsidies typically causes higher prices fluctuations, and as changes in energy prices grow, CO_2 emissions decrease. This result makes more sense because countries with higher wealth and resources are less affected by energy price fluctuations due to the small size of the energy consumption in the consumer price index (CPI) basket. Lastly, the impact of trade openness on CO_2 emissions was negative and significant in the high-income group and positive in non-high-income countries.

This study has contributed to recent debates concerning climate change and future economic prospects by suggesting that the transformation toward utilising renewable resources is essential to reducing greenhouse gas emissions. Moreover, economic reforms that eliminate energy subsidies could be crucial in mitigating environmental hazards. The present study has laid the groundwork for future research into the macroeconomics of climate change, which is an intriguing topic and could be usefully explored in further research. More analysis using specific country data could help to make more precise recommendations.

Although the results suggest that it is recommended for government representatives in Arab countries to adopt the EKC hypothesis as a foundation for their environmental quality initiatives, however, several countries' income level is yet to reach the turning point. Therefore, the authorities in Arab nations must adopt appropriate measures to limit environmental harm and resource depletion rather than relying only on gains in economic growth to reduce emissions, which may happen after reaching the income threshold. Additionally, advocating innovation and investment in green technologies will help reduce CO_2 emissions, i.e., decarbonisation and energy-efficient machines. Most importantly, relying more on investment in renewable energies, such as solar and wind energy, could be appropriate due to the region's geography.

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