Environmental Science and Pollution Research (2021) 28:59988–59999
https://doi.org/10.1007/s11356-021-14931-1

RESEARCH ARTICLE

Conflicts and ecological footprint in MENA countries: implications for sustainable terrestrial ecosystem

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Received: 18 April 2021 / Accepted: 12 June 2021 / Published online: 21 June 2021

Abstract

Conflicts are socio-political pressures that alter wellbeing, social structure, and economic sustenance. However, very limited studies have assessed the long-term impact of conflicts on environmental sustainability. This study investigates the role of internal and external conflicts on ecological footprint in the Middle East and North African countries (MENA) over the period 1995–2016. Here, we test whether the environmental Kuznets curve (EKC) hypothesis is valid for MENA countries during the period of internal and external conflicts—characterized by energy disasters and deteriorating income levels. Using robust econometric tools based on 12 MENA countries, the results show that income growth has negative impact with evidence of inherent heterogeneity across quantile distribution of ecological footprint. However, the positive impact of the square term of income decreases ecological footprint, thus, confirming U-shaped relationship between income and environmental indicator across MENA countries. The results further show that excessive energy consumption is attributed to a rising level of urbanization, while increase in conflicts stimulates environmental degradation. These findings are essential for effective conflict resolution and environmental policies across conflict-prone countries.

Keywords Conflicts · Panel quantile · Environmental sustainability · Ecological footprint · MENA countries

Introduction

The phenomenological relationship between climate change mitigation and sustained economic development is still debatable across disciplines with policy implications. Several studies have assessed the emission-growth relationship within the framework of the Environmental Kuznets Curve (EKC) expounded in Grossman and Krueger (1991)[1]. However, these studies have inconsistent empirical support and fail to account for conflicts, especially in vulnerable countries. Nonetheless, EKC-based studies can be classified into two strands. The first strand reports that the pursuit of economic growth has heightened environmental pollution, especially in developing countries (see Soytas and Sari 2006; Narayan and Smyth 2008; Apergis and Payne 2009; Kasman and Duman 2015; Farhani and Ozturk 2015; Jebli et al. 2016; Shahbaz et al. 2017; Rauf et al. 2018; Rafindadi and Usman 2019; Dogan et al. 2019; Dogan and Inglesi-Lotz 2020; Usman et al. 2019, 2020a, b). The second strand posits independence of environmental degradation and economic development, hence, does not follow the pattern of the EKC hypothesis due to sound environmental policies (see Mukhopadhyay and Chakraborty 2005; Mukhopadhyay 2008; Nasr et al. 2015).

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[1] Specifically, EKC as proposed by Grossman and Krueger (1991), suggests during development, income level would rise with the level of carbon emissions until a certain level of income is reached afterward CO_2 emissions begin to decline.

Taking seriously, even though the rapidly expanding economic growth is attributed to rising environmental pollution, the position of the EKC in the Middle East and North African Countries (MENA) has been considered controversial and unclear, especially in recent times. This is because the region has been marred by series of conflicts in the past decades such as, inter alia, tension in the Strait on Hurmuz, dispute between Qatar and Arab neighbors, Israel-Palestine unending conflict, USA-Iran tension, and Iran–Iraq crisis. These do not exclude other internally based social unrest such as the Arab Spring, decade war in Syria, and political crisis in Libya and Egypt. These catastrophic phenomena, which vary over time with respect to intensity, nature, and geographic distribution have resulted in energy disasters, physical and human capital destruction—leading to depreciation in investments, trade, productivity, and, hence, hampering economic growth in the region. As estimated by the World Bank in 2016, the damage assessment of the war in Syria in transport, housing, water and sanitation, energy, agriculture, health, and education is worth between 3.6 and 4.5 billion USD as of 2014. More so, the income level appears deteriorating in the region over the years. For example, the growth rate in the region fell to an average of 1.4% in 2017 from 4.3% in 2016. This further fell to 0.6% in 2019 and may likely turn negative if necessary steps are not taken to ameliorate the consequences of conflicts and terrorism in the region. Moreover, there are several reasons to believe that conflicts have direct effect on environmental quality. First, the modern armed forces consume energy rapaciously, which results in vast quantities of carbon emissions that may harm human endeavors. For example, Al-Mulali and Ozturk (2015) noted that a negative effect of political turmoil, violence, and conflict reduces environmental quality through huge air and water pollution as well as soil damage. Furthermore, conflicts (both internal and external) may contribute to the rising wave of the number of people living in urban areas where lives and property are secured. As shown by the World Bank (2018), the urban population in the MENA countries represents more than 70% of the total population. The concern here is whether the trend of urbanization puts upward or downward pressure on energy-related greenhouse gas emissions and environmental concerns. As revealed by various economic theories[2], societies would give no priority to environmental issues at early stages of development but once they become more prosperous at advanced stages of development, environmental issues become their top priority. This can be achieved through urbanization, i.e., moving from secondary sector to tertiary sector and technological innovation (Shahbaz and Lean 2012; Sadorsky 2014; Shahbaz et al. 2015).

[2] See theory of ecological modernization, the theory of urban environmental transition, and theory of compact city.

Given this background, the main objective of this study is to investigate the role of internal and external conflicts on ecological footprint in MENA region. Following this objective, we put forward the following key questions: how do internal and external conflicts affect ecological footprint in the MENA region? Amidst energy disasters and conflict-attributable deteriorating income levels, what is the position of the EKC for MENA countries? In light of this, our paper extends the literature of the EKC by incorporating the effects of internal and external conflicts, energy consumption, and urban development on environmental quality in MENA countries. While there is growing interest in empirically examining the EKC hypothesis at country-specific level and cross-sectional settings, several studies have incorporated energy consumption and other variables including globalization, urbanization, financial development, trade, foreign direct investment, and agriculture into the standard EKC equation (Rafindadi 2016; Shahbaz et al. 2017; Sarkodie et al. 2019a, b; Ike et al. 2020a, b; Usman et al. 2020a, b; Rehman et al. 2020, 2021). For example, Rafindadi (2016) established evidence in support of the EKC for Japan during the period of a rapid decline in income level as a result of energy disasters. Shahbaz et al. (2017) found a negative effect of globalization in the Chinese carbon dioxide function. This finding is similar to Usman et al. (2020a) who found globalization to have a significant effect on the decline of carbon emissions for South Africa. Moreover, Ike et al. (2020a) found evidence in support of the EKC for Thailand by controlling the role of fiscal policy. Based on panel data, Ike et al. (2020b) confirm the EKC hypothesis by incorporating oil production and electricity production for oil-producing countries. This result is analogous to Ike et al. (2020c) who found EKC for G-7 countries both in panel and time-series settings.

Turning to the effect of urbanization, Rafiq et al. (2016) and Katircioğlu and Katircioğlu (2018) indicated that the upsurge of CO2 emissions is traceable to rapid urbanization. However, some studies like Shahbaz et al. (2016) and Ali et al. (2020) showed that urbanization leads to energy efficiency and, hence, reduces CO2 emissions. Regarding conflicts, Fredriksson and Svensson (2003) found political instability and conflict as responsible for the weak environmental regulation, which in turn deteriorate environmental quality. Similarly, a study by Hsiang et al. (2013) revealed that about 11.1% of changes in intergroup conflicts are associated with 1 standard deviation increase in temperature (or rainfall). Also, Hsiang and Hsiang and Burke (2014) find a causal relationship between changes in climatology and conflict across major regions of the world.

This study contributes to the literature in several ways. First, we reconsider the nexus between environmental quality and income level amidst energy disaster and conflict-attributable deteriorating income level. Second, in adopting an alternative measure of environmental quality, i.e., ecological footprint, we account for atmospheric, biospheric, lithospheric, and hydrospheric degradations. Ecological footprint is calculated based on carbon, build-up land, cropland, fishing grounds, forest products, and grazing land. This makes our measurement of environmental quality more comprehensive and detailed. Third, we apply the novel Method of Moments panel Quantile Regression (MMQR) to investigate the heterogeneous effects of economic growth, energy consumption, urbanization, and conflicts on the entire distribution of ecological footprint across countries using the EKC procedure. This method provides other empirical advantages by controlling for time-invariant factors that underpin country-specific heterogeneity and effect on the tails of conditional distribution. Fourth, to check the robustness of our model to cross-sectional dependence and serial autocorrelation, we apply the Fixed Effects-Ordinary Least Squares (FE-OLS) regression with robust standard errors and Random Effects-Generalized Least Squares (RE-GLS) regression with Driscoll and Kraay (1998) standard errors.[3]

To drive this study, we outline the remaining parts of the study as follows: "**Theoretical background and empirical model development**" section follows the introduction and literature review and highlights methodological insight for the study. Particularly, it explains theoretical background and development of empirical models of this study. "**Data**" section presents empirical results and discussion. In the "**Empirical results and discussion**" section, we conclude the study and outline valuable policy implications.

Theoretical background and empirical model development

The implications of global warming and climate change are central in the energy policy spotlight. Although the relationship between economic growth and environment has well been established in the literature following the pioneering work of Kuznets (1955), which hypothesizes inequality in income would fall as income per capita rises. This forms the basis for the environmental Kuznets Curve (EKC) in the extant literature. As advocated by Grossman and Krueger (1991), during the period of economic development, income level tends to increase with the level of carbon emissions until a certain level of income is reached — but afterward, emissions begin to decline. Therefore, within the framework of EKC, emission is regarded as a function of per capita income. The a priori expectation is that an increase in income level (proxied by gross domestic product) tends to increase environmental degradation. The validity of the EKC is an active research area for scholars in environmental-related studies (Narayan and Narayan 2010; Onafowora and Owoye 2014; Apergis and Ozturk 2015; Al-Mulali and Ozturk 2016; Özokcu and Özdemir 2017; Apergis 2016; Apergis et al. 2017; Shahbaz et al. 2017; Katircioğlu and Katircioğlu 2018; Sarkodie and Sarkodie and Strezov 2018; Mesagan et al. 2018; Rafindadi and Usman 2019; Alola et al. 2019; Ike et al. 2020a, b).

Therefore, following the conventional EKC framework, our empirical specification is expressed as:

$$CO_{2i,t} = \Psi_0 + \beta_1 GDP_{i,t} + \beta_2 GDP_{i,t}{}^2 + \varepsilon_{i,t} \quad (1)$$

Where Ψ_0 is the intercept, CO_2 is per capita carbon emission, a measurement of environmental pollution. Income level is measured by per capita real GDP and its squared term is added to ascertain whether the EKC hypothesis is valid. ε_t is an error term, which is normally distributed. The second strand of literature incorporates energy consumption into the EKC equation. This is because changes in CO_2 emissions are mostly caused by fossil fuel consumption. Therefore, within the framework of the EKC, energy consumption and economic growth jointly determine the level of carbon emissions (See Kraft and Kraft 1978; Soytas and Sari 2006; Soytas et al. 2007; Soytas and Sari 2009; Narayan and Smyth 2008; Apergis and Payne 2009; Kasman and Duman 2015). Besides, urbanization can positively or negatively affect CO_2 emissions. As the population of urban areas rapidly increases, it tends to exert upward pressure on energy-related CO_2 emissions. However, where an increase in urbanization is accompanied by adequate renewable energy consumption and awareness about environmental protection, then such an increase could trigger efficient use of energy and consequently, improve environmental quality. Furthermore, both internal and external conflicts can determine the level of CO_2 emissions through their huge effects on air and water pollution including damage to the soil. Moreover, conflicts can increase the level of CO_2 emissions through the consumption of energy required by modern armed forces. In testing the EKC hypothesis, we account energy consumption, urbanization, internal and external conflicts. Moreover, we replace CO_2 emissions with ecological footprint per person (EF_K) which is more comprehensive compared to CO_2 emissions. Therefore, the augmented EKC empirical model is given by the following equation:

$$EF_{Ki,t} = f\left(EG_{Ki,t}, EG^2_{Ki,t}, EC_{Ki,t}, URB_{i,t}, INC_{i,t}, EXC_{i,t}\right) \quad (2)$$

Where EF_K represents ecological footprint measured by the global hectares per person, EG_K represents income level which is measured by the GDP per capita (Constant 2010 USD), URB denotes urbanization, which is measured by the

[3] The FE-OLS estimates are incorporated in the MMQR approach as location parameters with robust standard errors. This controls for cross-sectional dependence. Furthermore, to control for autocorrelation problem, we applied the Random Effects-Generalized Least Squares (RE-GLS) regression with Driscoll-Kraay Standard errors.

total number of the urban population. The INC and EXC capture the impact of internal and external conflicts while the squared GDP per capita $\left(EG_K^2\right)$ is considered to determine the shape of the EKC across countries. i and t subscripts represent countries (cross-sectional units) and time index, where i is the i-th series (i = 1, …, 16) and t = 1995, …, 2016. The natural logarithm expression of Eq (2) is given as:

$$\begin{aligned}\ln EF_{Ki,t} &= \alpha_0 + \alpha_{EG}\ln EG_{Ki,t} + \alpha_{EG^2}\ln EG^2_{Ki,t} \\ &+ \alpha_{EC}\ln EC_{Ki,t} + \alpha_{URB}\ln URB_{i,t} + \alpha_{INC}INC_{i,t} \\ &+ \alpha_{EXC}EXC_{i,t} + \varepsilon_{i,t}\end{aligned} \quad (3)$$

Where ln represents the natural logarithm expression of variables, which helps to stabilize the variances, α is the constant, ε implies white noise, expected to have a constant mean. The main contribution of our study is that the effect of conflicts and other explanatory variables on ecological footprint is likely to be observed in tails, which are not captured by the conventional regression methods. To address this problem, we estimate our panel data using the Method of Moments Quantile Regression (MMQR) with fixed effects. This method is robust to misspecification errors and does not hinge on any distributional assumption. The location-scale variant model of conditional quantile in panel form is given as (Machado and Silva 2019):

$$\begin{aligned}Q\ln EF_{Ki,t}\left(\tau|X_{i,t}\right) &= \alpha_0 + \alpha_{EG}\ln EG_{Ki,t} + \alpha_{EG^2}\ln EG^2_{K\,i,t} \\ &+ \alpha_{EC}\ln EC_{Ki,t} + \alpha_{URB}URB_{i,t} \\ &+ \alpha_{INC}INC_{i,t} + \alpha_{EXC}EXC_{i,t} + \varepsilon_{i,t}\end{aligned} \quad (4)$$

Where $Q\ln EF_{Ki,t}(\tau|X_{i,t})$ represents τ^{th} conditional quantile function, X_{it} denotes the explanatory variables defined in Eq. (3). By construction, Eq. (4) implies that:

$$Q\ln EF_{Ki,t}\left(\tau|X_{i,t}\right) = \left(\alpha_i + \theta_i q(\tau)\right) + X_{i,t}\beta + Z_{i,t}\gamma q(\tau) \quad (5)$$

Here $\alpha_i(\tau) \equiv \alpha_i + \theta_i q(\tau)$ is perhaps a scalar parameter indicative of the quantile-τ fixed-effect for country i. Z is denoted by a k-vector of identified components of X, a differentiable transformation with l element defined by $Z_l = Z_l(X)$, where $l = 1, \ldots, k$. Contrasting the least-squares fixed-effects, the individual effects do not represent intercept shifts, hence, the heterogeneous effects of time-invariant parameters can vary across quantiles of the conditional distribution of ecological footprint. The conditional quantile of ecological footprint function provides a solution to the following optimization problem:

$$min_q \sum_i \sum_t \rho_\tau \left(\widehat{R}_{it} - \left(\widehat{\delta}_i + Z_{it}\widehat{\gamma}\right) q\right) \quad (6)$$

From Eq. (6), the standard quantile loss function is generally expressed by $\rho_\tau(\mu) = (\tau - 1)\mu I\{\mu \le 0\} + \tau\mu I\{\mu > O\}$. To check the robustness of our results to autocorrelation, we employed the Random Effect–Generalized Least Squares (RE-GLS) estimator with Driscoll and Kraay's standard errors. This method controls for autocorrelation up to the specified lag with the robust Driscoll-Kraay standard errors. For the cross-sectional dependence (CD), the MMRQ model incorporates fixed-effects with robust standard errors, which controls for heterogeneity and cross-sectional problems. Hence, this is one of the significant advantages of using the panel quantile regression via Method of Moments recently advanced by Machado and Silva (2019).

To validate the estimated models, we use the average marginal effect based on a 95% confidence interval to verify MMQR models. This is in line with Alhassan et al. (2020) who argue the necessity of such estimates since MMQR does not have any reasonable diagnostic tests. The results are presented in Figs. 1 and 2, respectively.

Data

We explored data for the ecological footprint per person (EF_K), carbon footprint per person (CO), real Gross Domestic Product (real GDP) per capita which measures economic growth (or per capita income level), and its squared term (real GDP^2) denoted by (EG_K)and$\left(EG_K^2\right)$, energy consumption per capita (EC_K), urbanization (URB), Internal Conflict (INC) and External Conflict (EXC). The data for this study were collected over the period 1995 to 2016 for 12 countries in the Middle East and North African (MENA) region. Countries including Yemen, United Arab Emirates (U.A.E.), Tunisia, Saudi Arabia, Qatar, Oman, Libya, Lebanon, Kuwait, Jordan, Israel, and Bahrain[4] were selected based on the availability of data. The unbalanced data for the variables, measurements, and their sources are found in Table 1.

Empirical results and discussion

The summary statistics of the variables in the model are reported in Table 2. The mean of the squared real GDP is the largest followed by the mean of urbanization. Considering the absolute values, the mean Carbon footprint is the smallest. The values of the standard deviation of the variables indicate that, except for the squared term of real GDP, the rest of the variables exhibit little volatilities. Considering the absolute values, we find that the minimum (Maximum) value for real GDP is 6.6407 (11.152). For squared term of real GDP, it is 44.098 (124.36); urbanization is 13.098 (17.113); Carbon is

[4] The data for energy consumption is only available up to 2014 for all the countries. Also, the ecological footprint is only available for 12 countries from MENA countries, which limits our scope to only 12 countries. Furthermore, the ecological footprint data for Kuwait is only available from 1999.

[0] The negative values for internal and external conflicts are due to rescaling so that higher values would represent more risk to internal and external data.

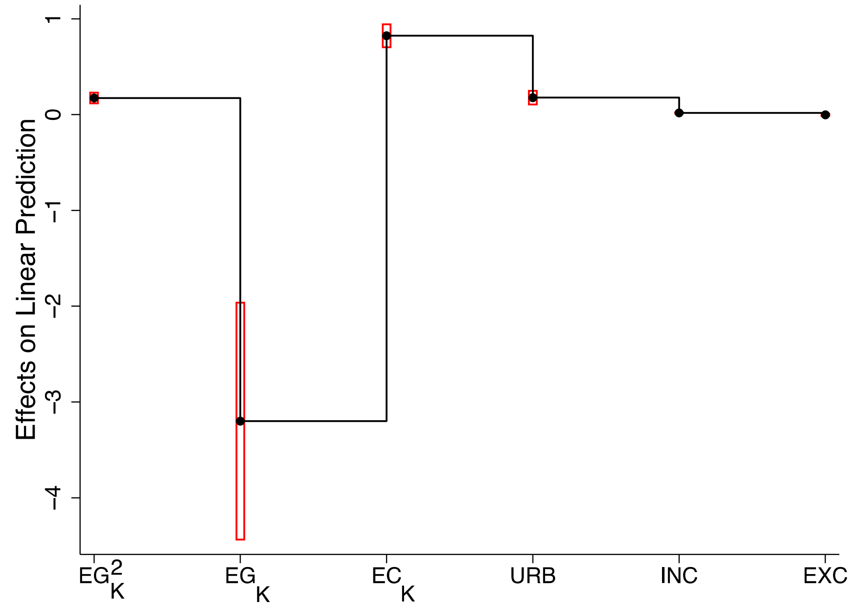

Fig. 1 Average marginal effect plot with ecological footprint as the dependent variable.

−1.4956 (2.7385) while INC and EXC are −12 (−4.38) and −12 (−2.58)[5].

To assess the impact of conflicts on ecological footprint and position of the EKC at different conditional quantile paths, we applied the MMQR method. The results represented in Table 3 confirm the non-existence of the EKC hypothesis in the lower, median, and higher ecological footprint countries. In other words, an increase in per capita real GDP causes ecological footprint to decline across quantiles and hence, improves environmental quality while the squared of per capita real GDP increases ecological footprint—which by implication, decreases environmental quality. The plausible explanation behind this result is that over years of internal and external conflicts in the MENA region have crippled economies, leading to deteriorating level of income. The effects of conflict have manifested in several ways—ranging from significant decline in demand for tourism due to operational restrictions placed on traveling from the rest of the world to the MENA region, trade and investment sanctions, and distortions in economic resource allocations. This catastrophic phenomenon has resulted in serious physical and human capital destruction, as well as, decrease in investments, trade, productivity, and hence, economic growth in the region. Moreover, conflicts in the region have created serious energy disasters leading to energy insecurity and poverty, which has significantly decreased energy produced and consumed in the region. As the level of energy consumed declines, growth in combusting fuels

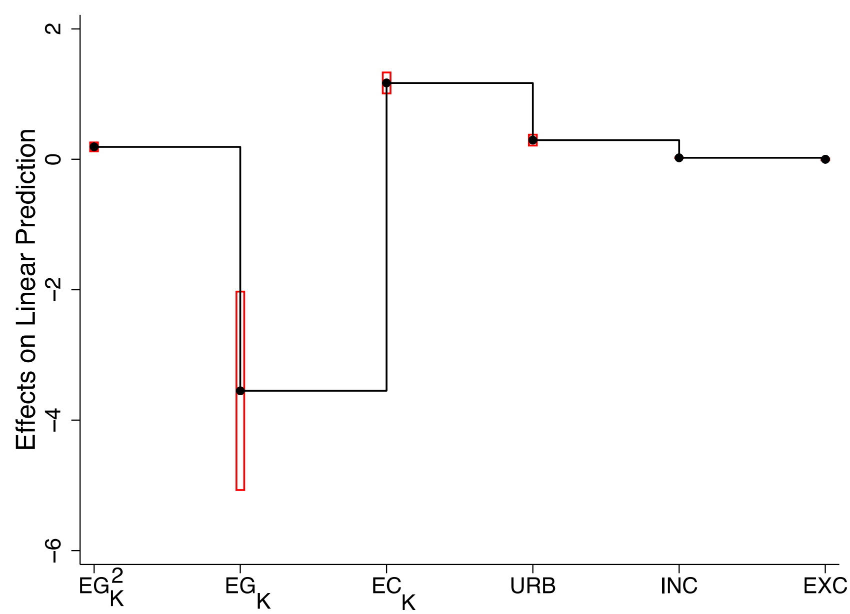

Fig. 2 Average marginal effect plot with carbon ecological footprint as the dependent variable. Legend: The connecting stairstep represents the marginal effects of estimated model whereas the red rbarm plot denotes 95% confidence interval

Table 1 Variable, measurement, and source

Variable and notation	Measurement	Source
Ecological footprint (EF_K)	Global hectares per person	Global Footprint Network (GFN)
Carbon footprint(CO)	Global hectares per person	Global Footprint Network (GFN)
Economic Growth (EG_K)	Gross Domestic Production in Millions per capita (Constant 2010 USD).	World Development Indicator
Energy Consumption (EC_K)	Energy consumption in kilotonnes (kt) of oil equivalent per capita	World Development Indicator
Urban Population (URB)	Number of people living in urban areas at a particular time	World Development Indicator
Internal Conflict (INC)	A sum of risk rating is assigned to three subcomponents, which include (i) civil war/coup threat, (ii) terrorism/political violence, and (iii) civil disorder.	International Country Risk Guide (ICRG) PRS Group
External Conflict (EXC)	A sum of risk rating is assigned to three subcomponents, which include (i) war, (ii) cross-border conflict, and (iii) foreign pressure.	International Country Risk Guide (ICRG) PRS Group

Notes: Internal and external conflicts are measured with the maximum score of 4 points and a minimum score of 0 assigned to each of the three subcomponents, making a total score of 12 points. 4 points correspond to very low risk of conflict, and 0 corresponds to high risk of conflict. To ensure a robust interpretation of results, we rescaled by using the inverse of the ICRG index, so that higher values represent more risk internal and external data so that higher value is assigned squarely to countries embroiled in civil war/coup threat, terrorism/political violence, civil disorder, cross-border conflict, and foreign pressures. In other words, rescaling redefines external and internal conflicts in such a way that the lower the total risk point, the lower the risk, and the higher the total risk point the higher the risk. Except for external and internal conflict variables, the rest of the variables are in their natural logarithm forms

including fossil fuel energy sources that spur resources for production without considering environmental damage reduces. This implies environmental quality would improve irrespective of whether income level is low and far from the turning point as described by Sarkodie and Sarkodie and Strezov (2018) and Usman et al. (2019). The results further show coefficients of economic growth are significantly elastic and decreasing in magnitude, tracking from the countries with low ecological footprint to countries with higher ecological footprint in the quantile distribution. This suggests the impact of economic development on ecological footprint in MENA region is heterogeneous. Therefore, our finding is consistent with Mukhopadhyay and Chakraborty (2005); Dietzenbacher and Mukhopadhyay (2007); Mukhopadhyay (2008) who found no evidence supporting the EKC hypothesis in India. The result also concurs with Nasr et al. (2015) who revealed the EKC hypothesis is not valid for South Africa and Katircioglu and Katircioğlu and Katircioğlu (2018) who documented U-shaped pattern of EKC for Turkey. On the contrary, our finding is inconsistent with the earlier findings by Farhani and Shahbaz (2014) who found EKC for the MENA region. The result also disagrees with Ike et al. (2020b),

Table 2 Summary of descriptive statistics

Variables	Mean	Std. Dev.	Min	Max	Obs.
$\ln EG_K$	9.4306	1.2035	6.6407	11.152	255
$\ln EG_K^2$	90.379	22.007	44.098	124.36	255
$\ln EC_K$	8.0648	1.2104	5.4186	10.004	241
lnURB	15.142	0.8889	13.098	17.113	264
INC	−9.1345	1.7896	−12	−4.38	264
EXC	−9.5401	1.5796	−12	−2.58	264
$\ln EF_K$	1.4746	0.7971	−0.4441	2.8344	260
lnCO	1.0539	1.0433	−1.4956	2.7385	260

Source: Authors' computation

Table 3 Results of Quantile Estimation when the dependent variable is ecological footprint per person

Variables	Quantiles via Moments										
	Location parameters	Scale parameters	Quantile Coeffs.								
			0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
$lnEG_K$	−3.1952* (1.4935)	−0.0955 (0.4873)	−3.0446** (1.2910)	−3.1022*** (0.9707)	−3.1350*** (0.8149)	−3.1697*** (0.6911)	−3.1994*** (0.6361)	−3.2309*** (0.6444)	−3.2687*** (0.7397)	−3.3002*** (0.8693)	−3.3417*** (1.0812)
$lnEG_K^2$	0.1731* (0.0829)	0.0030 (0.0272)	0.1684** (0.0690)	0.1702*** (0.0518)	0.1712*** (0.0435)	0.1723*** (0.0369)	0.1732*** (0.0340)	0.1742*** (0.0344)	0.1754*** (0.0395)	0.1764*** (0.0464)	0.1777*** (0.0578)
$lnEC_K$	0.8248*** (0.1433)	−0.0383 (0.0297)	0.8852*** (0.1338)	0.8621*** (0.1005)	0.8489*** (.0845)	0.8350*** (0.0717)	0.8231*** (0.0660)	0.8105*** (0.0669)	0.7953*** (0.0767)	0.7827*** (0.0900)	0.7661*** (0.1120)
lnURB	0.1756** (0.0696)	0.0308 (0.0399)	0.1271 (0.0835)	0.1456** (0.0627)	0.1562*** (0.0527)	0.1674*** (0.0448)	0.1770*** (0.0413)	0.1872*** (0.0418)	0.1993*** (0.0479)	0.2095*** (0.0561)	0.2229*** (0.0698)
INC	0.0179 (0.0176)	0.0001 (0.0057)	0.0177 (0.0161)	0.0178 (0.0121)	0.0178* (0.0101)	0.0179** (0.0086)	0.0179** (0.0079)	0.0180** (0.0080)	0.0180** (0.0092)	0.0181* (0.0108)	0.0181 (0.0135)
EXC	−0.0024 (0.0192)	0.0011 (0.0064)	−0.0042 (0.0225)	−0.0053 (0.0232)	−0.0032 (0.0143)	−0.0027 (0.0121)	−0.0024 (0.0111)	−0.0020 (0.0113)	−0.0016 (0.0129)	−0.0012 (0.0152)	−0.0007 (0.0189)
Constant	6.8247 (5.5713)	0.5707 (1.7470)									

Note: *, ** and *** indicate significance at 10, 5 and 1% levels. The values in the parentheses are robust standard errors of parameters

Table 4 RE-GLS results (dependent variable is ecological footprint per person)

Variables	Coefficient	Std. Error	p-value
$\ln EG_K$	-2.4535^{***}	0.5323	0.000
$\ln EG_K^2$	0.1331^{***}	0.0283	0.000
$\ln EC_K$	0.7660^{***}	0.0647	0.000
lnURB	0.1471^{***}	0.0380	0.000
INC	0.0187^{**}	0.0087	0.031
EXC	0.0052	0.0113	0.644
Constant	4.4166^{*}	2.2882	0.054

Note: ***, ** and * denote 1, 5 and 10% levels of significance. The Driscoll-Kraay standard errors are used

Usman et al. (2020a, b) who supported the EKC hypothesis and Usman et al. (2020c) and Iorember et al. (2020) who demonstrated that economic growth increases lead to increase in ecological footprint.

Besides, the effect of per capita energy consumption is positive, inelastic, heterogenous, and statistically significant across quantile distribution of the ecological footprint. This implies an increase in per capita energy consumption would have heterogeneous increase in ecological footprint, which by implication, reduces environmental quality. The magnitude of effects declines from lower ecological footprint countries to higher ecological footprint countries. This means countries with lower ecological footprint tend to have higher impact of energy consumption on ecological quality compared to countries with higher ecological footprint. This finding echoes the major conclusions in Dogan and Ozturk (2017); Shahbaz et al. (2017, 2018); Katircioğlu and Katircioğlu (2018); Ike et al. (2020a,b); Güngör et al. (2021); Musa et al. (2021), Rehman et al. (2020, 2021) that energy consumption is positively associated with environmental degradation.

The effect of urban population is positive, inelastic, and statistically significant across the quantiles (with exception of the first quantile). This suggests that urban development is a driving force behind an upsurge in ecological footprint, which in turn deteriorates the level of environmental quality in the region. A closer examination of this result reveals the effect of urbanization becomes larger tracking from lower ecological footprint countries to higher ecological footprint countries. This finding is similar to Zhang and Lin (2012); Fang (2014); Xu and Lin (2015); Rafiq et al. (2016) who found that urban population growth is responsible for energy-related emissions. On the contrary, this finding does not concur with Shahbaz et al. (2016) who found that 1% increase in urban population per capita causes ~12.39% decline in emissions in Malaysia. Our finding disagrees with the compact city theory, which reveals that urbanization reduces environmental degradation through economies of scale and usual technologies linked to urban development. These technologies can trigger energy efficiency and energy savings, as well as, promote renewable energy consumption.

The effect of internal conflict on ecological footprint is positive and significant across the quantile distribution of ecological footprint. This means that as internal conflict rises, ecological footprint increases by lowering or deteriorating environmental quality in the region through its huge effect on air and water pollution as well as soil damage. Another channel that conflicts deteriorate environmental quality could be through the burning of towns and cities, which increases the level of carbon dioxide accumulation in the atmosphere. Therefore, our finding corroborates the estimate of atomic war-driven carbon footprint documented by Berners-Lee and Clark (2010) — wherein ~15 kilotonnes missiles lead to ~690 million tonnes of CO_2 emissions. It also agrees with Fredriksson and Svensson (2003) who attributed lower environmental performance during periods of political instability to series of conflicts. Additionally, the result is consistent with Al-Mulali and Ozturk (2015) who found a negative effect of political turmoil and conflicts on environmental quality through huge air and water pollution as well as soil damage. Furthermore, increase in external conflict has smaller impact on ecological footprint compared to internal conflict, although exerts negative impact on ecological footprint. This impact is inelastic and statistically insignificant across the quantile distribution. While the magnitude of internal conflict gets larger from lower conditional quantile of ecological footprint to upper conditional quantile of ecological footprint, the case of internal conflict appears contrary.

The location parameters in Table 3 from fixed-effects incorporated in the MMQR model reveal GDP and its squared term are negative and positive, suggesting that economic growth is associated with a decline in ecological footprint while its square increases ecological footprint. The results confirm U-shaped association of economic growth and ecological footprint for MENA countries. The effects of energy consumption and urbanization are negative, inelastic, and statistically significant. This suggests that growth in energy consumption and urbanization increases ecological footprint through excessive use of fuel oil and other traditional patterns of energy consumption related to economic growth and urban development. This finding is agreeable with Katircioğlu and Katircioğlu (2018) who found that urban development drives environmental degradation in Turkey. The results also confirm that while internal conflict deteriorates environmental quality through an increase in ecological footprint, the effect of external conflict is positive and elusively insignificant. Moreover, from the scale parameters, we find that the variables are not statistically significant, suggesting no significant difference in the group of sampled countries. Although one of the advantages of the panel quantile-based method of moments regression is that it is suitable for both homogeneous and heterogeneous models.

Table 5 Results of Quantile Estimation when the dependent variable is carbon footprint per person

Variables	Quantiles via Moments										
	Location Parameters	Scale Parameters	Quantile Coeffs.								
			0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
$\ln EG_K$	−3.5826* (1.9009)	0.1804 (0.7124)	−3.8729** (1.7275)	−3.7476*** (1.2434)	−3.6708*** (0.9953)	−3.6204*** (0.8711)	−3.5503*** (0.7841)	−3.5037*** (0.7955)	−3.4476*** (0.8804)	−3.3859*** (1.0407)	−3.3169*** (1.2721)
$\ln EG_K^2$	0.1929* (0.1045)	−0.0127 (0.0401)	0.2134** (0.0932)	0.2046*** (0.0671)	0.1991*** (0.0537)	0.1956*** (0.0470)	0.1906*** (0.0423)	0.1873*** (0.0429)	0.1834*** (0.0475)	0.1790*** (0.0562)	0.1741** (0.0687)
$\ln EC_K$	1.1789*** (0.2287)	−0.0516 (0.0731)	1.2618*** (0.1969)	1.2261*** (0.1418)	1.2041*** (0.1136)	1.1896*** (0.0994)	1.1696*** (0.0894)	1.1563*** (0.0907)	1.1403*** (0.1003)	1.1226 (0.1185)	1.1028*** (0.1450)
lnURB	0.2879** (0.1016)	0.0340 (0.0559)	0.2331** (0.1106)	0.2568*** (0.0797)	0.2713*** (0.0638)	0.2808*** (0.0558)	0.2941*** (0.0502)	0.3028*** (0.0510)	0.3134*** (0.0563)	0.3251*** (0.0665)	0.3381*** (0.0814)
INC	0.0228 (0.0220)	0.0029 (0.0076)	0.0182 (0.0215)	0.0202 (0.0155)	0.0214* (0.0124)	0.0222** (0.0108)	0.0233** (0.0098)	0.0240** (0.0099)	0.0249** (0.0110)	0.0259** (0.0129)	0.0270* (0.0158)
EXC	0.0011 (0.0220)	0.0046 (0.0087)	−0.0085 (0.0323)	−0.0053 (0.0232)	−0.0034 (0.0186)	−0.0021 (0.0163)	−0.0003 (0.0147)	0.0009 (0.0149)	0.0023 (0.0164)	0.0038 (0.0194)	0.0056 (0.0238)
Constant	3.7790 (6.9773)	−0.4804 (2.4390)									

Note: *, ** and *** indicate significance at 10, 5 and 1% levels. The values in the parentheses are robust standard errors of parameters

Table 6 RE-GLS results (dependent variable is carbon footprint per person)

Variables	Coefficient	Std. Error	p-value
$\ln EG_K$	−2.5919***	0.6730	0.000
$\ln EG_K^2$	0.1382***	0.0358	0.000
$\ln EC_K$	1.0772***	0.0835	0.000
lnURB	0.2391***	0.0490	0.000
INC	0.0258**	0.0113	0.023
EXC	0.0102	0.0147	0.487
Constant	1.0554	2.8883	0.715

Note: This analysis is based on Driscoll-Kraay standard errors. *** and ** denote 1 and 5% levels of significance

Robustness checks

To check the robustness of the results, we used the carbon footprint as alternative environmental quality measure. The results are generally similar to those discussed, however, the little difference is the magnitude of effects of explanatory variables on environmental quality. The magnitudes of all fundamental variables are larger when carbon footprint is used as a measure of environmental quality. Moreover, the effect of external conflict is stronger in lower quantiles when carbon footprint is used but diminish towards the upper quantiles—suggesting that countries with lower carbon footprint tend to be sensitive to external conflict than countries with higher carbon footprint. The opposite of this result holds when ecological footprint is used as a measure of environmental quality. The effect of external conflict is negative and insignificant only in lower and middle quantiles whereas it is positive in upper quantiles although statistically insignificant. However, the effect of external conflict based on ecological footprint is insignificantly positive across the quantiles. In the same vein, due to the non-availability of existing valid diagnostic tests for the MMQR panel quantile estimation employed in this study, we applied the average marginal effect estimates based on a 95% confidence interval as shown in Figs. 1–2. The plots as argued in Alhassan et al. (2020) display the robustness of the MMQR model estimations. The result of the average marginal effect plot of the variables is consistent with the earlier results reported from the panel quantile regression.

Legend: The connecting stairstep represents the marginal effects of estimated model whereas the red rbarm plot denotes 95% confidence interval

Besides, we check for the autocorrelation problem by employing the random effect-Generalized Least Squares (RE-GLS) regression with Driscoll and Kraay's (1998) standard errors estimator since the MMQR can only control for cross-sectional dependence in the panel. As observed in Table 4, the real income and its squared term have negative and positive effects on ecological footprint. This relationship is statistically significant, which suggests that the EKC for MENA countries is not an inverted U-shape but a U-shape. This fails to validate the EKC hypothesis for MENA countries when conflicts, energy consumption, and urbanization are controlled. The effect of energy consumption and urban population is negative (p-value <0.01), suggesting energy consumption and urbanization exert upward pressure on ecological footprint, thereby reducing environmental quality. The results further reveal a positive although insignificant effect of internal and external conflicts on ecological footprint. This effect is due to the huge effect of conflicts on air and water pollution as well as soil degradation. These results, therefore, corroborate with the estimates of the MMQR model (Table 5 and 6).

Concluding remarks and policy implications

We investigated the role of internal and external conflicts on ecological footprint in MENA countries by controlling for energy consumption, income levels, and urban development over the period 1995 to 2016. In doing this, we employed the Method of Moments Quantile Regression—which incorporates a fixed-effect with robust standard errors. We also employed the RE-GLS with Driscoll-Kraay standard errors to control for autocorrelation. Our finding provided evidence that the EKC for MENA regions is not an inverted U-shape—as growth in economic development is associated with environmental improvement. However, there exists an inherent heterogeneous effect of economic growth across the quantile distribution. Energy consumption and urbanization exert upward pressure on ecological footprint in the region whereas internal conflict deteriorates environmental quality across quantiles. We further showed the effect of external conflict is elusively negative and statistically insignificant. Generally, growth in ecological footprint is traceable to excessive consumption of energy related to urban development, and internal conflicts—through huge air and water pollution as well as soil damaging effects. Therefore, our findings portend interesting policy implications essential for effective conflict resolution and environmental policies across conflict-prone countries such as the MENA region. Particularly, the policy implications of the findings of this study are as follows:

First, to achieve sustainable environmental quality, there is a need to enhance urban development-induced renewable energy. This will trigger new technologies that promote energy efficiency and carbon-free economies in the region. In other words, adopting an alternative clean energy system (i.e. renewable energy) is indeed important for protecting, restoring, and promoting sustainable use of terrestrial ecosystems, combating desertification, and managing forests as well as reversing land degradation and loss of biodiversity.

Second, to promote peaceful societies that are inclusive for sustainable development in the region, efforts should be made to curtail the incidence of internal and external conflicts. This is because conflicts do not only mount positive pressure on ecological footprint but also affect sustainable production and consumption and hence, deteriorating income levels in the region. The effect of conflicts could lead to energy disasters and decline in production and consumption through air and water pollution.

Third, these findings will help in drawing the attention of government and policymakers towards formulating effective environmental policies that achieve the goal of decarbonized economies and sustainable economic growth. To this end, we suggest further studies could concentrate on the underlying mechanisms through which internal and external conflicts affect ecological footprint.

Data and materials availability The datasets generated and/or analyzed during the current study are available in the repositories:

Ecological footprint per person is available at Global Footprint Network (GFN)

Real GDP per capita, energy consumption per capita, and Urbanization are available at World Development Indicators (WDI)

International and external Conflicts are available at International Country Risk Guide (ICRG) PRS Group

Author contribution Ojonugwa Usman: Conceptualization, Data curation, Formal analysis, investigation, methodology, Review & editing and Writing - original draft.

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Samuel Asumadu Sarkodie: Review & editing, Validation, Visualization, Supervision.

Declarations

Ethics approval and consent to articipate Not applicable

Consent for publication Not applicable

Competing interests The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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