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Research article

The validity of the environmental Kuznets curve in the presence of long-run civil wars: A case of Afghanistan

Mohammad Ajmal Hameed [*], Mohammad Mafizur Rahman, Rasheda Khanam

School of Business, University of Southern Queensland, Toowoomba, QLD, 4350, Australia

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ABSTRACT

The war in Afghanistan left significantly negative consequences in all spheres of its society, leading the country to the highest levels of poverty, hunger, and environmental damage. This study explores the long-run impact of civil wars on environmental degradation in Afghanistan using the conceptual framework of the Environmental Kuznets Curve and models augmented with pollutants, civil wars, comprehensive financial development index, and macroeconomic predictors on a set of data from the first quarter of 2002 to the first quarter of 2020. However, while the results confirm long-run relationships amid indicators by the autoregressive distributed lags bound test, the results of the vector error-correcting model to Granger causality reveal bidirectional causality links between CO_2 emissions, per capita real GDP, civil wars, the financial development index, energy consumption, trade openness, and the inflation rate in the long-run, while the findings extend to confirm multidimensionality and interdependencies among predictors in the short-run. Moreover, the results indicate dual findings. First, it confirms that civil wars, the financial development index, per capita real gross domestic product, population growth, and the inflation rate significantly increase CO_2 emissions, while the squared per capita real gross domestic product, energy consumption, and trade openness reduce CO_2 emissions both in the short and long runs. Second, the results confirm an inverted U-shaped relationship, supporting the validity of the Environmental Kuznets Curve hypothesis in Afghanistan. Based on the findings, appropriate policy measures are recommended.

1. Introduction

The population of Afghanistan is confronted with an increasing number of environmental issues, such as unceasing deforestation and land degradation, uncontrolled urbanization and solid waste disposal, worsening air and water pollution, groundwater depletion, illegal wildlife trade, an expanding mining footprint, including unofficial artisanal quarrying, a lack of renewable energy alternatives, and more frequent and severe floods, droughts, and landslides [1]. The widespread insecurity, armed conflicts between government and the insurent groups, inadequate infrastructure, and the rapid consequences of climate change are severely impeding efforts to better understand the deteriorating situation and its effects on human well-being. Despite the fact that most of the aforementioned issues are the result of four decades of ongoing civil wars and armed conflicts, it is essential to enhance the current body of knowledge on consequences of wars on environmental quality in Afghanistan. Therefore, this study is specifically designed to explore how long-term wars affect environmental quality using the Environmental Kuznets Curve (EKC) framework.

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* Corresponding author.
E-mail address: u1129358@usq.edu.au (M.A. Hameed).

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The initial idea of the EKC was put forward by Ref. [2] and then empirically described by Ref. [3]. Since the 1990s, the EKC hypothesis has gained prominence in the empirical literature, and numerous studies have explored the co-movement of environmental degradation and economic growth. It formed a consensus amongst environmental economists that environmental quality deteriorates in the early stages of economic development up to a certain level—a turning point—while it nosedives afterward. Given this background, on the one hand, higher economic performance requires higher material inputs, resulting in the production of large amounts of carbon emissions. On the other hand, higher employability and a rise in per capita real income make it joyful to ignore its long-run environmental consequences [4]. At a later stage of development, people with a higher per capita income are more sensitive and give more value to controlling and reducing environmental pollution [5]. This is where the changing pattern of the nexus between economic development and environmental degradation forms the EKC, that is, an inverted U-shaped curve between them.

Regardless, recent studies about the EKC hypothesis have mainly taken five directions. The first group (see, *inter alia*, Rahman and Alam,2022b [6–13], examined the EKC hypothesis in developed economies and presented mixed results. The second group of studies, such as [14–18]; Sultana et al., 2021, and [19]; explored the validity of the EKC in developing economies and provided controversial results due to the use of different predictors and estimation models. The third group of studies examined the EKC from global perspectives (see, *inter alia*, [20–25]. The fourth group of studies, such as [26–28]; Moghadam and Dehbashi (2018), [29,30]; and [31]; focused on individual economies to test the EKC. The fifth group of studies, like [32–34]; and [35]; tested the EKC hypothesis in post-conflict environments and presented implicit results. Nonetheless, the fifth group of studies ignored the effects of civil wars on environmental degradation in their analysis. Since war-torn societies host frequent and heavy military operations, it is widely perceived that the extensive amount of carbon emissions produced from the use of heavy military equipment results in higher pollution that significantly degrades environmental quality. A more extensive review indicates that almost all recent studies, to the best of our knowledge, have neglected to examine the impact of civil wars and armed conflicts on environmental quality; however, an exception is given to the implicit work of [35]. However, this gap motivates us to conduct this research, but our primary objective is to verify the empirical effects of long-term civil wars on environmental degradation. The verification of the size and magnitude of the effects of war on environmental degradation underlines key policy implications that help policymakers take prompt action. Moreover, we found that Afghanistan is a battlefield with the longest civil wars in the history of the world and has experienced more than four decades of war. Thus, it could represent a specific context for the present study, and the conclusion drawn could be generalized to a large extent to help policymakers. Fig. 1 depicts how carbon emissions (CO_2) and thus environmental degradation move in lockstep with the intensity of civil wars in Afghanistan, demonstrating a potential coexistence between civil wars and environmental degradation. Moreover, despite civil wars and rapid environmental degradation in Afghanistan, the per capita GDP was US$57 in 2000 and rose to US$587 in 2020. Therefore, it suggests to adopt the EKC framework for analysis.

This study is a new step in the existing literature on the EKC hypothesis for war-torn zones, and its contribution can be outlined as follows: First, the authors innovatively extend the common EKC model with civil war predictors. It highlights whether an inverted U-shaped curve exists between per capita real income and pollutant predictors in the presence of civil wars. Second, learning from recent gaps, the study extends the analysis and tests the short- and long-run causal nexus between the EKC predictors in a conflict zone. Third, since in the presence of war, it tests the EKC hypothesis for a specific war zone, say, Afghanistan, rather than panel analysis, it provides accurate and consistent results on which specific policy measures are recommended. The scope of the results highlights four key findings, among all others. First, the findings show that civil wars have a significant impact on environmental degradation in both the short and long run. Second, the results provide statistical evidence for the existence of an inverted U-shaped relationship between per capita real income and CO_2 emissions, thereby confirming the EKC hypothesis. Third, there exist bidirectional causality links between

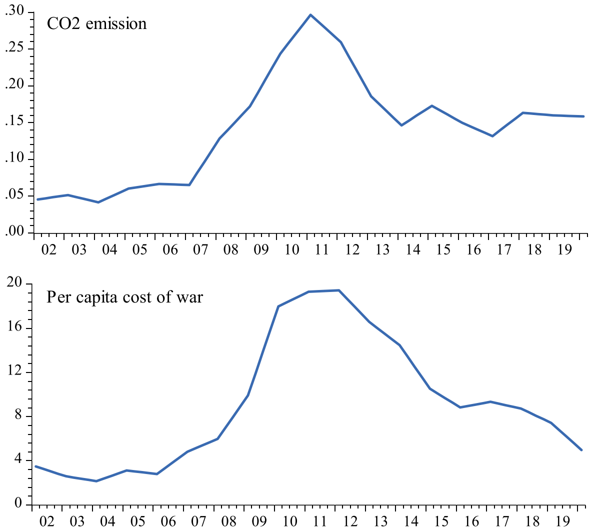

Fig. 1. CO_2 emissions and per capita cost of war; time-trend plot.
Sources: World Development Indicators (WDI) and US Department of Defense Budget.

CO_2 emissions, per capita real GDP, civil wars, the financial development index, energy consumption, trade openness, and the inflation rate. Fourth, interestingly, the findings reveal multidimensionality and interdependencies among predictors.

The remaining parts of the study are organized as follows: Section two, "Literature Review," reviews relevant empirical studies. Section three, "Methodology," explains the data, variables, key measurements, and econometric models. Section four, "Results and Discussions," presents the empirical results and discusses the findings. Section five, "Analysis of Results," presents a brief analysis of the main findings and compares the results with recent studies. Section six, "Conclusions," concludes the study.

2. Literature review

The existing literature widely documents a vast number of statistical arguments for the validity of the EKC hypothesis. Studies have attempted to examine the co-movement of economies through different stages of development with environmental quality in both developed and developing countries. In theory, an EKC hypothesis is valid when environmental degradation increases as a consequence of economic development at an early stage while it begins to improve at a later stages of development [5,36,37]. The pattern forms an inverted U-shaped curve between environmental degradation and economic development. Literally, the realization of this trend can be traced out through three key stages of economic development, such as a pre-industrialized economy that leads to decreased environmental quality—implying that an increase in per capita real income causes an increase in environmental degradation; an industrialized economy that reaches a certain level of growth and, therefore, is at a turning point; and a post-industrialized or service-based economy that leads to increased environmental quality—that is, an increase in per capita real income causes a decrease in environmental degradation [38].

Empirically, the inverted U-shaped curve does not only hold for the nexus between pollutants and real income predictors. It is also significantly influenced by a number of other determinants, such as population growth, free trade agreements, globalization, and economic variability [39]. According to Ref. [40]; incorporating different control variables into EKC modeling results in the emergence of new EKCs, making them more fragile and complicated than the initial concept sparked in the early 1990s. However, the literature owes much to Ref. [2]; who claimed the coexistence of growth and environmental degradation [41]. confirmed the validity of the EKC hypothesis by testing the transformation of environmental quality at different income levels across various economies. In war-hosting economies, industrial affairs are not the only sources of pollution. Soil and sea pollution, chemical pollution caused by shelling, wildfires caused by warfare, and the consequences of wars on industrial objects are significant sources of environmental damage that have concurrent and lasting effects on the environment [42]. Therefore, considering all these facts, the present study redefines the EKC hypothesis with the effects of civil wars and employs it as the conceptual framework of this investigation.

With respect to the empirical studies, the literature shows that [43] investigated the long-run relationship between sulfur emissions and economic growth for 74 countries over 31 years using cointegration analysis. Though the authors found a long-run relationship between the variables of growth and air pollutants supporting a concave pattern, they argue that due to the stochastic trend of the time-series dimension over time, a concave pattern is not necessarily true in all economies to confirm the validity of the EKC hypothesis [44]. explored the link between income, CO_2 emissions, foreign trade, and energy consumption in Pakistan from 1972 to 2008 and used cointegration analysis. They found a long-run relationship between income, CO_2 emissions, foreign trade, and energy consumption, supporting the existence of the EKC hypothesis, while their results failed to support the EKC in the short run.

[45] used bootstrapping panel unit root tests and cointegration techniques to examine the inverted U-shaped curve for Middle Eastern and North African economies from 1981 to 2015. The authors discovered a long-run positive relationship between CO_2 emissions and energy consumption, as well as quadratic relationships across the entire panel. As a result, their findings support the existence of the EKC hypothesis for the economies of the Middle East and North Africa [46]. investigated the EKC hypothesis in Romania using data from 1980 to 2010. Using the ARDL bound test, the authors discovered a long-run relationship between economic growth, energy consumption, and energy pollutants, implying the existence of the EKC hypothesis both in the short and long run. In addition [47], found that the income earned from the sector of tourism has a significant impact on explaining the EKC realization in Turkey. The authors discovered that foreign tourists visiting Turkey, as well as other economic and pollutant indicators like energy consumption, income, and squared income, exhibit significant cointegration with CO_2 emissions, implying that the EKC hypothesis exists in Turkey.

[48] investigated the EKC hypothesis in India and employed a set of time-series data spanning from 1991 to 2014. However, the author found a statistical relationship between CO_2 emissions and per capita GDP, but the EKC hypothesis did not hold in the context of India [49]. used an ecological footprint as a predictor of environmental quality and tourism-to-GDP ratio to test the existence of the EKC hypothesis. The authors used a GMM-based environmental degradation model with a dataset from 1988 to 2008 for a panel of 144 countries. Their findings indicate that the number of countries with a negative relationship between ecological footprint and its determinants was higher in upper-middle- and high-income economies. Furthermore, they provided statistical evidence supporting the EKC hypothesis in upper-middle and high-income countries [50]. also found the existence of EKC in the Philippines.

[51] used a set of data from 1980 to 2016 to test the EKC in 151 countries, focusing on global and countries categorized by income level. The authors discovered a statistical link between real per capita output and CO_2 emissions and supported the U-shaped curve between economic growth and pollutant predictors in middle-income, high-income, and low-income economies. They also discovered that urbanization has a positive impact on CO_2 emissions in middle-high and middle-low-income economies, while energy consumption and manufacturing have a positive impact on CO_2 emissions in all groups of countries.

[52] used provincial level data in China over the period of 1996–2015 and used a panel fixed effects model to examine the association between economic growth and CO_2 emissions. The authors found an inverted U-shaped relationship between CO_2 emissions and economic growth, while an inverted N-shaped nexus was also evident between CO_2 emissions and foreign direct investment.

Moreover, the authors showed that energy consumption has a positive effect on the production pace of CO_2 emissions [53]. explored the relationships between energy demand and globalization predictors in high-income, middle-income, and low-income economies, consisting of 84 countries from 1970 to 2015. The authors applied the cross-correlation method, which was a simple approach to investigating the EKC's existence and analyzing their datasets. They found that for 64 out of the 86 economies, the EKC hypothesis was supported, while the majority of these countries have been effective in reducing their energy consumption in the long run.

[54] examined the policy schemes of Asian economies' effectiveness in achieving sustainable environmental practices with respect to green growth, green financing, and CO_2 emissions reduction mechanisms. The authors used a set of data over the period of 1980–2015 and employed a fully modified ordinary least squares method to test their hypotheses. They found that the EKC exists in Asian countries, while GDP growth and its square have positive and negative effects on CO_2 emissions, respectively. They also add that the EKC hypothesis is not supported in the context of lower-income economies. However, their results show that the EKC is supported in high- and upper-middle-income countries [55]. used a vector autoregression model and a bootstrap Granger causality test to examine the causality nexus between economic growth and CO_2 emissions in Rwanda over the period from 1960 to 2014. The authors discovered that GDP has a negative influence on CO_2 emissions, and their results show that the EKC shows a decreasing trend. They add that the downward slope of the EKC is explained by the transition of the Rwandan economy from an industrial-based economy to a service-based economy. Comparatively [56], examined the EKC hypothesis in D8 countries over the period of 1972–2014. The author found an inverted N and N-shaped pattern and supported the EKC hypothesis. On the other hand [57], found the validity of the EKC for China for the period of 1971–2018.

[58] examined the effects of deforestation and the existence of EKC in Africa using a set of panel data from 1990 to 2016. The authors applied a generalized method of moment to account for any endogeneity issues in the panel and found that the EKC hypothesis is valid in the context of deforestation in Africa. The authors also found that the turning point was $3000. Based on the heterogeneous panel non-causality test, the authors added that Africa deters and reverses deforestation through forest product trade policies that would not impact their economic growth. Comparatively, in another study by Ref. [59] in the context of West African countries with the same level of per capita income over the period of 1970–2013, the authors found that economic growth positively affects CO_2 emissions, while the insignificant nexus between CO_2 emissions and the pollutant predictors confirms the invalidity of the EKC hypothesis in the West African economies. In exploring the literature, it shows that [60] examined the EKC hypothesis in the context of Bangladesh, using deforestation propensities as environmental predictors and energy consumption, population growth, and agricultural land coverage over the period from 1972 to 2018. The authors employed an ECM-based autoregressive distributed lag model to test the hypothesis and found a nonlinear inverted-U-shaped trend between deforestation and economic growth in Bangladesh. Moreover, they also found that the deforestation-induced EKC was a valid hypothesis in Bangladesh.

Relevant to the context of the present study, among all others [35], is an exceptional study that has employed a set of data from 1984 to 2019 for South Asian economies, such as Afghanistan, Bangladesh, Bhutan, India, Nepal, the Maldives, Pakistan, and Sri Lanka, to test the EKC hypothesis in the presence of armed conflicts and aggression between India and Pakistan. Though their dataset suffered from missing data for four out of eight countries, they found that the EKC hypothesis is valid in the context of South Asian economies. Furthermore, the authors showed that the hostility left India and Pakistan with relatively higher growth in defense and military operations that were found to significantly deteriorate environmental quality. The literature also reveals that [61] examined the effects of urbanization on redefining the EKC hypothesis in 134 countries over the period from 1996 to 2015. The authors found that urbanization is significant in increasing the positive effects of economic growth on environmental degradation [62]. analyzed the effects of financial development on CO2 emissions in the G7 countries from 1990 to 2019 through a fixed effect model. Their findings revealed a non-linear relationship between the composite financial development index and environmental degradation. It implied that financial development is monotonically positive and statistically significant for increasing CO_2 emissions [63]. investigated the effect of trade openness, human capital, renewable energy, and natural resource rent on CO_2 emissions using the EKC framework and the generalized method of moments technique in 208 countries over the period from 1990 to 2018. The authors found that the EKC hypothesis is valid when the effects of trade openness, human capital, renewable energy consumption, and natural resource rents are considered, and the relationship between income level and CO_2 emissions shows an inverted U-shaped curve.

The review of the above studies indicates two empirical gaps: First, although there are numerous studies that have examined the EKC hypothesis in the presence of various macroeconomic variables, the literature does not report any study considering the effects of civil wars on the validity of the EKC hypothesis. Second, while Afghanistan represents the longest civil war in history, we failed to find any study that examined the relationships between civil wars and environmental degradation. Therefore, to fill these gaps, three new hypotheses have been developed. H_1: Civil wars have significantly positive effects on environmental degradation. H_2: Civil wars, economics, and pollutant predictors form both short-run and long-run relationships. H_3: The validity of the EKC hypothesis can be confirmed by the presence of civil wars in Afghanistan.

3. Methodology

3.1. Data and variables

Based on the availability of data, the empirical analysis of this study employs a dataset containing annual observations ranging from 2002 to 2020. For accurate estimations of time-series analysis, the study follows [64,65]; and [66] and transforms the annual observations into quarterly series, using the linear interpolation method. This approach is rational because it accurately transforms the data into a higher number of observations without affecting the stationarity properties or trends of the variables. Thus, the dataset for analysis spans from 2000Q1 to 2020Q1. Afghanistan has been selected as the geographical context of the study for three key reasons:

First, from the review of the existing literature, we understand that, despite several studies, Afghanistan has not been studied by scholars. Second, Afghanistan is the battlefield of the longest war in the world's history. It requires critical investigation to highlight how long-term wars affect environmental factors. Third, Afghanistan is one of the top 20 most polluted countries, and in addition to pollutant predictors, war has also contributed to rising environmental degradation in the country. Due to the objectives, except for the civil wars and financial development variables that are innovatively used in the study, the choice of other variables is based on theoretical assumptions and recent EKC studies (see, *inter alia*, [7,17,67,68]; Nilüfer et al., 2022). The variables are measured by different units and include CO_2 emissions expressed in metric tons per capita, real GDP derived as the nominal GDP (constant 2015 US $) over the GDP deflator, energy consumption expressed in kilos of oil equivalent per capita, trade openness expressed as the sum of imports of goods and services to GDP (%) plus the sum of exports of goods and services to GDP (%), per capita cost of war expressed in millions of US$ spent by the United States in supporting the military operations in Afghanistan, population growth expressed as an annual (%), inflation rate based on GDP deflator (%), and the financial development index expressed as GDP (%). The financial development index comprises three key indicators, such as domestic credit to the private sector to GDP (%), liquid liabilities to GDP (%), and gross fixed capital formation to GDP (%). The construction of the financial development index follows a similar methodology used by the UNDP for constructing the human development index, GDI (gender development index), and HPI (human poverty index), using dimensional average indices (see, [69]; for detailed construction methodology). The per capita cost of war, which is a key variable of interest, measures the monetary value of military operations in Afghanistan as an aggregate index. This proxy has two features, viz., proxies used in recent studies. First, it allows more accurate estimations than the number of people killed and injured. Second, it provides actual data on the amount of money spent on operating pure military operations, thus reflecting the real economic cost of war and its impact on the outcome variable. The datasets for CO_2, nominal GDP, GDP deflator, trade openness, energy consumption, domestic credit to the private sector, liquid liabilities, inflation rate, population growth, and gross fixed capital formation are collected from the WDI (World Development Indicators), sources that are relevant to the World Bank, and the data for the cost of war is collected from the United States Department of Defense Budget.

3.2. Model specification

This study aims to test the effects of long-term civil wars on the environmental quality in Afghanistan by using the conceptual framework of the EKC hypothesis to take a new step in the existing literature on the war-environment nexus. To obtain a specification fit for the purpose, we begin with the common empirical approach used for the EKC specification (see [5], for a comprehensive EKC survey), which is as:

$$co_{2t} = \sigma + \beta_1 y_t + \beta_2 y_t^2 + \beta_3 en_t + \beta_4 to_t + \beta_5 pop_t + u_t \tag{1}$$

where CO_2 emissions present environmental degradation, y_t is the per capita real GDP that positively influences CO_2 emissions up to a certain limit [15], y_t^2 is the squared of the per capita GDP and it negatively affects CO_2 emissions [14,70], en_t refers to energy use, to_t is trade openness, and pop_t is population growth. However, some studies, such as [31,71,72]; and [73] have employed ecological footprints and trade-adjusted carbon emissions as proxies for environmental degradation. For three reasons, this study uses CO_2 emissions instead. First, CO_2 is a better proxy for the environmental quality in war-torn societies to measure the environmental damage. Second, the required data for ecological footprint during the most intense period of the civil war is not available. Third, according to Ref. [74]; military operations account for more than 5.5 percent of the total greenhouse gas emissions in the host country. Moreover, in recent studies, among all others [75], included the inflation rate and arms imports and exports indicators in testing the EKC hypothesis, assuming that real GDP shows the overall real economic function of a country, while the inflation rate controls for the economic variability in the EKC studies. Most recent empirical studies have used credit to the private sector as a proxy to measure the effects of financial markets on environmental quality (see, *inter alia* [28,30,76,77], which is not a comprehensive predictor of financial market progressions; rather, it only indicates the supply-side of credit to private borrowers. Therefore, the present study draws on the existing EKC literature and innovatively extend the analysis by fitting a model augmented with common EKC predictors, long-run civil war indicator, and comprehensive financial development index as:

$$\begin{aligned} co_{2t} = {} & \sigma + \beta_1 y_t + \beta_2 y_t^2 + \beta_3 en_t + \beta_4 to_t + \beta_5 pop_t \\ & + \beta_6 inf_t + \beta_7 cw_t + \beta_8 fd_t + u_t \end{aligned} \tag{2}$$

where cw = per capita cost of war used to capture the effects of long-run civil war on the environmental quality, inf = inflation rate is employed to control for economic variability, and fd = financial development index, comprising domestic credit to the private sector, liquid liabilities, and gross fixed capital formation is used to capture the effects of financial market progression on the outcome variable. For the purpose of empirical analysis, the variables are transformed into their natural logarithmic form with a long-run linear function as:

$$\begin{aligned} \ln co_{2t} = {} & \varphi + \beta_1 \ln y_t + \beta_2 \ln y_t^2 + \beta_3 \ln en_t + \beta_4 \ln to_t \\ & + \beta_5 \ln pop_t + \beta_6 \ln inf_t + \beta_7 \ln cw_t + \beta_8 \ln fd_t + \varepsilon_t \end{aligned} \tag{3}$$

where ln = the natural log of the predictors, φ = the intercept, β_1 to β_8 = long-run coefficients of the explanatory variables, and ε_t = the error term of the model. All other variables hold the same meaning as described before. Due to the EKC—that is, the inverted U-Shaped curve hypothesis, we expect that $\beta_1 > 0$ implying that an increase in CO_2 emissions is associated with an increase in per capita real GDP up to a certain limit and then it begins falling $\beta_2 < 0$, squared per capita real GDP. The coefficient signs for energy consumption, trade openness, population growth, and inflation rate are expected to be positive (see, for instance, Ref. [78]. For the financial development index, its coefficient sign is also expected to be positive. It is because the progression in financial development that eases capital-intensive projects in an economy contributes to increased CO_2 emissions and, therefore, reduces environmental quality [8,13,25,79,80]. Since civil wars strongly contribute to the rise in CO_2 emissions, the expected sign for $\beta_7 > 0$, that is, the increase in civil wars is positively associated with an increase in environmental degradation. Moreover, the turning point arising from the representing values is calculated as $\tau = \exp[-\beta_1 / (2\beta_2)]$ (see, *inter alia*, [10,23].

3.3. Econometric methods

The estimation begins with the test of unit root, which is important to determine the integrating order of the variables in time-series analysis. In this faith, Augmented Dickey and Fuller (ADF) (1979), Phillips and Perron (PP) (1988), and [81] methods are employed. With all the variables following mixed integrating orders of I(0) and I(1) without any I(2), the study proceeds to test the long-run relationship between them using the autoregressive distributed lags (ARDL) bound test of [82]. The use of ARDL test with an optimal lag length addresses the issues of serial correlation and endogeneity, provides consistent coefficients for small sample sizes, allows the dependent and independent variables to follow mixed integration, permits the dependent and independent predictors to use different lags, and estimates both short and long run coefficients simultaneously [83]. We fit the error-correcting ARDL test as:

$$\begin{aligned}\Delta \ln co_{2t} = {} & \theta_i + \lambda_1 \ln co_{2t-1} + \lambda_2 \ln y_{t-1} + \lambda_3 \ln y_{t-1}^2 + \lambda_4 \ln cw_{t-1} + \lambda_5 \ln fd_{t-1} + \lambda_6 \ln pop_{t-1} \\ & + \lambda_7 \ln en_{t-1} + \lambda_8 \ln to_{t-1} + \lambda_9 \ln inf_{t-1} + \sum_{i=1}^{p} \varphi_1 \ln co_{2t-i} + \sum_{i=1}^{q} \varphi_2 \ln y_{t-i} \\ & + \sum_{i=1}^{q} \varphi_3 \ln_{t-i}^2 + \sum_{i=1}^{q} \varphi_4 \ln cw_{t-i} + \sum_{i=1}^{q} \varphi_5 \ln fd_{t-i} + \sum_{i=1}^{q} \varphi_6 \ln pop_{t-i} \\ & + \sum_{i=1}^{q} \varphi_7 \ln en_{t-i} + \sum_{i=1}^{q} \varphi_8 \ln to_{t-i} + \sum_{i=1}^{q} \varphi_9 \ln inf_{t-i} + \eta ECT_{t-1} + u_t\end{aligned} \tag{4}$$

where $\theta =$ intercept, $\lambda_1 - \lambda_9 (\varphi_1 - \varphi_9) =$ long-run (short-run) coefficients, $p =$ lag operator of the dependent variables, $q =$ lag operator of the explanatory variables, and all other variables hold the same meaning as described before. Equation (6) tests the joint null of $H_{null} : \lambda_1 = \lambda_2 = \lambda_3 = \lambda_4 =, \ldots, = \lambda_9 = 0$ vs. $H_{alt.} : \lambda_1 \neq \lambda_2 \neq \lambda_3 \neq \lambda_4 \neq, \ldots, \neq \lambda_9 \neq 0$ using F-statistics viz-a-viz the critical values for the lower bound I(0) and upper bound I(1) for a desired significant level. The null is rejected if the F-statistics are greater than the upper bound, and it is not if the F-statistics are otherwise [84]. Once the cointegration is established among the predictors, the study employs the vector error-correcting model (VECM) to granger causality. This method is superior in showing the long- and short-run causality between variables. Verifying causal links between the predictors helps highlighting specific policy implications [85]. Consistent with [86]; the following VECM-Granger causality equation is used:

Table 1
Descriptive statistics.

Summary statistics	$lnco_2$	Lncw	lnen	Lnfd	lninf	lnpop	lnto	lny	lny^2
Mean	−2.120	1.972	3.144	2.749	1.594	1.093	3.181	6.162	37.97
Maximum	−1.216	2.967	3.909	3.074	3.273	1.548	3.493	6.376	40.65
Minimum	−3.178	0.763	2.441	1.741	−0.553	0.833	2.412	5.800	33.64
Std. Dev.	0.589	0.710	0.428	0.389	0.805	0.205	0.279	0.219	0.047
Correlation matrix	$lnco_2$	Lncw	lnen	Lnfd	lninf	lnpop	lnto	lny	lny^2
$lnco_2$	1								
Lncw	0.489	1							
Lnen	−0.499	−0.244	1						
Lnfd	0.308	0.197	−0.502	1					
Lninf	0.214	0.566	0.199	−0.162	1				
Lnpop	0.400	0.255	0.408	0.389	0.204	1			
Lnto	0.543	0.502	−0.537	0.119	−0.054	−0.530	1		
Lny	0.448	0.384	−0.388	0.304	−0.496	−0.485	0.260	1	
lny^2	−0.367	0.499	−0.266	0.421	−0.429	−0.405	0.453	0.689	1

Notes: Std. Dev. = Standard deviation, lnco2 = natural log of CO2, lncw = natural log of per capita cost of war, lnen = natural log of energy consumption, lnfd = natural log of financial development index, lninf = natural log of inflation rate, lnpop = natural log population growth, lnto = natural log of trade openness, lny = natural log of per capita real GDP, lny2 = natural log of square of per capita real GDP.

$$\begin{bmatrix} \ln co_2 \\ \ln y \\ \ln y^2 \\ \ln cw \\ \ln fd \\ \ln pop \\ \ln to \\ \ln en \\ \ln inf \end{bmatrix} = \begin{bmatrix} \vartheta_1 \\ \vartheta_2 \\ \vartheta_3 \\ \vartheta_4 \\ \vartheta_5 \\ \vartheta_6 \\ \vartheta_7 \\ \vartheta_8 \\ \vartheta_9 \end{bmatrix} = \begin{bmatrix} \vartheta_{11k}\vartheta_{12k}\vartheta_{13k}\vartheta_{14k}\vartheta_{15k}\vartheta_{16k}\vartheta_{17k}\vartheta_{18k}\vartheta_{19k} \\ \vartheta_{21k}\vartheta_{22k}\vartheta_{23k}\vartheta_{24k}\vartheta_{25k}\vartheta_{26k}\vartheta_{27k}\vartheta_{28k}\vartheta_{29k} \\ \vartheta_{31k}\vartheta_{32k}\vartheta_{33k}\vartheta_{34k}\vartheta_{35k}\vartheta_{36k}\vartheta_{37k}\vartheta_{38k}\vartheta_{39k} \\ \vartheta_{41k}\vartheta_{42k}\vartheta_{43k}\vartheta_{44k}\vartheta_{45k}\vartheta_{46k}\vartheta_{47k}\vartheta_{48k}\vartheta_{49k} \\ \vartheta_{51k}\vartheta_{52k}\vartheta_{53k}\vartheta_{54k}\vartheta_{55k}\vartheta_{56k}\vartheta_{57k}\vartheta_{58k}\vartheta_{59k} \\ \vartheta_{61k}\vartheta_{62k}\vartheta_{63k}\vartheta_{64k}\vartheta_{65k}\vartheta_{66k}\vartheta_{67k}\vartheta_{68k}\vartheta_{69k} \\ \vartheta_{71k}\vartheta_{72k}\vartheta_{73k}\vartheta_{74k}\vartheta_{75k}\vartheta_{76k}\vartheta_{77k}\vartheta_{78k}\vartheta_{79k} \\ \vartheta_{81k}\vartheta_{82k}\vartheta_{83k}\vartheta_{84k}\vartheta_{85k}\vartheta_{86k}\vartheta_{87k}\vartheta_{88k}\vartheta_{89k} \\ \vartheta_{91k}\vartheta_{92k}\vartheta_{93k}\vartheta_{94k}\vartheta_{95k}\vartheta_{96k}\vartheta_{97k}\vartheta_{98k}\vartheta_{99k} \end{bmatrix} = \begin{bmatrix} \Delta\ln co_{2t} \\ \Delta\ln y_t \\ \Delta\ln y_t^2 \\ \Delta\ln cw_t \\ \Delta\ln fd_t \\ \Delta\ln pop_t \\ \Delta\ln to_t \\ \Delta\ln en_t \\ \Delta\ln inf_t \end{bmatrix} = \begin{bmatrix} n_1 \\ n_2 \\ n_3 \\ n_4 \\ n_5 \\ n_6 \\ n_7 \\ n_8 \\ n_9 \end{bmatrix} = ECT_{t-1} + \begin{bmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \\ \varepsilon_{3t} \\ \varepsilon_{4t} \\ \varepsilon_{5t} \\ \varepsilon_{6t} \\ \varepsilon_{7t} \\ \varepsilon_{8t} \\ \varepsilon_{9t} \end{bmatrix} \quad (5)$$

where all variables are explained before, $\vartheta_{12}, \dots, \vartheta_{99}$ = coefficients, $t = 2002, 2003, \dots, 2020$, and -1 presents the lag of the error correction, where its negative sing implies long-run causality nexus and the disturbance term of the model. The significant result of the error term, the statistical significance of $t - stat.$, and significant nexus imply the causality direction of the short-run association in the first difference order of the predictors—that is, $\vartheta_{12k} \neq 0 \forall i$ indicates that natural log of per capita real GDP granger causes the natural log of CO_2 emissions and $\vartheta_{21k} \neq 0 \forall i$ shows a flip-side causality from natural log of CO_2 to the natural log of per capita real GDP (see, for instance, Ref. [87]. Finally, the study confirms the robustness and accuracy of the estimates using various diagnostic tests that are consistently reported with the results.

4. Results and discussion

4.1. Descriptive statistics

The study begins the analysis with some important descriptive statistics reported in Table 1. During the study period, the *lnco2*—simplified, CO2—stands at 0.12 metric tons per capita with a maximum of 0.30 metric tons per capita, while the average per capita cost of war rounds up to US$7.19 million with a maximum of US$19.43 million, both showing growth over time.

Moreover, the mean per capita real GDP (*lny*) is US$474.38 with a maximum of US$587.57, whereas the average financial development index (*lnfd*) rounds up to 15.63 % of GDP with a maximum of 21.63 % of GDP in Afghanistan. Although one can read through the summary statistics, the rear part of Table 2 reports the correlation analysis between the predictors, indicating no significant correlation between them except for the association between per capita real GDP (*lny*) and its squared values (*lny2*), which is as expected.

4.2. Stationarity analysis

In time-series analysis, ascertaining the integrating orders of the variables leads to appropriate specification. To that end, the results of three methods testing the null of non-stationarity, such as Augmented [88,89]; and [81]; are reported in Table 2. The results demonstrate that *lnfd*, *lnpop*, *lnto*, *lny*, and *lny2* are significant at 1 % and 5 % levels to reject the null of non-stationarity, while other remaining variables, such as *lnco2*, *lncw*, *lnen*, and *lninf*, can only reject the null after the first difference by all three methods. The mixed integration orders of I(0) and I(1) without any I(2) series support the estimation of the ARDL bound test model to establish the cointegration, if any, between the predictors (see, *inter alia* [82,90], covered in the following section.

Table 2
Stationarity tests.

Variables	ADF test		PP test		Ng and Perron	
	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)
$lnco_2$	−1.818	−3.991***	−1.681	−4.100***	−1.681	−14.266***
lncw	−1.786	−4.206***	−1.190	−4.231***	−4.212	−17.126***
lnen	−1.851	−4.598***	−1.552	−4.722***	−2.192	−14.552***
lnfd	−3.127***	−4.836***	−3.511***	−4.264***	−11.564**	−14.898***
lninf	−1.669	−3.994***	−1.794	−3.590***	−2.011	−15.977***
lnpop	−3.579***	−5.835***	−3.736***	−5.136***	−13.429***	−19.253***
lnto	−3.801***	−4.349***	−2.953**	−3.306***	−12.512***	−16.200***
lny	−2.341**	−4.469***	−2.512**	−3.016***	−9.227**	−13.920***
lny^2	−2.353**	−4.410***	−2.908**	−4.958***	−9.004**	−14.034***

Notes: *** and ** indicate 1 % and 5 % respectively. ADF = Augmented Dickey-Fuller, PP = Phillips-Perron. Critical values of Ng-Perron for 1 %, 5 %, and 10 % are −13.80, −8.10, and −5.70, respectively. Critical values come from Ref. [81] table. Anoptimal lag length of 1 has been selected using the Schwarz Information Criterion (SIC).

4.3. Cointegration analysis

Considering the results of the predictors' integration shown in Table 2, the study proceeds to estimate the ARDL bound test model to establish the long-run relationship between the variables and reports its results in Table 3. Before estimation, the optimal lag length selection using the Akaike information criterion (AIC), Schwarz information criterion (SIC), and Hannan-Quinn information criterion (HQIC) was estimated in the VAR environment. All three criteria suggested two lags. The ARDL bound test results indicate that the F-statistics ($F = 13.940 > CV = 3.77$) is greater than the critical value of I(1) bound at a 1 % level of significance and thus rejects the null of $\lambda_1 = \lambda_2 = \lambda_3 = \lambda_4 =, ..., = \lambda_9 = 0$ (no cointegration). The rejected null implies that there exists a long-run relationship between the variables, and therefore, they move together in the long-run. However, since the results provide a clear indication of significant nexus and important long-run properties of the variables, we proceed to estimate the short- and long-run coefficients to determine the size and magnitude of the effects using equation (6).

4.4. Short and long run estimates

Next, the present study estimates the ECT-based ARDL model to test the effects of long-run civil wars on the environmental quality using the conceptual framework of the EKC, presented in equation (6). The results of the ECT-based ARDL model are reported in Table 4. Interestingly, the results indicate that the natural log of per capita real GDP (*lny*) has significantly positive effects on the *lnco2* emissions. It implies that an increase in per capita real GDP increases the carbon emissions by a log of 3.344 and 3.681 in the short- and long-runs, respectively, whereas the *lnco2* decreases by a unit decrease led by the squared per capita real GDP by 0.305 and 0.281 in the short- and long-runs, respectively. Therefore, it confirms the validity of the EKC hypothesis with a turning point of $699.120 in Afghanistan. However, the results must be used with serious caution in conflict zones such as Afghanistan. They demonstrate that, based on the size of the economy proxied by per capita real GDP, environmental quality deteriorates up to a certain limit—hence, the $699.12 turning point—and then it improves afterward—where the EKC emerges in the context of Afghanistan. Like most of recent studies, such as [7,9,91]; and [92]; who also verified the existence of the EKC hypothesis, our results are much similar to those of [15] for Asian economies, and [21] for low-income economies with a turning point of $652.47 in aggregate. Moreover, the results reveal that civil war, the key variable of interest, proxied by the per capita cost of war significantly impacts CO_2 emissions both in the short- and long-runs. It indicates that the natural log of per capita cost of war (*lncw*) increases the natural log of CO_2 emissions (*lnco2*) by 0.119 % and 1.091 % in the short- and long-runs, respectively. In a theoretical sense, the utilization of massive weapons and the continuity of military operations negatively affect environmental quality. Recent studies also show that war is a damaging factor to environmental quality [32]. Unlike most countries, Afghanistan is a country that has hosted more than four decades of war and has experienced almost all types of massive damage due to civil war. The findings are consistent with the fact that war degrades environmental quality, increasing CO_2 emissions both in the short- and long-run.

The natural log of the financial development index (*lnfd*) is found to have positive association with the *lnco2*. It implies that in the short- and long-runs, *lnfd* increases *lnco2* by 0.323 % and 0.277 %, respectively. The results are consistent with the findings of [93] in the context of Pakistan [94]; in the context of Iran [95]; in the context of Sub-Saharan African countries; and [19] in the context of South Asian countries, who also provided evidence of positive effects of financial development progressions on environmental degradation. The results are in contrast with those of [96,97]; who argued that financial development improves environmental quality in the contexts of the United Arab Emirates and Sub-Saharan African countries, respectively.

The results also indicate that the natural log of energy consumption (ln*en*) and trade openness (*lnto*) negatively impact *lnco2* in the short- and long-runs. This implies that an increase in *lnen* decreases the *lnco2* by 1.119 and 0.471 units in the short- and long-runs, respectively. The results are linked to the facts in Afghanistan, though they are in contrast with the findings of [29,98]; and [99]. Some recent studies, such as [21,100] demonstrate that energy consumption that encourage higher capital-intensive projects increase environmental degradation in low and middle-income economies. In both the short- and long-run, population growth (lnpop) is found to be a significant factor in increasing lnco2. The results indicate that *lnpop* increases *lnco2* by 0.104 % and 0.362 % in the short and long runs, respectively. The results correspond with the findings of [11,101]; who also found that the incremental effects of population growth on CO_2 emissions are undeniable. Furthermore, the inflation rate (*lninf*) is a significant factor in increasing *lnco2*. The results demonstrate that *lninf* increases *lnco2* by 0.023 % in the short-run and by 0.08 % in the long-run. The results are consistent with those of [75]; who also incorporated the inflation rate into the EKC model and found that the inflation rate negatively impacts environmental quality. Finally, the effects of trade openness are tested on the *lnco2*. The results show that increasing trade openness reduces *lnco2* levels in both the short- and long-runs, implying that increasing trade openness improves environmental quality in Afghanistan. The results are consistent with the findings of [27,102]; and [78]; who found that trade openness improves environmental quality, but in contrast with those of [103]. While the results are statistically robust and do not suffer from heteroskedasticity, serial correlation, or

Table 3
ARDL bound test results.

Model estimated	F-statistics	1 % CV		Robustness checks		
		1(0)	I(1)	ARCH	LM	RAMSEY
$\ln co_2 \vert \ln y, \ln y^2, \ln cw, \ln fd, \ln pop, \ln to, \ln en, \ln inf$	13.940***	2.62	3.77	0.961 [0.326]	3.689 [0.158]	0.040 [0.960]

Notes: *** indicates significance at 1 % level. [ ] indicates *p-values*.

Table 4
Short-run and long-run estimates.

Variables	Short-run effects			Long-run effects		
	Coefficients	t-statistics	*p-values*	Coefficients	t-statistics	*p-values*
Lny	3.344***	4.681	0.000	3.681***	3.656	0.000
lny2	−0.305*	−1.758	0.089	−0.281***	−3.855	0.000
lncw	0.119***	4.212	0.001	1.091***	3.312	0.000
lnfd	0.323**	2.278	0.027	0.277**	2.318	0.028
lnen	−1.192***	−7.383	0.000	−0.471***	−3.947	0.000
lnpop	0.104*	1.815	0.075	0.362**	2.018	0.049
lnto	−0.110*	−1.844	0.071	−0.384*	−1.959	0.089
lninf	0.023***	3.497	0.000	0.080**	2.623	0.011
Constant	−11.996***	−4.143	0.000			
ECT	−0.281***	−6.851	0.000			
Turning point $= \exp[-3.681/(2 \times 0.281)]$				$699.120		
Per capita real GDP 2020				$502.481		
EKC results				Inverted U-shaped		
Sensitivity checks						
Adjusted r-squared	0.968					
F-statistics	62.334***					
F-probability	0.000					
Durbin Watson	1.802					
Diagnostic checks						
Breusch-Pegan Godfrey	1.187	[0.101]				
Breusch Godfrey LM	2.689	[0.258]				
Jarque-Bera	0.611	[0.728]				
CUSUM	Stable					
CUSUMSQ	Stable					

Notes: ***, **, and * indicate significance at 1 %, 5 %, and 10 %, respectively. Values in [ ] present the *p-values*. CUSUM = Cumulative sum, CUSUMSQ = Cumulative sum of squares.

abnormal residuals' distribution issues, they verify the EKC hypothesis in Afghanistan. The turning point has been calculated using the long-run effects, which represent $699.120. For the stability of parameters, the study computes the cumulative sum (CUSUM) and cumulative sum of squares (CUSUMSQ) tests that are depicted in Fig. 2, showing that the estimated residuals are within 5 % critical bounds. The results imply that the estimated model and coefficients are stable.

4.5. *VECM granger causality analysis*

Finally, this article tests the Granger causality nexus between the *lnco2* and the augmented predictors using the VECM Granger causality approach (see, equation 7), which is appropriate for the case of this study. The results of the short-run and long-run causality are reported in Table 5. First, the results indicate a significant long-run causality link between *lnco2*, *lny*, *lny2*, *lncw*, *lnfd*, *lnen*, *lnpop*, *lnto*, and *lninf* at a 1 % level. Rejecting the null of $\vartheta_{12,\dots,nk} \neq 0 \forall i$ implies that all the predictors significantly Granger cause *lnco2*. Extending the analysis to the short-run causality links, the results indicate that *lny*, *lny2*, *lncw*, *lnfd*, and *lnpop* have significant bidirectional causality links with *lnco2*, while *lnen*, *lnto*, and *lninf* indicate only unidirectional causality with *lnco2*. The results also highlight some multidimensionality and interdependencies between the variables. For instance, there is a bidirectional causality between *lny*, *lny2*, and *lninf*, and *lnen* and *lnto* with *lnfd* in the short-run. The results are robust and consistent as reported by the diagnostic checks reported at the rear part of Table 5. Though contexts are different, the results are similar to those of [22,68,104]; and [75]; who also found causality nexus between the environmental quality and their predictors explaining the pollutant, macroeconomic, and energy predictors.

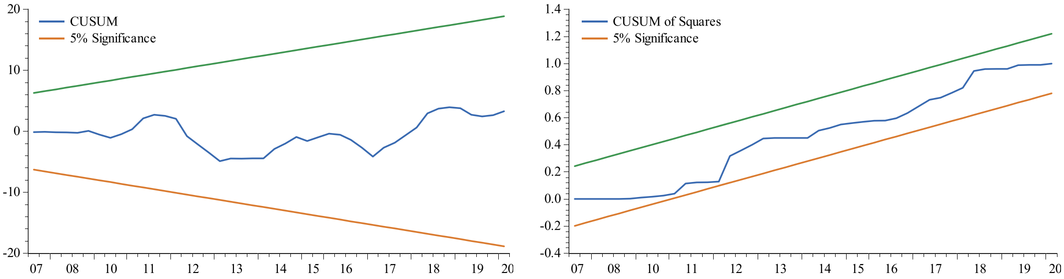

Fig. 2. CUSUM and CUSUMSQ results.
Source: Authors' estimations.

Table 5
Short and long run causality results.

Predictors	*t-stat.* long-run causality (*ECT_{t-1}*)	Wald statistics for short-run causality								
		$lnco_2$	lny	lny^2	lncw	lnfd	lnen	lnpop	lnto	lninf
$lnco_2$	−0.247***	–	3.128***	−0.238**	0.122***	0.298***	−1.010*	0.118**	−0.099**	0.104*
Lny	−0.623***	4.212***	–	1.023*	−0.723***	0.616***	0.019	−0.449	−0.026	−0.122
lny^2	−0.502***	−0.338***	0.881***	–	−0.028**	0.009*	−0.022	−0.016	−0.004	−0.013
Lncw	−0.618***	0.281***	−0.273**	−0.012*	–	0.437	0.288	1.019	0.721	0.491
Lnfd	−0.395***	0.845**	0.441***	0.016**	0.105	–	0.166***	0.367	0.273***	−0.111
Lnen	−0.426***	−0.126	0.087	0.008	0.174	0.449	–	0.244	0.093	0.404
Lnpop	−0.747***	0.377***	−0.184**	−0.028*	0.005	0.019	0.080	–	0.383	0.128
Lnto	−0.189***	−0.107	0.019*	−0.017	0.634	0.441	0.413	0.165	–	0.449
Lninf	−0.318***	0.225	−0.181***	−0.022***	0.115	−1.010	0.220	0.066	−0.301	–
Diagnostic checks										
Hetero-chi^2	715.24	[0.459]								
SC-LM	1.284	[0.193]								
NT-JB	1.270	[0.428]								

Notes: ***, **, and * indicate significance at 1 %, 5 %, and 10 %, respectively. SC-LM = Serial correlation Lagrange Multiplier test, NT-JB = Joint normality test of Jarque-Bera. Values in [ ] indicate *p-values*.

5. Analysis of results

Despite filling the existing gaps in the literature of war-environment nexus, the key findings of this study are worth further discussion. First, the results empirically support the significant effects of civil wars on environmental degradation—that is, civil wars increase CO_2 emissions both in the short and long runs. Intuitively, this implies that civil wars are not only environmentally destructive but also emit large amounts of carbon emissions and contribute to the depletion of resources. This includes the depleted uranium from warfare and oil from military vehicles have contaminated the water supply. The animal and bird populations in Afghanistan have also suffered from the deterioration of their natural resources and the drastic destruction of their forest cover [105]. Furthermore, the use of major agricultural lands as battlefields in most parts of the country significantly increased environmental degradation. Second, using the conceptual framework of the EKC, the results confirm the existence of an inverted U-shaped nexus between per capita real income and CO_2 emissions, thereby supporting the EKC hypothesis in Afghanistan. Third, the empirical findings support bidirectional causality relationships between CO_2 emissions, per capita real GDP, civil wars, the financial development index, energy consumption, trade openness, and the inflation rate. Fourth, the purview of findings also indicates multidimensionality and interdependencies among predictors. It is also worth comparing the results of this article with some leading recent studies in war-torn societies [33]. examined the EKC hypothesis in Myanmar, that is, a conflict zone, and found that the EKC hypothesis exists by identifying two different regimes. Although [106] did not capture the effects of armed conflicts on the environmental quality, they did confirm the existence of the EKC hypothesis in South Asian countries from 1972 to 2013 [34]. found significant effects of terrorism, energy consumption, economic growth, and foreign direct investments on environmental pollution in Afghanistan, Pakistan, Iraq, Syria, Nigeria, the Philippines, Yemen, and Thailand using panel analysis for data spanning from 1975 to 2017 and bidirectional long-run causality between their variables of concern [35]. also confirm the existence of the EKC hypothesis in South Asian economies, two of which, such as Pakistan and Afghanistan, were conflict zones. However, our findings are consistent with recent studies; they significantly add to the existing literature on the incremental effects of civil wars on environmental pollutants, providing robust results from a real-life example of the longest war-torn society, thereby, Afghanistan.

6. Conclusion

This article explored the effects of long-run civil wars on environmental degradation in Afghanistan, a country that is a war-torn society with the longest war history in the world. In doing so, this study uses the conceptual framework of the Environmental Kuznets Curve (EKC) hypothesis and econometric models augmented with civil wars, pollutants, financial development, and macroeconomic predictors on a set of data ranging from 2002Q1–2020Q1.

The primary results from unit root analysis indicate that all predictors follow a combination of I(0) and I(1) integration. The results of the autoregressive distributed lags (ARDL) bound test indicate that there is a long-run relationship between CO_2 emissions, civil wars, financial development, and macroeconomic indicators. Using the EKC framework and employing the ARDL model, the findings present interesting results. They indicate that civil wars (a key variable of interest), financial development index, per capita real GDP, population growth, and the inflation rate have positive effects on CO_2 emissions, whereas the squared per capita real GDP, energy consumption, and trade openness have negative effects on CO_2 emissions in the short- and long-run. Further, the results confirm an inverted U-shaped relationship in Afghanistan with a turning point of US$699.52. It supports the validity of the EKC hypothesis in the presence of civil wars. Finally, the results obtained from the vector error-correcting approach to Granger causality reveal that there exists bidirectional causality relationship between CO_2 emissions, per capita real GDP, civil wars, the financial development index, energy consumption, trade openness, and the inflation rate in the long-run. In the short run, the results indicate that there is multidimensionality and interdependencies among predictors.

6.1. Policy implications

The critical findings entail three key policy implications: First, the government needs to engage the international community in bridging the gaps in the process of peace negotiation with the insurgent groups. This will help to eradicate the civil wars or even minimize them to low levels, as they not only result in the loss of human capital, the loss of economic infrastructure, and an economic nosedive but also seriously harm the environmental quality. Second, inspired by the effects of energy consumption in the short and long runs and learning from the practical consumption of substitute materials for warming, public baths, and industrial production, the government needs to attempt to replace them with energy consumption by enhancing energy production capacity, while in the long run, energy consumption should also be controlled to reduce CO_2 emissions. Third, an overall consumption behavior campaign seems necessary to promote natural resource protection, appropriate consumption, and reduce the exploitation of pasturelands in Afghanistan.

6.2. Study limitations

This study suffers from two major limitations: First, the unavailability of higher observations for datasets relevant to the employed variables; more observations before 2000 could have provided better insights about the impact of long-term wars on environmental degradation. Second, the unavailability of data for national expenditures on war has forced us to use the cost of war spent by the US government. Future studies may overcome these issues as long as the required data are made available.

Data and materials

Datasets relevant to nominal GDP, GDP deflator, population growth, imports of goods and services, imports of goods and services, inflation rate, credit to the private sector, gross fixed capita formation, and liquid liabilities are collected from the World Development Indicators sources available at (https://databank.worldbank.org/source/world-development-indicators) and dataset relevant to cost of war is collected from the Department of Defense Budget of the United States available at (https://www.state.gov/countries-areas/afghanistan/).

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Mohammad Ajmal Hameed: Writing – original draft, Methodology, Formal analysis, Data curation, Conceptualization. **Mohammad Mafizur Rahman:** Writing – review & editing, Supervision. **Rasheda Khanam:** Writing – review & editing, Supervision.

Declaration of competing interest

The authors do not have any conflict of interest for declare.

Abbreviations

ARDL	Autoregressive distributed lags
ADF	Augmented Dickey and Fuller
AIC	Akaike information criterion
CUSUM	Cumulative sum
CUSUMSQ	Cumulative sum of squares
SIC: ECT	Error-correction term, Schwarz information criterion
HQIC	Hannan-Quinn information criterion
CO2	Carbon emissions
cw	Per capita cost of war
VECM	Vector error-correcting model
EKC	Environmental Kuznets Curve
GDP	Gross domestic product
en	Energy consumption
inf	Inflation rate
fd	Financial development index

pop	Population growth
to	Trade openness
PP	Phillips and Perron

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