Do geopolitical risk and energy consumption contribute to environmental degradation? Evidence from E7 countries

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Abstract

Environmental degradation is frequently cited as one of the eminent issues in the modern era. To limit environmental degradation, prior literature discerns several macroeconomic, socio-economic, and institutional factors that affect environmental degradation. However, the relationship between geopolitical risk and environmental degradation is understudied in the previous literature. To fill this gap, the inquiry at hand aims to scrutinize the influence of geopolitical risk on environmental degradation for E7 countries while controlling the effect of renewable energy, non-renewable energy, and GDP. Further, we utilize both the ecological footprint and CO₂ emissions as proxies of environmental degradation and employ second-generation panel methods for robust findings. In addition to this, the present study uses augmented mean group (AMG) estimator to provide long-run relationship among the selected variables. The findings from the AMG estimator expound that there exists environmental Kuznets curve (EKC) for E7 countries. Moreover, renewable energy ameliorates environmental quality because it plunges both ecological footprint and CO₂ emissions. On the contrary, non-renewable energy consumption escalates both ecological footprint and CO₂ emissions. Finally, geopolitical risk tends to decrease CO₂ emissions as well as ecological footprint. Our findings deduce a few policy implications to replenish environmental quality. For instance, the share of renewables in the energy mix should be surged to ameliorate the environmental quality. Further, to control both the geopolitical risk and environmental degradation at the same time, policymakers should put forward reforms and initiatives (e.g., policies to escalate R&D, technological innovations, and tax exemptions on imports of renewables) that can help to improve environmental quality without affecting geopolitical risk. At times of low geopolitical risk, environmental degradation will surge; therefore, the rate of environmental control taxes should be increased by the policymakers.

Keywords Ecological footprint · CO₂ emissions · Geopolitical risk · Renewable energy · Non-renewable energy · Augmented mean group estimator

Introduction

The growing number of state and regional instability, energy crisis, terrorist attacks, political crises, and other unfavorable events worldwide has aggravated the issue of geopolitical risk. Geopolitical risk (GPR) is referred to tensions linked with terrorism, wars, and unfriendly relations among countries (Adams et al. 2020) and is important to the economies susceptible to wars or war-like tensions, terrorism, ethnicity, conflict, and political violence. Furthermore, major geopolitical events such as 9/11, London bombing, Madrid bombing, Bombay attacks, China–USA trade war, Korea's nuclear issues, and Iranian trade tensions all pose a serious threat to the economic stability of a country (Cai and Wu 2020). Geopolitical risk can affect economic performance and investment decisions and trigger business cycles that

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impact natural resource rents and financial markets (Price-waterhouseCoopers 2018; Balcilar et al. 2018; Dogan et al. 2021). Unfavorable geopolitical events change the direction of investment spending towards less productive uses like reconstruction and security (Olanipekun and Alola 2020). Moreover, extreme geopolitical events will cause panic among investors and businesses that will create abnormal fluctuations in the market and eventually influence energy returns and volatility (Qin et al. 2020). Subsequently, GPR is considered as one of the top five business threats globally (Price Waterhouse Coopers 2018). Recently, Syed et al. (2021) highlight that geopolitical risk also exerts detrimental impacts on tourism.

Geopolitical events have a harmful consequence not only on social and economic life but also on the environment. Anser et al. (2021a) put forward two theoretical channels that link GPR and the environment. The first channel is called the “escalating effect” which describes that GPR mitigates renewable energy consumption (hereafter REC) which in turn leads to higher carbon emissions. Parallel to this, the “mitigating effect” expounds that GPR curtails non-renewable energy consumption (hereafter NREC) and economic growth leading to a reduction in CO₂ emissions. In another study, Anser et al. (2021b) pointed out that GPR affects economic growth, R&D investment, innovations, technological advancements, and investment in clean energy. These aforementioned indicators eventually escalate emissions. Therefore, GPR may either curb or surge carbon emissions.

Based on the above milieu, this research contributes to the existing empirical literature by exploring the impact of GPR, economic growth, NREC, and REC on environmental degradation. To attain this, firstly, we use the recently introduced GPR index developed by Caldara and Iacoviello (2018). Despite the significance of the prior studies and their results, the proxies of geopolitical events (e.g., terrorism/terrorist attacks, war or militarization, and political instability) have some limitations of not in real-time, being discontinuous, and not covering the real geopolitical events. Moreover, these proxies do not accurately describe GPR as they do not account for all events, ranging from economic crisis to wars to climate change (Bouoiyour et al. 2019). The GPR index captures the risk associated with terror attacks, military threats, war risk, political tensions, and geopolitical uncertainty. This index is superior to other indicators as it offers a time-consistent, holistic, and real-time approach to capture GPR. Moreover, the GPR index integrates both present and expected future risks (Muhammad and Long 2021).

Secondly, many countries aim to achieve the goal of energy security for the smooth functioning of their economies and easy access of their people to modern and clean energy supplies (Ayoo 2020). Economic, social, and human well-being depends on the production of goods which further depend on the availability of energy (Bompard et al.

2017). It is a well-established fact that economic growth and well-being are closely correlated (Warr and Ayers 2010). A plethora of energy challenges including high energy prices, uncertain energy supplies, environmental degradation, and inadequate supplies of energy sources are being faced by both developed and developing economies. Countries with high reliance on energy imports are vulnerable to risks and threats associated with energy supplies (Yergin 2006). E7 countries, with their ever-increasing energy demand due to population growth and robust economic expansion, heavily depend on energy imports to reduce poverty and to uplift the well-being of their people. Therefore, economic security which is strongly correlated with energy security remains a challenge for E7 countries.

Thirdly, the study focuses on E7 countries (Brazil, China, Indonesia, India, Mexico, Turkey, and Russia), which according to Earth System Science Data (ESSD) (2020) emit approximately 45% of global CO₂ emissions. Four of the world's highest CO₂ emitter countries (China, India, Russia, and Indonesia) are part of this group. A high level of growth and the consequent high energy consumption in these economies cause a substantial increase in CO₂ emissions. Moreover, these countries are strong political powers, and they have political tensions as well. According to Global Risks Report (2021), E7 countries are among the most critical countries based on their socio-economic and geopolitical conditions. For instance, being the second largest economy and most populated country in the world, China has been an important political economy that might affect the whole world. Moreover, the China–USA trade war has been one of the prime reasons behind the geopolitical tensions between these countries that have led to global tensions worldwide. Further, border tensions between China and India exert pressure on both countries which in turn affect the social and economic life of consumers and producers of both countries. Brazil has disputes with Uruguay and Colombia on smuggling and immigration. Moreover, unstable governments and impeachments contribute to geopolitical instability in the case of Brazil. As mentioned earlier, India has a long history of border tensions with its neighbors such as China and Pakistan. Also, the world has witnessed several wars between India and its neighbors which have created spikes in geopolitical tensions. Further, following the USA and UK, India is the third country with the highest number of cyber-attacks in the last two decades. Likewise, Mexico, Turkey, and Russia have been facing several issues with the USA and a few other countries. E7 economies have border tensions with their neighbors, and they also have (geo)political instability that contributes to economic uncertainty. It is worth mentioning that, according to the Global Risks Report (2021), COVID-19 has been exerting a detrimental impact on the economies of E7 countries which have experienced even negative economic growth during the COVID-19 pandemic.

Moreover, due to lockdowns and other stringency measures, the energy sector has also witnessed a negative supply shock that has led to the high vulnerability of the energy sector.

Fourthly, we employ a comprehensive measure of environmental degradation, i.e., ecological footprint (hereafter EF) along with CO₂ emissions to have more robust and insightful conclusions. Fifthly, we have disaggregated energy consumption by source, NREC, and REC, to see their separate role in escalating environmental degradation in anticipation of GPR. Finally, to overcome the problem of heterogeneity and cross-sectional dependency, the present study uses the second generation of panel data methods. In addition to this, we also employ CIPS unit root tests, Westerlund cointegration test, and augmented mean group (AMG) estimator to render robust and consistent estimates in the existence of cross-sectional dependence and heterogeneity (Baloch and Wang 2019).

Literature review

Environmental pollution has been the core of empirical as well as theoretical discussion for many years until now. (Dahish and Recep 2020).

Based on the GPR index presented by Caldara and Iacoviello (2018), the role of GPR on energy consumption and environmental degradation has been explored by a few studies in recent years. In the case of Russia, Rasoulinezhad et al. (2020) tested the relationship between energy transition and GPR from 1993 to 2018. They detected a positive influence of GPR, CO₂ emissions, financial openness, and exchange rate on energy transition, whereas the economic growth, inflation rate, and population growth negatively affect the energy transition. Moreover, the relationship between economic growth, energy transition, CO₂ emissions, inflation rate, and population growth is negative in the short run. On the contrary, financial openness, GPR, and exchange rate accelerate the energy transition. Their results further revealed that in the short run, GPR is the main contributor to the energy transition. Recently, Alsagr and Hemmen (2021) explored the dynamic impact of GPR and financial development on REC during 1996–2015 in 19 emerging economies. The results of GMM revealed a positively significant influence of financial development on energy consumption. Similarly, in the case of the USA, Sweidan (2021) concluded that GPR has a statistically significant and positive effect on energy diffusion. It implies that GPR drives energy rather than depressing it.

Adams et al. (2020) investigated the relationship between economic policy uncertainty and NREC for 10 resource-rich economies with a high level of GPR from 1996 to 2017 in the long run. The findings of Kao's test reveal a cointegration association among GPR, NREC, economic

policy uncertainty, economic growth, and CO₂ emissions. Moreover, the PMG-ARDL results show that uncertainty, economic growth, and NREC contribute to CO₂ emissions. This indicates that economic policy uncertainty has a detrimental impact on the environment. They found a significant relationship between uncertainty and emissions in the long run. Lastly, the results of the DH causality test show a one-way causal relationship running from CO₂ emissions to GPR and a two-way causal relationship among CO₂ emissions and NREC, economic growth and CO₂ emissions, and economic policy uncertainty and CO₂ emissions.

Likewise, Anser et al. (2021a) probe the effect of GPR on the EF in the case of BRMCC (Brazil, Russia, Mexico, China, Colombia) using AMG estimators. The study concludes that GPR mitigates environmental degradation. Zhao et al. (2021) examined the asymmetric impact of GPR on carbon emissions in the case of BRICS countries using the NARDL approach. The findings from the study reveal that the impact of GPR on carbon emissions is asymmetric, and it is heterogeneous across the BRICS countries. Anser et al. (2021b) estimated the impact of GPR, REC, NREC, economic growth, population, and economic growth on CO₂ emissions in BRICS countries. They employed the second-generation analysis and AMG estimator. The results indicate that GPR, GDP, population, and NREC escalate CO₂ emissions and REC reduces emissions in BRICS. It is worth mentioning that prior studies on the GPR–environment nexus either use CO₂ emissions or EF as a proxy for environmental degradation. Next, no study expounds on the renewable energy–environment and non-renewable energy–environment nexus amidst GPR. However, we employ both CO₂ emissions and EF as a proxy for the environment. Recently, Hashmi et al. (2021) use global emissions and GPR to explore the worldwide nexus between GPR and emissions. They note that GPR is a key determinants of global carbon emissions.

It is important to know that risk due to the COVID-19 pandemic has also affected both energy and the environment. For instance, Iqbal et al. (2021) revealed that the COVID-19 outbreak mitigates both NREC and carbon emissions. In the case of India, Aruga et al. (2020) conclude that lockdown amid the COVID-19 outbreak plunges NREC. Algamdi et al. (2021) find that the COVID-19 outbreak impedes oil prices. Additionally, Wang and Su (2020) reported that the COVID-19 outbreak decreases NREC and hence improved the environmental quality in China. In the case of India, Lokhandwala and Gautam (2020) conclude that the COVID-19 outbreak improved both air and water quality. So, it could be perceived that the risk associated with COVID-19 has a positive effect on energy security and environmental quality (Table 1).

Table 1 A summary review of recent studies

Study	Country	Time frame	Methodology	Variables, (geopolitical risk proxies) used	Conclusion
Zhao et al. (2021)	BRICS	1985–2019	Non-linear autoregressive distributed lag (NARDL)	CO ₂ emissions, NREC, GDP per capita, GPR index, and government stability index	GPR reduces CO ₂ emissions in South Africa and NREC in India in the short run. In the long run, GPR reduced NREC in South Africa, India, and Brazil and CO ₂ emissions in South Africa
Adams et al. (2020)	10 resource-rich countries (China, Brazil, Saudi Arabia, India, Turkey, Russia, South Africa, Ukraine, Israel, and Venezuela)	1996–2017	PMG-ARDL	CO ₂ emissions, real GDP, NREC, GPR, economic policy uncertainty	CO ₂ emission → GPR, CO ₂ emission ↔ NREC, CO ₂ emission ↔ economic policy uncertainty
Rasoulinezhad et al. (2020)	Russia	1993–2018	ARDL method	CO ₂ emissions, GPR, economic growth, population growth, energy transition, financial openness, exchange rate	The negative impact of population, inflation, and economic growth on energy transition found The positive impact of GPR, CO ₂ emissions, financial openness, and exchange rate on energy transition was detected
Anser et al. (2021b)	BRICS	1995–2015	Augmented mean group	GPR, per capita GDP, NREC, REC, population growth, CO ₂ emissions	GPR, population, and NREC escalate CO ₂ emissions REC impedes CO ₂ emissions
Bildirici (2020)	China, India, Israel, and Turkey	1975–2017	Pedroni cointegration test, DH causality test	Terrorism (GPR proxy), NREC, economic growth, FDI inflow, and CO ₂ emissions	Terrorism → FDI, energy use → CO ₂ emissions, GDP ↔ CO ₂ emissions, GDP ↔ FDI, energy use ↔ CO ₂ emissions
(Bildirici and Gokmenoglu, (2020)	Afghanistan, Philippines, Iraq, Pakistan, Nigeria, Syria, Thailand, Somalia, and Yemen	1975–2017	Panel cointegration test, ANOVA test, panel trivariate test	CO ₂ emissions, terrorism (GPR proxy), FDI, NREC, GDP	FDI → CO ₂ emissions, terrorism ↔ CO ₂ emissions, FDI ↔ CO ₂ emissions
Sarkodie and Adams (2018)	South Africa	1971–2017	Structural break cumulative sum (CUSUM), OLS, ARDL	Political institutional quality (GPR proxy), NREC, GDP, urban population, REC, fossil fuel energy, nuclear electricity net generation	Political and institutional stability mitigate emissions
(Bildirici (2017a)	G7 countries	1985–2015	Panel ARDL, panel trivariate causality test	NREC, defense expenditure (a measure of militarization and proxy of GPR), CO ₂ emissions, per capita GDP	Militarization → CO ₂ emissions, NREC → CO ₂ emissions, NREC ↔ militarization, GDP ↔ militarization, GDP ↔ NREC
Bildirici (2017b)	USA	1960–2013	MWALD, Rao's F test	Militarization (GPR proxy), CO ₂ emissions, NREC, GDP	Militarization → CO ₂ emissions, NREC → CO ₂ emissions, militarization → NREC
Bildirici (2017c)	USA	1984–2015	ARDL, dynamic OLS, FMOLS, cointegration regression, MWALD, and Rao's F test	Defense expenditure (a measure of militarization and GPR proxy), biofuel consumption, CO ₂ emissions, per capita GDP	Militarization ↔ biofuel consumption, CO ₂ emissions ↔ biofuel consumption, biofuel consumption ↔ GDP

Table 1 (continued)

Study	Country	Time frame	Methodology	Variables, (geopolitical risk proxies) used	Conclusion
Abid (2016)	25 sub-Saharan African economies (SSA)	1996–2010	GMM dynamic panel method	CO ₂ emissions, per capita GDP, political stability (GPR proxy), corruption, trade openness, democracy, regulatory quality, rule of law, government effectiveness, domestic credit	The negative impact of political stability, government effectiveness, control of corruption, and democracy on CO ₂ emissions found

Model and methods

In the literature of environmental economics, several empirical models have been developed to link the environment with the economy. It is worth noting that the EKC hypothesis has been regarded as the most critical theory of environmental economics that has been extensively tested in empirical studies. The EKC is an inverted U-shaped relationship between environment and income, and, in this analysis, we extend the EKC framework by including GPR and energy consumption:

$$CO_2 = f(GDP, GDP^2, NREC, REC, GPRI) \quad (1)$$

$$EF = f(GDP, GDP^2, NREC, REC, GPRI) \quad (2)$$

In Eqs. (1) and (2), GDP and GDP² denote real GDP per capita and square of real GDP per capita, respectively. NREC and REC represent non-renewable energy consumption and renewable energy consumption, respectively. Further, GPRI is the geopolitical risk index. CO₂ is carbon dioxide emissions, whereas EF is the ecological footprint. These aforementioned variables (CO₂ and EF) are employed as an environmental degradation proxy. It is hypothesized that the magnitude of the coefficient of GDP and GDP² is > 0 and < 0, respectively. This means that EKC does exist, implying that, at the initial stages of economic growth, environmental degradation also increases and decreases as economic growth exceeds a certain point. Several recent studies use the EKC framework to explore the determinants of environmental degradation (see, for example, Destek and Sarkodie 2019; Syed and Bouri 2021; Haider et al. 2020). In addition to this, we further hypothesized that the coefficient of NREC and REC is > 0 and < 0, respectively. This indicates that non-renewable energy escalates environmental degradation, while renewable energy impedes it (see, for example, Anser et al. 2021c; Bhowmik et al. 2021; Ali et al. 2020; Gardiner and Hajek 2020). Next, it is hypothesized that the coefficient of GPRI is < 0, depicting that GPR plunges the environmental degradation (see, for example, Adams et al. 2020). It is stated that this outcome is possible if the mitigating effect exceeds escalating effect.

The present study utilizes an annual panel dataset for E7 economies (Brazil, China, India, Indonesia, Mexico, Russia, and Turkey) over the period 1990–2015. The dependent variables are CO₂ emissions (measured in metric tons per capita) and ecological footprint (measured in Gha per person). On the other hand, independent variables are real GDP per capita (GDP), NREC, REC, and GPR index (GPRI). GPRI is established by Caldara and Iacoviello (2018), which is calculated based on the frequency of the newspaper articles containing the words, for example, “geopolitics,” “geopolitical risk,” and “geopolitical

Table.2 Descriptive statistics

	<i>EF</i>	<i>CO2</i>	<i>GDP</i>	<i>NREC</i>	<i>REC</i>	<i>GPRI</i>
Mean	6.381	1.655	13.221	10.282	2.012	7.991
St. Dev	0.435	0.311	0.272	0.224	0.192	0.101
Kurtosis	2.113	1.983	1.873	2.322	2.465	3.284
Skewness	−0.100	−0.091	−0.171	−0.212	−0.161	0.132
Jarque–Bera	(0.001)***	(0.004)***	(0.002)***	(0.002)***	(0.004)***	(0.003)***

Table.3 Cross-sectional dependence test

	Breusch–Pagan LM	Pesaran scaled LM	Pesaran CD
$CO_2 = f(GDP, REC, NREC, GPRI)$	(17.010) [0.001]***	(12.052) [0.001]***	(4.170) [0.002]***
$EF = f(GDP, REC, NREC, GPRI)$	(15.311) [0.001]***	(17.513) [0.001]***	(5.752) [0.002]***

(.) indicates *t* statistics, whereas [.] shows *P* values. *, **, and *** represent 10%, 5%, and 1% levels of significance, respectively.

tension. The summary of data is given in Table 10 in the Appendix. In addition, we employ several cross-sectional dependence tests, second-generation unit root tests, second-generation cointegration tests, and augmented mean group (AMG) estimator for robust analysis.

Table 2 exhibits the descriptive statistics of study variables. The mean value of GDP is the highest, whereas it is the lowest for CO_2 emissions. Also, the standard deviation is the highest for EF, while it is the minimum for GPRI. Moreover, GPRI is positively skewed, while all other variables are negatively skewed. In addition to this, Jarque–Bera test statistics highlight that the selected dataset follows the non-normal distribution.

All variables are transformed into logarithmic form. (.) denotes *P* value. Further, ***, **, and * represent 1%, 5%, and 10% levels of significance, respectively.

Results and discussion

Results

To achieve its objective (i.e., probing the impact of GPR, NRE, and REN on the environment), in this section, the current study reports the results from second-generation panel data methods and AMG estimators coupled with the panel causality test. First, we report the results of the Breusch–Pagan LM test, the Pesaran LM test, and the Pesaran CD test in Table 3.

Table.4 Findings from CIPS test

Variable	CIPS test		CADF test	
	<i>I</i> (0)	<i>I</i> (1)	<i>I</i> (0)	<i>I</i> (1)
<i>CO2</i>	−1.010	−2.881***	−2.131	−3.325***
<i>EF</i>	−2.132	−3.635***	−1.932	−3.783***
<i>GDP</i>	−0.791	−2.712***	−2.071	−2.646***
<i>NREC</i>	−1.563	−2.609***	−2.484	−4.182***
<i>REC</i>	−0.931	−2.985***	−1.462	−3.368***
<i>GPRI</i>	−2.327	−3.821***	−1.396	−2.591***

The critical value of CIPS at 1% is −2.51, whereas the critical value of CADF at 1% is −2.57.

Table.5 Results from Westerlund test

$CO_2 = f(GDP, GDP^2, REC, NREC, GPRI)$				
Statistic	Value	Z value	<i>P</i> value	Bootstrap <i>P</i> value
G_t	−3.321	−3.092	0.002***	0.002***
G_a	−4.252	−5.363	0.001***	0.001***
P_t	−5.471	−6.331	0.011***	0.001***
P_a	−4.124	−4.933	0.001***	0.001***
$EF = f(GDP, GDP^2, REC, NREC, GPRI)$				
Statistic	Value	Z value	<i>P</i> value	Bootstrap <i>P</i> value
G_t	−3.132	−3.591	0.002***	0.002***
G_a	−4.411	−5.357	0.001***	0.001***
P_t	−5.142	−6.423	0.011***	0.001***
P_a	−3.513	−3.832	0.003***	0.003***

Null hypothesis of the Westerlund test indicates that there is no cointegration among the variables. In addition, ***, **, and * report 1%, 5%, and 10% levels of significance, respectively.

The null hypothesis of all CD tests describes that there is no cross-sectional dependence (CD). The findings from CD tests reveal that at 1% level of significant, null hypothesis could be rejected, indicating that there exists CD in our case. This implies that shocks in one country can transmit to another country. Next, we test unit root in all selected variables to identify the order of integration. The results from the CIPS unit root test of Pesaran (2007) are given in Table 4.

We fail to reject the null hypothesis of “there is no unit root at *I* (0).” However, at a 1% level of significance, we could reject the null hypothesis at *I* (1). This specifies that

Table.6 Long-run estimates from AMG estimator

Variable	CO ₂ emissions			
	Coefficient	St. error	Z stat	P value
<i>GDP</i>	0.211	0.220	2.669	(0.003)***
<i>GDP2</i>	−0.060	0.122	−3.213	(0.002)***
<i>NREC</i>	0.171	0.330	2.851	(0.003)***
<i>REC</i>	−0.094	0.121	−3.202	(0.002)***
<i>GPR</i>	−0.082	0.212	−2.694	(0.002)***
<i>Constant</i>	0.011	0.121	0.091	(0.921)
RMSE (sigma)	0.0171			
Wald test	(0.001)***			

*** represents the level of significance at 1%. (.) denotes *P* value.

all selected variables are integrated of order 1. In Table 5, the results of the Westerlund (2007) test of cointegration are shown. The test consists of four different test statistics, and the null hypothesis of all these statistics postulates that cointegration does not exist.

We employ ecological footprint (EF) and carbon dioxide emissions (CO₂) as a proxy for environmental degradation, hence applying Westerlund (2007) test two times. We do not fail to reject the null hypothesis, which indicates that there is no cointegration among the selected variables. Hence, we can conclude that there is an existence of cointegration among the selected variables used in the model.

Further, Westerlund (2007) test does not render long-run estimates (elasticities); therefore, we apply the AMG estimator to avail long-run estimates. The findings of the AMG estimator using CO₂ emissions as environmental degradation's proxy are reported in Table 6.

In Table 6, all reported variables are statistically significant. Further, the sign of GDP and GDP² is positive and negative, respectively. Therefore, we note the validity of EKC for E7 countries. This outcome is in line with the conclusion of Anser et al. (2021b). Next, the value of NREC is 0.17, indicating that a 0.17% upsurge in carbon emissions is fostered by a 1% raise in NREC. Therefore, we conclude that NREC escalates emissions. This finding conforms with the results reached by Gardiner and Hajek (2020). Additionally, the value of REC is −0.09, implying that a 1% rise in REC plunges CO₂ emissions by 0.09%. This means that REC reduces CO₂ emissions in E7 countries (Alola et al. 2019). The coefficient of GPRI is −0.08, indicating that a 0.08% decrease in CO₂ emissions is fostered by a 1% surge in GPRI. There are a few possible reasons behind the negative impact of GPRI on CO₂ emissions. First, high GPRI may discourage consumption and production, which sequentially impedes CO₂ emissions. Second, GPRI could affect energy prices, international trade, and tourism activities. These factors may constraint CO₂ emissions. Our findings are also

Table.7 Results from AMG estimator

Variable	Coefficient	Ecological footprint		
		St. error	Z stat	P value
<i>GDP</i>	0.171	0.243	4.581	(0.001)***
<i>GDP2</i>	−0.050	0.136	−3.553	(0.002)***
<i>NREC</i>	0.131	0.221	4.512	(0.001)***
<i>REC</i>	−0.024	0.143	−3.612	(0.002)***
<i>GPRI</i>	−0.107	0.127	−3.001	(0.002)***
<i>Constant</i>	−0.11	7.501	0.852	(0.394)
RMSE (sigma)	0.0271			
Wald test	(0.002)***			

*** represents the level of significance at 1%

backed by the study of Adams et al. (2020) and Anser et al. (2021a) who noted that GPR impedes environmental degradation. However, our findings are inconsistent with the conclusion of Anser et al. (2021b) who reported that GPR leads to higher carbon emissions.

Likewise, we use EF as a proxy for environmental degradation and scrutinize the impact of *REC*, *NREC*, and *GPRI* employing an AMG estimator. The estimates are reported in Table 7.

Table 7 depicts that all coefficients are statistically significant. Next, the GDP and GDP² coefficients are positive and negative, respectively. Thus, we validate the presence of EKC which is an inverse U-shaped relationship between income and environment. This outcome is supported by the conclusion of Destek et al. (2018). Additionally, the value of NREC is 0.13, explaining that a 1% rise in NREC surges EF by 0.13%. This conclusion is in line with the conclusion reached by Destek and Sinha (2020). On the contrary, the coefficient of REC is −0.02 implying that a 0.02% decrease in EF is fostered by a 1% increase in REC. Additionally, the value of GPRI is −0.10 inferring that a 1% upsurge in GPR impedes EF by 0.10%. As mentioned earlier, a decrease in production and consumption activities due to high GPR could be the possible reason behind low levels of EF. This result is supported by Adams et al. (2020) who argue that GPR plunges environmental degradation.

Finally, we employ the DH causality test to examine the direction of causality. The findings of the DH test are reported in Tables 8–9.

As can be seen from Table 8, there exists one-way causality running from GDP to carbon emissions. Next, one-way causality is also running from GPRI to CO₂ emissions. Likewise, one-way causality is running from CO₂ emissions to NREC, from GDP to NREC, from REC to GDP, from REC to GPRI, and from NREC energy to REC.

According to Table 9, there exists unidirectional causality running from NREC to GDP, from REC to GDP, from NREC to GPRI, from GPRI to EF, from NREC to EF, and

Table.8 Findings from DH causality test using CO₂ emissions as a proxy for environment

Null hypothesis	W stat	Zbar stat	Prob
GDP = > CO ₂	2.48881	2.02459	0.0429**
CO ₂ = > GDP	0.56538	−0.77937	0.4358
GPRI = > CO ₂	6.02583	7.18082	7.E-13***
CO ₂ = > GPRI	0.90403	−0.28568	0.7751
NREC = > CO ₂	1.31691	0.31621	0.7518
CO ₂ = > NREC	5.87251	6.95731	3.E-12***
REC = > CO ₂	2.04930	1.38387	0.1664
CO ₂ = > REC	2.04357	1.37553	0.1690
GPRI = > GDP	0.76339	−0.49071	0.6236
GDP = > GPRI	2.05134	1.38685	0.1655
NREC = > GDP	4.58700	5.08331	4.E-07***
GDP = > NREC	1.84262	1.08259	0.2790
REC = > GDP	3.50567	3.50696	0.0005***
GDP = > REC	1.54096	0.64282	0.5203
NREC = > GPRI	1.83005	1.06425	0.2872
GPRI = > NREC	1.69667	0.86983	0.3844
REC = > GPRI	3.30901	3.22027	0.0013***
GPRI = > REC	0.33797	−1.11088	0.2666
REC = > NREC	2.03659	1.36535	0.1721
NREC = > REC	5.04578	5.75211	9.E-09***

from REC to EF. Moreover, there exists bi-directional causality between EF and GDP, REC and GPRI, and between REC and NREC.

Discussion

We first scrutinize the CD in the selected set of panel data, since it is essential for reliable results. The outcomes from these approaches confirm the null hypothesis rejection at a 1% significance level; therefore, variables endure CD. That means EF, CO₂, GDP, NREC, REC, and GPRI shocks in one country are also correlated with other countries. In this way, due to interdependency between countries, economic shocks have spillover effects via trade channels (Bello et al. 2018). It has been observed that a shock in one of the E7 countries will transmit to other countries. For instance, the COVID-19 pandemic (i.e., originated from China) has been spread to other countries. This result is consistent with the findings of Dogan and Seker (2016) who report similar findings for top renewable energy-consuming countries; Sharif et al. (2019) for 74 nations; Destek and Sinha (2020) for 24 OECD economies; Danish et al. (2020) for BRICS countries; Nathaniel and Khan (2020) for ASEAN countries; Le and Bao (2020) for Latin America, the Caribbean emerging markets, and developing economies; Inglesi-Lotz and Dogan (2018) for Sub-Saharan Africa; Hacıııımoğlu and Sandalcılar (2020) for

35 developed and developing countries; and Sharma et al. (2021) for eight developing economies of Asia.

The Westerlund (2007) cointegration test illustrates that all variables in the current study are cointegrated (which proposes that there is an effective long-term connection among EF, CO₂, GDP, NREC, REC, GPRI in E7 countries). The findings are in line with the results of Sharma et al. (2021) for eight developing countries of Asia, Sharif et al. (2019) for 74 nations, Le and Bao (2020) for 16 developing economies, Shafiei and Salim (2014) for OECD economies, and Zafar et al. (2019) for emerging economies. The long-run estimates from AMG show that NREC significantly promotes environmental degradation in E7 countries. The use of NREC exerts pressure on natural resources exploitations, and NREC emits higher carbon gas. As a result, environmental degradation occurs at a higher pace. The use of NREC still dominates in E7 countries; therefore, environmental degradation has been increasing over time. The results expound that a 1% raise in NREC fostered the emissions by 17%. In the empirical literature, there is a predictable consent on the adverse environmental effect of NREC based on fossil fuel. Some respective studies including Gorus and Aydin (2019) for MENA countries; Nathaniel and Khan (2020), Tuna and Tuna (2019), and Hanif et al. (2019) for ASEAN countries; Sinha et al. (2017) and Sinha et al. (2019) for N-11 economies; Sharif et al. (2019) for 74 nations; Zhang et al. (2019) for BRICS countries; Nathaniel and Iheonu (2019) for sub-Saharan Africa; and Shahbaz et al. (2019) for Vietnam are similar to our findings. On the other hand, results depict that REC contributes significantly to environmental improvements in E7 countries. That is, a 1% rise in REC tends to reduce CO₂ emissions by 9%. Renewables in the form of wind energy, hydropower energy, and solar energy, etc. do not emit greenhouse gases (e.g., CO₂). Further, renewables do not exploit and deplete the natural resources and hence environmental degradation plunges. Since E7 countries are among the top countries that are shifting from NREC to REC, hence, they are at the right part by escalating the REC to achieve sustainable development. These findings are parallel with the conclusions attained by Al-Mulali and Ozturk (2015) for 23 selected European countries, Nathaniel and Khan (2020) for ASEAN countries, Sharif et al. (2019) for 74 nations, and Dogan and Aslan (2017) for EU countries. In contrast, our findings are inconsistent with the conclusions of Mehdi and Slim (2017) who report findings opposite to our conclusion for North African countries.

Furthermore, the results also indicate that a 1% hike in GPRI tends to reduce CO₂ emissions by 8%. GPRI adversely affects NREC and economic growth, which results in a decline in CO₂ emissions. Also, GPRI affects economies through international trade, equity market, production and consumption, energy prices, military tensions, and war and terrorism. Further, GPRI is the main determinant of

investment decisions and can alter financial and economic businesses because countries with secure political and social conditions witness a high level of investment. The change in investment decisions (due to GPRI) could be the reason behind the decline in the levels of CO₂ emissions. It is worth reporting that the mitigating effect dominates the escalating effect in E7 countries, depicting that the net impact of GPR on the environment is negative. Although E7 countries have become the hub of GPR nowadays and they are being economically affected by GPR, GPR does not affect the environmental degradation in these countries. Our findings are compatible with Akadiri et al. (2020) Turkey, Kannadhasan and Das (2020) Asian emerging stock market, Balcilar et al. (2018) BRICS countries, Al Mamun et al. (2020) USA, Das et al. (2019) Asian emerging stock market, and Cheng and Chiu (2018) for 38 emerging countries.

AMG estimator indicates that a 1% rise in NREC will escalate EF by 13%, whereas a 1% rise in REC will lessen the EF by 2%. This argument is compatible with the conclusions reached by Destek and Sinha (2020) in the case of 24 OECD nations and Sharif et al. (2020) for Turkey. The impact of REC is significant and negative on the EF. This describes the clean role of REC in depleting the EF. The findings also expound that E7 economies are on the right track towards achieving the goal of development through the incorporation and progression of environmentally friendly advances. This is equivalent to the conclusion of Danish et al. (2020) for BRICS economies, Destek and Sinha (2020) for 24 OECD nations, Wang and Dong (2019) for 14 SSA countries, and Destek et al. (2018) for EU economies. A 1% rise in GPRI hinders EF by 10%. As mentioned above, it is because of a decrease in production and consumption activities due to high GPRI. Also, GPRI creates uncertainty, which drives firms to put their tentative plans on hold and decrease current production to their limited capacity in anticipation to lower consumption. As GPRI has become the main indicator in economic and business cycles, significant players of economic activities including bankers, industrialists, and market traders accept that GPRI changes the element of the capital market and impedes the dynamics of investment (Caldara and Iacoviello 2018). Moreover, due to the negative and positive signs of GDP and GDP², the current study validates the EKC for E7 countries. The other studies that confirm the existence of EKC include Al-Mulali and Ozturk (2016) for 27 advanced economies, Bilgili et al. (2016) for OECD nations, and Bölük and Mert (2015) for Turkey. In contrast, Al-Mulali and Ozturk (2015) in the case of 23 European economies do not support the presence of EKC.

The findings from the DH causality test highlight that there exists one-way causality running from GPRI to EF and from GPRI to CO₂ emissions. This implies that GPR affects environmental degradation, but environmental degradation

does not affect GPR in the selected countries. That is, environmental degradation is not one of the reasons behind geopolitical tensions, but GPR alters environmental degradation. Next, there exists one-way causality running from NREC to economic growth, indicating that non-renewables contribute to economic growth. However, economic growth does not affect NREC. Thus, the current study validates the growth hypothesis. Likewise, regarding the nexus between REC and economic growth, we also find the existence of a growth hypothesis. Hence, it could be concluded that E7 countries depend on energy consumption, and any action to conserve energy will affect economic growth.

Conclusion

The threat due to global warming and environmental degradation calls for investigating the socio-economic factors that drive these critical issues (i.e., global warming and environmental degradation). In the prior literature, economic growth and NREC have widely been probed as drivers of environmental degradation; however, there is a dearth of literature on the geopolitical risk–environment nexus. In addition, the limited literature on geopolitical risk–environment nexus has a contrasting conclusion that calls for further exploration of this line of research. Hence, this study probes the impact of GPR on environmental degradation, controlling the effects of economic growth, NREC, and REC in the case of E7 countries. This study contributes to the existing literature by using carbon emissions and EF as proxies for the environment in the case of E7 countries that provide robust findings. In addition, this study employs several second-generation panel data methods, AMG estimators, and DH causality tests for robust and reliable findings.

The empirical evidence shows that the data set has cross-sectional dependence revealing spillover effects of macroeconomic shocks occurring in any of the countries. All variables are cointegrated which suggests that there exists an effective long-term connection among all the considered variables in the case of E7 countries. The long-run empirical estimates from AMG estimator show that there is a significant impact of NREC on environmental degradation; however, REC contributes to environmental improvements. This provides a solid argument that escalating REC helps decrease CO₂ emissions. Secondly, results also depict that if GPR increases, it will reduce CO₂ emissions. On the contrary, using EF as a proxy for environmental degradation, we report that NREC escalates EF and REC lessens the EF. Furthermore, results also depict that rise in GPR will tend to impede EF. The present study also confirms the presence of EKC for E7 countries. Findings from the causality test imply that GPR affects environmental degradation, but environmental degradation does not lead to geopolitical risk.

Table.9 Findings from DH causality test using EF emissions as a proxy for environment

Null hypothesis	Obs	F statistic	Prob
GPRI = > GDP	150	0.75714	0.3856
GDP = > GPRI	0.11763	0.7321	
NREC = > GDP	150	13.8135	0.0003***
GDP = > NREC	0.73266	0.3934	
REC = > GDP	150	10.6580	0.0014***
GDP = > REC	1.24775	0.2658	
EF = > GDP	150	13.3061	0.0004***
GDP = > EF	38.2782	6.E-09***	
NREC = > GPRI	150	4.18941	0.0425**
GPRI = > NREC	1.28351	0.2591	
REC = > GPRI	150	4.99227	0.0270**
GPRI = > REC	3.14574	0.0782*	
EF = > GPRI	150	0.00237	0.9613
GPRI = > EF	25.6840	1.E-06***	
REC = > NREC	150	4.37775	0.0381**
NREC = > REC	5.01726	0.0266**	
EF = > NREC	150	0.04967	0.8240
NREC = > EF	28.1238	4.E-07***	
EF = > REC	150	1.51391	0.2205
REC = > EF	33.3736	4.E-08***	

Moreover, we report the validity of the growth hypothesis (in the case of both renewable and non-renewable energy consumption) which is one-way causality running from NREC to economic growth.

The results suggest that to guarantee sustainable growth, E7 countries should invest in clean energies since global warming is becoming a more serious problem worldwide. Next, investment in REC is more proficient to limit CO₂ emissions. Different sectors must be urged to adopt innovation that limits contaminations, and it will also help them to lessen their dependency on energy as well as to stimulate the energy security of countries that import energy. Furthermore, governments should provide subsidies on the import of renewable energy productions, as they ameliorate the environmental quality. There should be special research grants for renewable energy development. On the contrary, the government should impose high trade barriers on the import of non-renewable energy. Also, programs and schemes should be initiated to make people aware of the adverse effects of non-renewable energy use. Moreover, E7 countries are on the right track, as the findings from the EKC hypothesis suggest that high real income (above a threshold) leads to improved environmental quality. Further, we report that if governments try to reduce GPR, environmental degradation increases. Therefore, policymakers should keep in mind the environmental impacts of reducing GPR. In addition to this, if policymakers aim to reduce GPR

and environmental degradation simultaneously, they should explore the other factors (e.g., renewables) that impede environmental degradation without affecting GPR. Moreover, policymakers should devise policies to encourage R&D investment, technological advancement, and green energy investment because these factors might curb environmental degradation without causing a surge in GPR. Additionally, at the time of low GPR, government officials and/or policymakers should divert their attention towards environmental degradation because low GPR leads to higher energy consumption and economic growth, which in turn deteriorate the environment. Apart from this, keeping in view the inverse relationship between GPR and the environment, higher environmental taxes should be imposed at times of high GPR and vice versa.

Regarding the limitations of this study, we analyze the emerging countries; so, this study does not propose any policy suggestions for developed countries. Next, the present study does not explain the country-wise findings on the relationship between GPRI and the environment. Regarding future research directions, researchers can explore the nexus between GPR and the environment in the case of developed countries. In terms of methodology, the non-linear or asymmetric impact of GPR on the environment could be examined. The direct and indirect impact of GPR on the environment can also be probed. Furthermore, structured machine learning panel data regression models can be used for future prediction to test the hypothesis related to GPR, carbon emissions, and environmental degradation.

Appendix

Table 10

Author contribution Iftikhar ul Husnain: supervision.

Qasim Raza Syed: conceptualization and data analysis.

Arooj Bashir: drafting.

M. A. Khan: drafting.

Data availability Available upon request.

Declarations

Ethics approval Not applicable.

Consent to participate Not applicable.

Consent for publication Not applicable.

Conflict of interest The authors declare no competing interests.

Table.10 Variables with their measures and sources

Abbreviation	Indicator name	Measurement scale	Source
<i>EF</i>	Ecological footprint	Gha per person	GFN
<i>CO₂</i>	CO ₂ emissions	Metric ton per capita	WDI
<i>GDP</i>	GDP per capita	Constant 2010 \$US	WDI
<i>NREC</i>	Non-renewable energy consumption	Oil equivalent per capita	WDI
<i>REC</i>	Renewable energy consumption	Percentage of total final energy	WDI
<i>GPRI</i>	Geopolitical risk index	Frequency of newspaper articles containing “geopolitics”-related words	Polic-yuncertainty.com

GFN, Global Footprint Network; WDI, World Development Indicators.

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