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Revisiting the impact of energy consumption, foreign direct investment, and geopolitical risk on CO_2 emissions: Comparing developed and developing countries

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A growing body of literature probes the impact of geopolitical risk (GPR) on CO_2 emissions. However, no study compares the findings in the case of developed and developing countries. Hence, this study aims to probe the impact of GPR on CO_2 emissions for selected developed and developing countries while controlling for energy consumption, foreign direct investment, and economic growth. For this purpose, we make use of a panel dataset covering the period 1990–2020. In the long-run, we report that the Environmental Kuznets Curve hypothesis exists for developing countries. Next, the pollution haven hypothesis is validated for the developed countries in the long-run. Also, GPR escalates emissions for developed and developing countries in the long-run. In the short-run, the Environmental Kuznets Curve and pollution haven hypothesis are found invalid. Moreover, in the short-run, GPR impedes emissions in both developed and developing countries. Further, energy consumption upsurges emissions across all samples (i.e., either developed or developing countries) in either its short- or long-run. The heterogeneous findings across the long- and short-run, for developed and developing countries, propose to formulate unalike policies for countries with different levels of income.

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Abbreviations: LR, long–run; SR, short–run; EMS, CO_2 emissions; ECG, economic growth (GDP); ENC, energy consumption; FDIN, foreign direct investment; GPR, geopolitical risk; EKC, environment Kuznets curve; PMG–ARDL, pooled men group–autoregressive distributed lags; CRD, cross–sectional dependence.

KEYWORDS

energy consumption, geopolitical risk, foreign direct investment, environmental kuznets curve, pollution haven hypothesis

1 Introduction

Environmental degradation has witnessed an unprecedented upsurge, especially after the recent episodes of the industrial revolution. Extreme weather events, a hike in average global temperature, and climate change are the key concerns that are triggered by environmental degradation. Moreover, environmental deterioration affects the decisions of economic agents related to buying and selling of goods and services (Hashmi et al., 2022). Not only this, environmental degradation triggers various human diseases. Thus, it is an unavoidable global issue, which needs to be addressed.

The researchers/scientists claim that carbon dioxide emission (henceforth EMS) is a key component of greenhouse gases, which mainly deteriorate the environment (Mirza et al., 2022). Global emissions have been escalating over the years, especially after the 1950's. This unparalleled hike in emissions has been a concern for the entire world. To curb emissions, several global efforts have been made such as Paris Agreement and COP26. However, the volume of carbon emissions is yet considerably high, calling for research-based endeavors to discern the factors that affect carbon emissions.

Hence, the literature on environmental economics attempts to seek the impact factors of EMS. The prior literature highlights that economic growth (ECG) enhances the EMS (Saboori et al., 2012). Thereafter, energy consumption (ENC) mainly leads to ECG (Ray, 2021a, Ray, 2021b) at the cost of EMS (Tang and Tan, 2015). Similarly, financial development (Shoaib et al., 2020), Energy efficiency (Liu et al., 2022), unemployment (Bhowmik et al., 2022), trade (Dou et al., 2021), information technology (Wen et al., 2022), and policy-related uncertainties (Syed and Bouri, 2021) affect EMS. One line of research notes that geopolitical risk (GPR) is one of the emerging factors that explain EMS. Anser et al. (2021a) propose two channels, linking GPR with EMS. The first channel argues that GPR may impede ECG and ENC, which ultimately mitigate EMS. The second channel notes that GPR may plunge innovations, technological improvement, and R&D. As a result, EMS witness an escalation.

Regarding the literature on the GPR-environment nexus, Anser et al. (2021b) employ the AMG estimator to conclude that GPR deteriorates environmental quality in emerging countries. Using the ARDL approach, a similar conclusion is reported by Adams et al. (2020) in the selected resource-rich countries. Similarly, Husnain et al. (2022) conclude that GPR decreases EMS in E7 countries. Contrarily, using quantile-based methods, Syed et al. (2022) note that GPR enhances EMS at various quantiles in BRICST countries. Using the bootstrap ARDL method, Hashmi et al. (2022) declare that GPR triggers global emissions in the long-run. It is worth noting point that existing studies on the GPR-emissions nexus report ambivalent findings. On top of this, prior studies overlook some key issues, which may lead to unauthentic outcomes. Firstly, no study attempts to explore the GPR-emissions nexus for developed countries. Next, no study compares the GPR-emissions nexus for developed and developing countries. Hence, filling the aforementioned research gaps is imperative to reach an unambiguous conclusion.

Therefore, the study's objective is to reinvestigate the impact of GPR on EMS in selected developed and developing countries. For this purpose, we choose eight countries from the top 10 carbon emitters, which are further divided into two sets: 1) developed countries; 2) developing countries. We enhance the existing literature through two empirical innovations. First, this is an earliest attempt to investigate the GPR-emissions nexus in the case of developed countries. Second, we compare the GPR-emissions nexus for developed and developing countries for the first time in the literature.

Regarding the beneficiaries of this study, the present study will help the policymakers to introduce policies to achieve carbon neutrality through managing foreign direct investment, energy demand, geopolitics, and economic growth. Not only this, the current study will assist researchers to understand the dynamic nexus among the considered variables across developed and developing countries. Finally, this study will help to resolve the dilemma of ambivalent findings on the GPR-EMS nexus.

The remainder of this study is reported as follows. Section 2 provides the literature survey while methods are discussed in section 3. We note the empirical findings in section 4 whereas the conclusion and policy implications are presented in section 5.

2 Review of relevant literature

This part of the study provides a brief review of existing literature on the impact factors of EMS. There exists well-established literature that argues that ECG is the most fundamental driver of EMS. To model the link between ECG and EMS, the Environmental Kuznets Curve (EKC) framework has repeatedly been adopted. The EKC points out that there is an inverse U-shaped association between ECG and EMS. For the Central American economies, Apergis and Payne (2009) noted that ENC causes EMS. Moreover, the authors validated the EKC hypothesis. Similar findings are reported by Jalil and Mahmud (2009) for China, wherein the authors validated the EKC hypothesis. Seker et al. (2015) also confirmed the existence of the EKC hypothesis for Turkey. Besides, the study notes that ENC and foreign direct investment (henceforth FDIN) are the key drivers of EMS. For Tunisia, Shahbaz et al. (2014) validate the EKC hypothesis. Moreover, the authors report that ENC and trade cause EMS. Pao and Tsai (2011) noted that the EKC and pollution haven hypothesis exist in the case of BRIC countries. Hitam and Borhan (2012) validated the EKC hypothesis in consort with the pollution halo hypothesis for Malaysia. Yu et al. (2020) noted that the structure and intensity of energy affect energy-related emissions in China. Similar findings are reported by Yu et al. (2021) and Jiang et al. (2022a), Jiang et al. (2022b).

Acharya (2009) noted that FDIN increases EMS in India. Contrarily, Zhang and Zhang (2018) reported that FDIN does not affect EMS in China. Salahuddin et al. (2017) revealed that FDIN exerts a positive impact on EMS in the long-run (henceforth LR). Next, in Pakistan, Khan et al. (2019) noted that FDIN, ENC, and trade enhance EMS. Wang (2019) revealed that trade and ENC enhance EMS. Cheng et al. (2019) noted that FDIN and renewables plunge EMS whereas ECG and exports lead to higher EMS. Saud et al. (2018) concluded that, interestingly, natural resources do not exert any impact on EMS in selected developing countries. Ke et al. (2022) noted that ICT reduces EMS. Moreover, the authors validate the presence of the pollution haven hypothesis in selected developing countries. For the MINT countries, Li et al. (2022) reported that green investment, globalization, and innovations affect EMS. Similarly, Yildirim (2014) probes the causality among FDIN, ENC, and EMS for countries with different levels of income. The study validates the pollution haven hypothesis for certain countries while the pollution halo hypothesis is validated for the remaining countries. In the case of BRI countries, Lu et al. (2021) note that FDIN escalates ECN. We can infer that a rise in ECN will upsurge emissions. Recently, Udeagha and Muchapondwa (2022) conclude that economic uncertainty acts as a moderator among ECN, ECG, and EMS in South Africa. Next, Udeagha and Ngepah (2019), Udeagha and Ngepah (2022), and Udeagha and Ngepah (2021a) noted that trade affects both ECG and EMS across the short- and long-run. Similarly, Udeagha and Ngepah (2021b) investigate whether disaggregated energy has a heterogeneous impact on EMS. The findings highlight that renewables mitigate EMS whereas non-renewables escalate it. Contrarily, Udeagha and Breitenbach (2021c) reported that trade escalates environmental quality by mitigating emissions in the selected African countries.

Concerning the GPR-emissions nexus, Anser et al. (2021a) propose two channels, linking GPR with EMS. The first channel notes that GPR may mitigate ECG and ENC, which ultimately plunge EMS. The second channel argues that GPR may decrease innovations, technological improvement, and R&D. As a result, EMS witnesses an escalation. Anser et al. (2021b) employ the AMG estimator to conclude that GPR deteriorates environmental quality in emerging countries. Using the ARDL approach, a similar conclusion is reported by Adams et al. (2020) in the selected resource-rich countries. Similarly, Husnain et al. (2022) conclude that GPR decreases EMS in E7 countries. Contrarily, using quantile-based methods, Syed et al. (2022) note that GPR enhances EMS at various quantiles in BRICST countries. Using the bootstrap ARDL method, Hashmi et al. (2022) declare that GPR triggers global emissions in the long-run. Recently, Zhao et al. (2021) discern whether GPR affects ENC and EMS for BRICS countries using NARDL modeling. The authors report that there exists an asymmetric impact of GPR on EMS. Adebayo et al. (2019) adopted the quantile-based method to discern the GPR-EMS nexus for India. The study reports that GPR escalates EMS at median quantile whereas it plunges EMS at lower and higher quantiles.

The aforementioned literature on the GPR-EMS nexus contains some short comings. Firstly, no study analyses the impact of GPR on EMS for developed countries. Moreover, there does not exist any study that compares the relationship between GPR and EMS in the case of developed and developing countries. Hence, the current study fills these research gaps.

3 Materials and methods

3.1 Model

To attain its objective (i.e., investigating whether GPR affects EMS in developed and developing countries), the current study adopts the environmental Kuznets curve (EKC) model. The EKC model explains that income and environment have an inverted U-shaped association. Recently, various research outlets adopt the EKC model to investigate the drivers of EMS (see, e.g., Hashmi et al., 2022). Next, ENC is perceived as a core driver of EMS (Syed et al., 2022), therefore, we incorporate ENC as a control variable. Finally, we include GPR as a focused variable, and hence the final model yields:

$$\mathbf{EMS} = \mathbf{f}\,(\mathbf{ECG}, \mathbf{ECG2}, \mathbf{FDIN}, \mathbf{ENC}, \mathbf{GPR}) \tag{1}$$

In Eq. 1, EMS refers to CO_2 emissions, ECG is per capita GDP, ECG2 denotes the square of per capita GDP, ENC represents energy consumption, FDIN is foreign direct investment, and GPR indicates geopolitical risk. If ECG and ECG2 are >0 and <0, we will validate the existence of the EKC. We expect ENC to be > 0, implying that ENC enhances EMS. Since the relevant literature reports ambivalent findings for the GPR-EMS relationship, we do not envisage the sign for GPR.

3.2 Methodology

Since we make use of panel data with T > N, the four-step methodological procedure is followed. In the first stage, we probe the existence of cross-sectional dependence (hereafter CRD) with three tests. It is a point to note that CRD refers to a situation in which a shock to one country (cross-section) transfers to another. The existence of CRD may provide unreliable inferences, therefore, proper handling of the CRD is imperative (Pesaran, 2015).

We test the order of integration, with the help of the unit root test, in the second step. The study adopts the second-generation unit root test (i.e., CIPS test) due to its capability to cover the CRD (Pesaran, 2007). This ability of the CIPS test makes it superior to other first-generation unit root tests, which do not handle the CRD.

After probing the order of integration, we discern co-integration through the Westerlund (2007) test. Unlike conventional co-integration tests (i.e., first-generation panel data methods), The Westerlund test (i.e., the second-generation test) counters the CRD and hence provides robust outcomes (Anwar et al., 2021). The Westerlund test provides four statistics (i.e., Gt, Ga, Pt, and Pa) with the H_0 of no co-integration.

Finally, we adopt the PMG-ARDL approach of Pesaran and Smith (1995), which is further upgraded by Pesaran et al. (1999). This method is viable in the case of mixed ordering of the dataset. However, no variable should be integrated at I (2) to employ the PMG-ARDL model. Moreover, this model renders homogeneous estimates in the LR whereas it renders heterogeneous estimates in the SR.

3.3 Data

To compare the impact of GPR on EMS for developed and developing countries, we make use of panel data for eight countries that are opted from the top ten emitter countries. These eight countries are further segregated into two panels: 1) the first panel contains four developed countries (i.e., the US, Germany, Japan, and Saudi Arabia); 2) the second panel covers the developing countries (i.e., China, Russia, India, and Indonesia). Moreover, for both panels, the data covers the period 1990–2020. We use CO2 emissions (EMS—measured as a metric ton per capita) as a dependent variable, whereas per capita GDP (ECG–measured in constant $2015), foreign direct investment (FDIN- the percentage of GDP), and energy consumption (ECN–measured in oil equivalent per capita) are adopted as control variables. Next, geopolitical risk (GPR-measured as geopolitical risk index) is the core independent variable. The data on EMS, ECG, FDIN, and ENC are gathered from WDI[1]. However, the data on GPR is downloaded from policyuncertainty.com. Following the methodology of Baker et al. (2016), Caldara and Iacoviello (2022) propose the GPR index that is measured through the text mining approach. The entire dataset is transformed into logarithmic formation.

1 World Development Indicators.

The descriptive statistics are presented in Table 1, containing three samples of the panel dataset: 1) full sample; 2) developed countries' sample; 3) developing countries' sample. Note that the mean value is the largest for ECG across all samples. Moreover, the standard deviation is the highest for ECG, FDIN, and GPR in the full sample, developed countries' sample, and developing countries' sample, respectively. The entire dataset follows non-normal distribution except for GPR (full sample).

4 Empirical findings

We report the empirical outcomes in this part of the study. First of all, we report the findings from the CRD tests. In the panel dataset, CRD is considered as an imperative issue which needs to be properly addressed to report reliable findings. The CRD is transmission of a shock from one cross-section (i.e., country in our case) to another. If a shock transmits from one country to another, it could affect the economic dynamics of the other country. To control for this transmission, we need to adopt the appropriate econometric methods. We adopt three tests to probe the presence of CRD, namely, the Breusch-Pagan LM test, Pesaran CRD test, and Pesaran scaled LM test. The H_0 of these tests is no CRD whereas the H_1 notes vice versa. Table 2 depicts that there exists CRD in all panels. Hence, we confirm that a shock in one country may transmit to another country.

Testing the variables' ordering is an imperative part of empirical analysis to apply an appropriate method, which helps to avoid spurious outcomes. Therefore, we test the order of integration through the CIPS unit root test. The CIPS unit root test is one of the eminent second-generation tests, having the ability to counter the issue of CRD. Therefore, it outperforms the first-generation unit root tests. The CIPS has H_0 that there exists a unit root, implying that data is not stationary. We report the findings from the CIPS test in Table 3.

It can be concluded that all variables are either integrated at I (0) or I (1) in all samples, allowing for adopting the PMG–ARDL approach.

In the third step, we probe for the co–integrating association among the selected variables. This analysis uses Westerlund (2007) test, which is a second–generation method and hence counters the CRD. The findings from the test are noted in Table 4.

We can claim that there exists co–integration among the selected variables since we can reject the H_0 for all samples.

Finally, we employ the PMG–ARDL approach to retrieve the short–run (SR) and long–run (LR) estimates. The findings for the developed countries' samples are presented in Table 5. In the LR, all coefficients are statistically significant. ECG and ECG2 are negative and positive, respectively. This indicates the validity of N–shaped EKC. In particular, a 1% increase in ECG plunges the EMS by 0.84% while a 1% increase in ECG2 upsurges EMS by

TABLE 1 Descriptive statistics.

Full sample	ECG	EMS	ENC	FDIN	GPR
Mean	9.151030	1.787600	7.813602	0.027600	1.270236
Median	9.466476	2.245097	8.280547	0.274471	1.266932
Maximum	11.01595	3.019055	8.994280	2.544080	4.193435
Minimum	6.268176	−0.439898	5.858150	−7.198535	−1.714798
Std. Dev	1.401066	1.013606	0.967022	1.325615	1.180785
Skewness	−0.423847	−0.779471	−0.635586	−1.827245	−0.053742
Kurtosis	1.815921	2.136205	1.889237	8.090601	2.905231
Jarque-bera test	(0.000017)***	(0.000000)***	(0.000000)***	(0.000000)***	(0.899340)
Developed countries					
Mean	10.38298	2.501847	8.512259	−0.294635	1.620068
Median	10.42105	2.406970	8.360453	0.011872	1.396134
Maximum	11.01595	3.019055	8.994280	2.544080	4.193435
Minimum	9.686246	2.146912	8.139895	−7.198535	−0.371064
Std. Dev	0.367384	0.288832	0.292396	1.550144	1.130709
Skewness	−0.303941	0.456409	0.425219	−1.587413	0.467697
Kurtosis	2.094804	1.691166	1.531477	6.493981	2.111202
Arque-bera test	(0.046360)**	(0.001391)***	(0.000588)***	(0.000000)***	(0.013554)**
Developing countries					
Mean	7.919084	1.073354	7.114946	0.349835	0.920404
Median	7.838218	0.754469	6.773552	0.547580	1.123304
Maximum	9.246707	2.683110	8.689731	1.822431	2.804572
Minimum	6.268176	−0.439898	5.858150	−3.603600	−1.714798
Std. Dev	0.864236	0.975260	0.898994	0.957336	1.128974
Skewness	−0.092595	0.239827	0.486866	−1.378097	−0.596452
Kurtosis	1.920857	1.569545	1.775467	5.574306	2.376071
Jarque-Bera test	(0.045184)**	(0.002794)***	(0.001794)***	(0.000000)***	(0.009262)***

(.) represents *p*-value. Also, ***, **, and * show $p < 0.01$, $p < 0.05$, and $p < 0.1$, respectively.

0.02%. These findings are also backed by Gyamfi et al. (2021). ENC is 0.92, showing that a 1% upsurge in ENC escalates EMS by 0.92%. This outcome is also reported by Dogan et al. (2017). Next, FDIN is 0.03%, claiming that a 1% increase in foreign direct investment enhances emissions by 0.03%. Thus, we report the validity of the Pollution haven hypothesis for selected developed countries. These results are somehow in line with the findings of Banerjee and Murshed (2020). Finally, GPR is 0.04, indicating that a 1% increase in geopolitical risk escalates emissions by 0.04%. It might be possible that GPR plunges R&D, green investment, and innovation. As a result, EMS witnessed an upsurge over time. Over findings, related to GPR, are similar to the findings of Hashmi et al. (2022).

Regarding the SR results, all coefficients are statistically significant excluding ECG and ECG2. The insignificancy of ECG and ECG2 indicates that the EKC does not exist in the SR. Moreover, ENC is 0.53, implying that a 1% upsurge in ENC leads to 0.53% emissions. FDIN is −0.00, indicating that although foreign direct investment affects EMS but its impact is not profound. Next, GPR is −0.01, showing that a 1% rise in geopolitical risk impedes emissions by 0.01%. It might be possible that GPR mitigates economic growth and energy utilization which in turn exerts detrimental impacts on emissions. This conclusion is backed by Adams et al. (2020). The error correction term (ECT) is negatively significant and <1, implying that any shock will converge and the equilibrium will be achieved. The Jarque−Bera test and ARCH tests are adopted as diagnostics. The findings from these aforementioned tests report that there is neither the issue of non−normality nor heteroskedasticity.

We report the findings from the PMG−ARDL approach, for the developing countries, in Table 6. In the LR, all coefficients are statistically significant. ECG and ECG2 are positive and negative, respectively. This indicates the validity of the EKC hypothesis. In

TABLE 2 CRD test.

Test	p-value
Full Sample	
Breusch-Pagan LM test	(0.0000)***
Pesaran scaled LM test	(0.0000)***
Pesaran CRD test	(0.4573)
Developed countries	
Breusch-Pagan LM test	(0.0000)***
Pesaran scaled LM test	(0.0000)***
Pesaran CRD test	(0.0000)***
Developing countries	
Breusch-Pagan LM test	(0.0000)***
Pesaran scaled LM test	(0.0000)***
Pesaran CRD test	(0.0000)***

***Denotes p< 0.01.

TABLE 3 Unit root test.

Variable	I (0)	I (1)
Full sample		
ECG	−2.53**	—
EMS	−2.63***	—
ENC	−4.18***	—
FDIN	−2.10	−3.12***
GPR	−2.42**	—
Developed countries		
ECG	−2.38**	—
EMS	−1.57	−3.23***
ENC	−1.04	−2.98***
FDIN	−3.77***	—
GPR	−2.55**	—
Developing countries		
ECG	−2.78***	—
EMS	−3.66***	—
ENC	−4.33***	—
FDIN	−1.60	−3.01***
GPR	−1.75	−3.08***

***, **, and * show $p < 0.01$, $p < 0.05$, and $p < 0.1$, respectively.

TABLE 4 Testing co–integration.

Statistic	p-value
Full sample	
G_t	0.00***
G_a	0.00***
P_t	0.20
P_a	0.01**
Developed countries	
G_t	0.11
G_a	0.07*
P_t	0.00***
P_a	0.02**
Developing countries	
G_t	0.00***
G_a	0.00***
P_t	0.02**
P_a	1.75

***, **, and * show $p < 0.01$, $p < 0.05$, and $p < 0.1$, respectively.

TABLE 5 Findings from PMG–ARDL for developed countries.

Variable	Coefficient	p-value
LR results		
ECG	−0.84***	0.00
ENC	0.92***	0.00
FDIN	0.03***	0.00
GPR	0.04***	0.00
ECG2	0.02***	0.00
SR results		
ECG	12.10	0.12
ENC	0.53***	0.00
FDIN	−0.00***	0.00
GPR	−0.01***	0.00
ECG2	−0.54	0.25
ECT	−0.14***	0.00
Jarque–Bera Test		0.12
ARCH test		0.15

***, **, and * show $p < 0.01$, $p < 0.05$, and $p < 0.1$, respectively.

particular, a 1% increase in ECG increases the EMS by 0.52% while a 1% increase in ECG2 impedes EMS by 0.03%. These findings are also backed by Alola and Ozturk (2021). ENC is 1.12, showing that a 1% upsurge in ENC escalates EMS by 1.12%. This outcome is similar to the conclusion of Anser et al. (2021a). Next, FDIN is insignificant, reporting that foreign direct investment does not affect emissions in the LR. Thus, we report the invalidity of the Pollution haven hypothesis for selected developing countries. These results are somehow in line with the findings of Zhang and Zhou (2016). Finally, GPR is 0.03, indicating that a 1% increase in geopolitical risk escalates emissions by 0.03%. It

TABLE 6 Findings from PMG–ARDL for developing countries.

Variable	Coefficient	*p*-value
LR results		
ECG	0.52***	0.00
FDIN	−0.00	0.30
ENC	1.12***	0.00
GPR	0.03***	0.00
ECG2	−0.03***	0.00
SR results		
ECG	2.0	0.12
ENC	0.31***	0.00
FDIN	−0.00	0.10
GPR	−0.02***	0.00
ECG2	−0.40	0.17
ECT	−0.76***	0.00
Jarque–Bera test		0.11
ARCH test		0.17

***, **, and * show $p < 0.01$, $p < 0.05$, and $p < 0.1$, respectively.

TABLE 7 Findings from PMG–ARDL for the full sample.

Variable	Coefficient	*p*-value
LR results		
ECG	0.39***	0.00
ENC	1.11**	0.03
FDIN	0.02***	0.00
GPR	0.02**	0.02
ECG2	−0.02***	0.00
SR results		
ECG	4.62	0.52
ENC	0.35***	0.00
FDIN	−0.00**	0.01
GPR	−0.01***	0.00
ECG2	−0.19	0.19
ECT	−0.37***	0.00
Jarque–Bera test		0.17
ARCH test		0.13

***, **, and * show $p < 0.01$, $p < 0.05$, and $p < 0.1$, respectively.

might be possible that GPR plunges R&D, green investment, and innovation. As a result, EMS witnessed an upsurge over time. Over findings, related to GPR, are similar to the findings of Syed et al. (2022).

Regarding the SR results, all coefficients are statistically significant excluding ECG and ECG2. The insignificancy of ECG and ECG2 indicates that the EKC does not exist in the SR. Moreover, ENC is 0.31, indicating that a 1% surge in ENC leads to 0.31% emissions. FDIN is insignificant, indicating that foreign direct investment does not affect EMS. Next, GPR is −0.02, showing that a 1% rise in geopolitical risk impedes emissions by 0.02%. It might be possible that GPR mitigates economic growth and energy utilization which in turn exerts detrimental impacts on emissions. This conclusion is backed by Adams et al. (2020). The error correction term (ECT) is negatively significant and <1, implying that any shock will converge and the equilibrium will be achieved. We employ the Jarque–Bera test and ARCH test as diagnostics. The findings from these aforementioned tests report that there is neither the issue of non–normality nor heteroskedasticity.

We report the findings from the PMG–ARDL approach, for the full sample, in Table 7. In the LR, all coefficients are statistically significant. ECG and ECG2 are positive and negative, respectively. This indicates the validity of the EKC hypothesis. In particular, a 1% increase in ECG increases the EMS by 0.39% while a 1% increase in ECG2 impedes EMS by 0.02%. These findings are also backed by Farooq et al. (2022). ENC is 1.11, showing that a 1% upsurge in ENC escalates EMS by 1.12%. This outcome is similar to the conclusion of Apergis and Payne (2009). Next, FDIN is 0.02, reporting that a 1% surge in foreign direct investment enhances emissions by 0.02%. Thus, we report the validity of the Pollution haven hypothesis. These results are somehow in line with the findings of Guzel and Okumus (2020). Finally, GPR is 0.02, indicating that a 1% increase in geopolitical risk escalates emissions by 0.02%. It might be possible that GPR plunges R&D, green investment, and innovation. As a result, EMS witnessed an upsurge over time. Over findings, related to GPR, are similar to the findings of Anser et al. (2021a).

Regarding the SR results, all coefficients are statistically significant excluding ECG and ECG2. The insignificancy of ECG and ECG2 indicates that the EKC does not exist in the SR. Moreover, ENC is 0.35, indicating that a 1% surge in ENC leads to 0.35% emissions. FDIN is significant, indicating that foreign direct investment affects EMS but the strength of the relationship is negligible. Next, GPR is −0.01, showing that a 1% rise in geopolitical risk impedes emissions by 0.01%. It might be possible that GPR mitigates economic growth and energy utilization which in turn exerts detrimental impacts on emissions. This conclusion is backed by Anser et al. (2021b). The error correction term (ECT) is negatively significant and <1, implying that any shock will converge and the equilibrium will be achieved. We employ the Jarque–Bera test and ARCH test as diagnostics. The findings from these aforementioned tests report that there is neither the issue of non–normality nor heteroskedasticity.

While comparing the findings for all samples, we conclude the following points in the LR: 1) the EKC exists for the full sample and developing countries' sample; 2) ENC escalates EMS across all samples and the magnitude of the relationship is the strongest for the developing countries; 3) pollution haven hypothesis is validated for the full sample and developed countries; 4) GPR escalates EMS across all samples, however, its impact on EMS is the strongest for the developed countries, which is followed by developing countries. Next, a comparison of findings in the SR notes that: 1) the EKC does not exist in any sample; 2) ENC upsurges emissions in all samples and its impact on EMS is the strongest for developed countries; 3) FDIN does not exert a profound impact on emissions; 4) GPR impedes emissions in all samples, whereas, its impact is the strongest for the developing countries.

5 Conclusion

It is a well–established argument that environmental degradation has been upsurging with a positive growth rate. The Researchers claim that carbon emissions are the key culprit for this critical issue. To combat carbon emissions, it is imperative to explore its impact factors. Therefore, we probe the impact of GPR, ENC, FDIN, and ECG for selected developed and developing countries.

We find that the entire dataset is integrated either at I (0) or I (1). We also confirm the validity of co–integration among the selected variables. The long–run findings confirm that ENC enhances emissions in both developed and developing countries. Next, the EKC is validated in developing countries while the N–shaped EKC is observed in developed countries. We document the existence of the pollution haven hypothesis for developed countries. Next, GPR upsurges emissions both in developed and developing countries. However, the impact of GPR on emissions is relatively strong for developed countries.

In the short–run, the EKC does not exist for developed and developing countries. We also report that the pollution haven hypothesis does not present across selected developed and developing countries. Also, ENC leads to higher emissions. Finally, GPR mitigates emissions in developed and developing countries. While its impact on emissions is relatively profound for developing countries.

While proposing policy recommendations, we suggest that the share of renewables should be increased in order to offset the detrimental impact of fossil fuel energy. The income level (i.e., whether the country is developed or developing) does not matter in the case of the energy–emissions nexus, therefore, both developed and developing countries need to cut the share of non–renewables in their energy mix across the short– and long–run. Next economic growth should be derived through innovation, technological advancement, institutional reforms, and clean energy in order to avoid the adverse environmental impacts of economic growth. To decrease the reliance on energy led–growth, both developed and developing countries should introduce reforms to upsurge energy efficiency which in turn escalates ECG without deteriorating environmental health. The developed countries should reshape the sectors wherein FDIN is being consumed. For this purpose, developed countries have to incentivize green investment and green sectors. To this end, developed countries may set high returns on investment in green investment and green sectors. Moreover, both developed and developing countries should try to shrink geopolitical risk to mitigate emissions in the long–run. For this purpose, countries should sign peace treaties and agreements. Parallel to this, countries should build strong friendly relations with their neighbors and trade partners. Not only this, the international organizations/institutions (e.g., The United Nations, etc.) should play an active role to impede conflicts within and among countries. Further, to offset the adverse environmental impacts of low geopolitical risk, renewables, R&D, and green investment should be promoted, especially in the short run.

Regarding future research directions, the researchers can investigate the asymmetric impact of GPR on emissions. Moreover, quantile–based methods could be adopted to investigate the impact of GPR on emissions. Also, the interaction of GPR with energy and/or economic growth could be used to probe the impact of energy and growth amidst GPR.

Data availability statement

Publicly available datasets were analyzed in this study. This data can be found here: policyuncertainty.com.

Author contributions

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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