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Do Economic Policy Uncertainty and Geopolitical Risk Lead to Environmental Degradation? Evidence from Emerging Economies

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Abstract: Since the turn of twenty first century, economic policy uncertainty (EPU) and geopolitical risk (GPR) have escalated across the globe. These two factors have both economic and environmental impacts. However, there exists dearth of literature that expounds the impact of EPU and GPR on environmental degradation. This study, therefore, probes the impact of EPU and GPR on ecological footprint (proxy for environmental degradation) in selected emerging economies. Cross-sectional dependence test, slope heterogeneity test, Westerlund co-integration test, fully modified least ordinary least square estimator, dynamic OLS estimator, and augmented mean group estimator are employed to conduct the robust analyses. The findings reveal that EPU and non-renewable energy consumption escalate ecological footprint, whereas GPR and renewable energy plunge ecological footprint. In addition, findings from the causality test reveal both uni-directional and bi-directional causality between a few variables. Based on the findings, we deduce several policy implications to accomplish the sustainable development goals in emerging economies.

Keywords: ecological footprint; economic policy uncertainty; geopolitical risk; renewable energy consumption; non-renewable energy

1. Introduction

Economic policy uncertainty (EPU) could be defined as ambiguity and/or vagueness in economic policies, and it has been escalating since the turn of twenty first century. The recent events, e.g., financial crisis, Brexit, US-China trade war, and COVID-19 pandemic have surged the EPU worldwide. According to the country reports of the International Monetary Fund (IMF), EPU is among the leading factors responsible for sluggish economic growth. In addition to this, there exists profusion of studies that expound the economic impacts of EPU. For instance, several studies report that EPU effects economic growth [1,2], energy prices [3], stock market [4], and investment [5], etc. Hence, it could be concluded that EPU is an indispensable factor that has profound impact on economic indicators.

In addition to its economic impacts, EPU might have environmental impacts as well. EPU can plunge economic growth and energy consumption, which in turn ameliorates environmental quality. Also, EPU can impede renewable energy, R&D, and innovation. These aforementioned factors ultimately cause an upsurge in environmental degradation. Hence, EPU can either improve or mitigate environmental degradation.

Recently, one of the studies on the relationship between EPU and environmental quality proposes two channels that relate EPU with environmental degradation: (1) consumption effect; and (2) investment effect [6]. According to consumption effect, EPU mitigates the use of energy consumption and pollution-intensive commodities. As a result, environmental degradation will be mitigated. However, investment effect expounds that EPU impedes the investment in renewable energy and R& D, which ultimately leads to environmental degradation. There exist a few research outlets that explore the impact of EPU on environmental degradation. Regarding the relationship between EPU and environment, one strand of literature notes that EPU upsurges the environmental degradation [6–9], whereas second strand of literature reports that EPU plunges environmental degradation [10–12]. Besides, there exists a study which highlights that EPU does not affect environment [13]. The contrasting findings of the prior literature call for the further investigation of the impact of EPU on environmental degradation.

Parallel to this, geopolitical risk (i.e., risk related to terrorism, war, militarization, and conflicts within & between countries) has also been surging over the last few decades. The events, e.g., 9/11 attack, Bombay attack, US-Iraq war, and China-India conflicts are the key episodes of geopolitical risk (GPR) over the last few decades. It has also been noticed that GPR adversely affects businesses, investment, and other economic activities. There exists a line of research that notes the economic effects of GPR. For instance, a several studies highlight that GPR effects economic growth and tourism [14], energy consumption [15], financial markets [16], and research and development [17,18].

Contrary to its economic impacts, GPR may have environmental impacts as well. We propose two channels/effects through which GPR could affect the environment. The first channel is "mitigating effect", which argues that GPR plunges economic growth and energy consumption, and these factors (i.e., economic growth and energy consumption) impede environmental degradation. the second channel is an "escalating effect", which proposes that GPR mitigates R&D, innovations, and renewable energy, which in turn surge environmental degradation. On the basis of this, we can report that GPR can either increase or decrease environmental degradation. Therefore, it is imperative for the researchers to explore the net impact of GPR on environmental degradation. In the prior literature regarding the impact of GPR on environment, there exists contrasting conclusion [19,20] which propels researchers to further investigate this issue.

To complement the above backdrop, the objective of this study is to explore the impact of EPU and GPR on environmental degradation in Brazil, Russia, Mexico, Colombia, and China (BRMCC) from 1995 to 2015. This study will provide insightful information to these countries in a sense that the policy makers could devise appropriate policies to curb environmental degradation and accomplish sustainable development goals. BRMCC are a set of emerging countries which produced 22.07% of global GDP, and almost 25% of world population belongs to these countries (https://www.worldometers.info, accessed on 22 May 2021). Moreover, BRMCC countries contribute almost 36.76% to world energy consumption. Last but not least, BRMCC countries produce 30.90% of the global ecological footprint (EF). Parallel to this, BRMCC countries are the economic and political powers of the new era. These countries have geopolitical tensions with each other, and with rest of the world.

More specifically, after the global financial crisis, Brazil also faced a severe financial crisis during 2013–2016 that raised its EPU. In addition, the protests and impeachments in Brazil aggravated the uncertainty. The significant fluctuations in the currency of Brazil are responsible for a high spike of EPU. It is worth to mention that Brazil also has geopolitical tensions. For instance, Brazil and Uruguay have critical territorial issues while Brazil and Colombia have disputes due to smuggling. Additionally, several periods of military government have surged the GPR in Brazil. According to the Brazilian Federal Police, seven terrorist groups are actively operating in Brazil, which also contributes to a higher GPR.

Being an oil-dependent economy, the EPU of Russia remains high due to the repeated oil price fluctuations. The economic crisis in 1998 also surged its EPU. Furthermore, the

15 economic, 12 financial and 22 corporate sanctions that were imposed on Russia by the US and European Union pushed up its EPU and GPR. The Russia-Ukraine conflict is one of the prime sources of high GPR in Russia. The Moscow theater hostage crisis in 2002, Moscow school hostage event in 2004, Moscow market bombing in 2006, Moscow suicide bombing incident in 2010, airport suicide bombing in 2013, and the incident of Metro-jet Flight 9268 in 2015 are examples of geopolitical unrest in Russia.

Being the 6th largest oil producer, the EPU in Mexico remains high due to oil price fluctuations. Mexico has faced several economic crises which escalated its EPU. For instance, the Peso crisis in 1994 that occurred due to the devaluation of its currency and capital flight had adverse effects on economy and contributed to high EPU. The global financial crisis in 2008 exerted an adverse impact on the economy of Mexico, which in turn aggravated its EPU. Additionally, Mexico and the US have geopolitical tensions due to drug smuggling and illegal migration.

Likewise, Colombia confronted economic crises during the late 1990s and early 2000s. As a result, EPU in Colombia approached its peak. Apart from this, oil price fluctuations raised its EPU because the Colombian economy heavily depends on oil. Additionally, several terrorist groups operating in Colombia are responsible for the deaths and displacement of thousands of people. Operation Traira, the Mexican drug war, operation Atalanta, and Operation Ocean Shields are a few examples that have generated geopolitical tensions in Colombia.

Similarly, global financial crisis had generated profound EPU in China. Moreover, the US-China trade war also responsible for the high EPU in China. Besides, the China-India conflicts on territorial issues increased its GPR. Several countries have imposed sanctions related to CO_2 emissions on China that created geopolitical tensions. The US, European Union, and Canada also imposed sanctions on China due to the Uighurs issue that have escalated its GPR.

In sum, the social, economic, and geopolitical status of the BRMCC countries motivates us to explore the impact of EPU and GPR on environmental degradation. Based on above backdrop, we propose two hypotheses as follows:

Hypothesis 1 (H1). *The investment effect of EPU is greater than the consumption effect, implying that EPU escalates environmental degradation.*

Hypothesis 2 (H2). *The mitigating effect of GPR is greater than the escalating effect, indicating that GPR impedes environmental degradation.*

The present study contributes to the existing body of literature in two dimensions. First, this is the first study to investigate the impact of EPU and GPR on environmental degradation in the BRMCC countries. There is scant knowledge that links both EPU and GPR with environmental degradation. Nevertheless, the limited studies in the prior literature showed contrasting findings. Second, prior studies extensively employed CO_2 emissions as an indicator for environmental degradation [11]. However, CO_2 emission is just a subset of environmental degradation, and it is unable to capture the complex nature of environmental degradation [21]. To overcome this limitation, ref. [22] proposed ecological footprint (EF) as an indicator for environmental degradation. EF is a comprehensive indicator that captures the environmental degradation in many aspects. It is the area required to reproduce the resources that are being consumed by a country, and to absorb the waste it produces at a given level of technology.

The remainder of this study is ordered as follows: Section 2 reviews the literature related to EF. We present the data in Section 3. Model and methodology are discussed in Section 4. Results are mentioned in Section 5. Discussion on the basis of results is presented in Section 6. Section 7 concludes the study.

2. Literature Review

2.1. Literature on Determinants of Ecological Footprint

This section reviews the literature related to determinants of ecological footprint (EF). In addition to this, the current section also reports the literature on the relationship among EPU, GPR, and environment.

There are many studies that probe the validity of environmental Kuznets curve (inverted U-shaped relationship between income and environment). The studies are different from each other on the basis of results, methodologies, and data. Few studies conclude that environmental Kuznets curve does not exist. For instance, one of the studies employ ordinary least squares (OLS) model and weighted least squares (WLS) model on 141 countries to probe the environmental Kuznets curve using EF as an indicator of environmental quality. The findings reveal that environmental Kuznets curve does not hold [23]. Similarly, another study borrows spatial econometric approach to test environmental Kuznets curve. The study also notes that environmental Kuznets curve is not valid for selected countries [24]. Next, a group of researchers re-investigates the validity of environmental Kuznets curve for BRICST countries using FMOLS, DOLS, and AMG approaches. The results conclude that an environmental Kuznets curve is does not exist for BRICST countries. Few studies use time series data to investigate environmental Kuznets curve. For instance, using ARDL approach for Qatar, it is found that environmental Kuznets curve is not valid for Qatar [25].

On the contrary, there exists literature that supports the environmental Kuznets curve. By using the GMM approach, one of the studies investigated the environmental Kuznets curve for high-income, upper-middle, lower-middle, and low-income countries using EF. The results show that environmental Kuznets curve holds for high-income and upper-middle income countries [26]. Similarly, EKC also exists in 15 MENA countries [27]. Using DOLS and FMOLS approaches, a group of researchers confirms the validity of EKC in the case of BRICS countries [28].

There exists an extensive body of literature that probes the economic and non-economic factors that influence EF. For instance, tourism is one of the determinants of EF. It may either increase or decrease EF. That is, tourists admire improved environment quality that compels policy makers to adopt strict environment measures. As a result EF will be mitigated [29]. On the other hand, tourism can escalate the use of non-renewable energy and pollution intensive goods and services, which escalates EF [30]. Likewise, energy consumption, urbanization, trade, and industrialization are reported key determinants of EF in MENA region [31]. It is also noted that economic globalization increases EF, while social globalization decreases it. Additionally, political globalization does not affect EF in 146 selected countries [32]. Likewise, one of the studies notes that economic growth, energy consumption, urbanization, FDI, and financial development surge EF in 59 Belt and Road countries [33]. Similarly, in OIC countries, trade openness, FDI, and urbanization escalate EF [34]. In one-belt-one road countries, financial development leads to higher EF while globalization impedes it [35]. Similarly, in 16 EU countries, economic growth, energy consumption, renewable energy consumption, and fertility are highlighted as key determinants of EF [36]. One the other hand, urbanization decreases the EF whereas human capital contributes to higher EF in G-7 countries [37]. Parallel to this, another study expounds that economic growth, energy consumption, financial development, urbanization and non-renewable energy consumption increase EF, whereas renewable energy consumption impedes EF [38] Table 1.

2.2. Literature on the Impact of EPU and GPR on Environmental Degradation

There exists one-way causality running from EPU to carbon emissions in case of the USA due to the fact that EPU discourages investment in clean energy and turns the attention of policymakers toward economic stability, which effects carbon emissions [7]. Further, it is also concluded that EPU upsurges energy consumption, which increases CO_2 emissions in both short- and long-run [57]. Additionally, it is also noted that EPU escalates carbon emissions in both developed and developing countries [6,8]. Regarding the impact

of provincial level carbon emissions, it is highlighted that EPU of China at provincial level increases the provincial level carbon emissions [58]. Recently, it is documented that EPU also surge CO_2 emissions in top ten carbon emitter countries [9]. In the case of the UK, EPU discourages economic growth and energy consumption, and hence CO_2 emissions decrease in the short-run [10]. Recently, it is also found that EPU decreases the CO_2 emissions in the long-run [11]. Similarly, EPU discourages investment in R&D and renewable energy, which ultimately mitigates CO_2 emissions [12]. Regarding the literature on the relationship between GPR and environmental quality, GPR mitigates renewable energy consumption and investment in R&D. as a result, GPR leads to environmental degradation [19]. Recently, one of the studies reports that GPR asymmetrically effects carbon emissions in BRICS countries [20].

Table 1. Summary of literature related to determinants of ecological footprint.

Reference	Country	Method	Determinants
[23]	141 countries	OLS and WLS	Economic growth
[24]	150 countries	Spatial econometric approach	Economic growth
[26]	High-income, middle-income, low-income	Fixed effect model and GMM model	Energy consumption, urbanization, and trade
[29]	144 countries	GMM approaches	Tourism
[31]	MENA region	FMOLS	Energy, urbanization, trade, and political instability
[25]	Qatar	ARDL methodology	Oil prices and trade
[39]	Malaysia	ARDL and Bayer & Hanck approach	Economic growth, energy, population, urbanization, and globalization
[40]	Pakistan	ARDL approach	Natural resources
[27]	15 MENA countries	Panel co-integration and causality test	Energy, political institutions, urbanization, life expectancy, and fertility
[32]	146 countries	Extreme bounds analysis	Economic globalization, social globalization, and political globalization
[41]	Pakistan	ARDL approach	Economic growth, human capital, and biodiversity
[42]	Turkey	Bootstrap time-varying causality	Economic growth
[43]	India	Bayer and Hanck approach	Human capital
[33]	59 Belt-and-road countries	Driscoll-Kraay approach	Urbanization, FDI, financial development, energy, and economic growth
[28]	BRICS	FMOLS and DOLS	Energy, urbanization, and natural resources
[34]	OIC	DCCE	Trade, FDI, urbanization, institutions
[35]	One-belt-one-road countries	PMG-ARDL method	Financial development and globalization
[44]	MINT	ARDL approach	Exports, imports, financial development, urbanization, (non)renewable energy
[21]	11 Newly industrialized countries	AMG methodology	Economic growth
[45]	BRICS	FMOLS and DOLS	Urbanization, natural resources, renewable energy
[36]	16-EU countries	PMG-ARDL method	Economic growth, energy consumption, and fertility
[37]	G7 countries	CUP-FM and CUP-BC methodologies	Human capital and urbanization
[38]	MENA	AMG approach	Economic growth, energy, financial development, and urbanization
[30]	35 Tourism countries	Fixed effect model and GMM model	Inbound and outbound tourism
[46]	Turkey	QARDL	Economic growth, (non)renewable energy
[47]	Indonesia	Bayer and Hanck approach	Economic growth, energy, urbanization, and trade
[48]	BRICST	FMOLS, DOLS, and AMG approach	Economic growth
[49]	US	ARDL approach	Economic growth, energy, human capital, and FDI
[50]	Newly industrialized countries	Second generation panel data methods	FDI
[51]	Developing countries	Bayesian model	22 determinants
[37]	China	Bayer and Hanck approach	Human capital, urbanization, and natural resources
[52]	US	ARDL approach	Economic growth, energy, financial development, and globalization
[53]	16 CEECs	DSUR, FGLS, GMM, and D-H panel causality test	economic growth, energy consumption, and financial development
[54]	15 Globalized countries	qantile-on-quantile regression	Globalization
[55]	South Asian countries	Panel ARDL	Globalization and technology
[56]	Nigeria	NARDL approach	Financial development

3. Data

The purpose of this study is to probe the determinants of ecological footprint (EF) in five emerging countries (i.e., Brazil, Mexico, Russia, Colombia, and China). We employ annual data from 1995 to 2015. We selected these countries and time span on the basis of data availability. Data on EF is downloaded from global footprint network (GFN). Next, data on economic policy uncertainty (EPU) (see Baker et al. (2016) [1] for further details on economic policy uncertainty index.) and geopolitical risk (see Caldara and Jacoviello (2018) [59] for further details on geopolitical risk index). GPR data is taken from policyuncertainty.com. On the other hand, data on GDP per capita (GDP), non-renewable energy consumption (EN), renewable energy consumption (REN), and population (POP) is gathered from World Development Indicators (WDI). Table 2 reports the data description.

Table 2. Data description.

Abbreviation	Indicator Name	Measurement Scale	Source
EF	Ecological footprint	Gha per person	GFN
GDP	GDP per capita	GDP per capita (constant 2010$ US)	WDI
EN	Non-renewable energy consumption	Oil equivalent per capita	WDI
REN	Renewable energy consumption	Percent of total final energy	WDI
POP	Population	Total population	WDI
EPU	Economic policy uncertainty index	Number of newspaper articles having uncertainty related words (e.g., economic, and uncertainty etc.)	Policyuncertainty.com
GPR	Geopolitical risk index	Number of newspaper articles having geopolitics related words (e.g., geopolitics, and uncertainty etc.)	Policyuncertainty.com

Note: "GFN" indicates global footprint network while "WDI" represents world development indicators.

We transform all variables into logarithmic form to control heteroscedasticity [60] Further, Table 3 highlights the descriptive statistics of the data.

Table 3. Descriptive Statistics.

Statistics.	EF	EN	EPU	GDP	GPR	POP	REN
Mean	1.07	7.32	7.10	8.81	7.04	18.95	2.73
Median	1.07	7.31	7.09	9.04	7.04	18.78	2.87
Maximum	1.77	8.55	8.38	9.39	7.52	21.03	3.89
Minimum	0.60	6.42	5.78	7.11	6.53	17.41	1.17
Std. Dev.	0.33	0.64	0.48	0.54	0.18	1.11	0.90
Skewness	0.44	0.57	−0.05	−1.47	−0.06	0.76	−0.47
Kurtosis	2.21	2.29	3.02	4.62	3.02	2.67	1.93
Jarque-Bera	(0.03) **	(0.01) **	(0.97)	(0.00) ***	(0.95)	(0.00) ***	(0.00) ***

Note: (.) indicates the value of probability. **, *** represent level of significance at 5%, and 1% respectively.

As can be seen in Table 3, REN has highest standard deviation. It implies that there are large fluctuations in renewable energy series. Next, all series are either positively or negatively skewed. Jarque-Bera test highlights that all variables follow the non-normal distribution except EPU and GPR, which follow the normal distribution.

4. Model and Methodology

To investigate the impact of economic policy uncertainty (EPU), geopolitical risk (GPR), and energy consumption on ecological footprint (EF), we employ IPAT approach (influence = population, affluence, and technology) that examines the environmental impacts of human activities [61]:

$$\text{EF}_{it} = \beta_0 + \beta_1 \text{GDP}_{it} + \beta_2 \text{EN}_{it} + \beta_3 \text{REN}_{it} + \beta_4 \text{POP}_{it} + \beta_5 \text{EPU}_{it} + \beta_6 \text{GPR}_{it} + \varepsilon_{it} \quad (1)$$

Equation (1) shows the empirical model that we develop for the current study, where i and t represent the cross-section and time, respectively. ε_{it} indicates the error term of the model. EF represents ecological footprint. Next, GDP, EN, REN, POP, EPU, and GPR show GDP per capita, non-renewable energy consumption, renewable energy consumption, population, economic policy uncertainty, and geopolitical risk, respectively. In the IPAT model, GDP growth rate is used as a proxy of affluence, population is employed to capture the environmental impact of population growth, and (non)renewable energy is used as a proxy of technology [62]. The prior literature reports that GDP, population and non-renewable energy often surge environmental degradation [9]. On the contrary, renewable energy plunges the environmental quality [11].

The present study employs fully modified OLS (FMOLS), dynamic OLS (DOLS), augmented mean group (AMG), and Dumitrescu and Hurlin [63] panel Grainger causality approach to explore the relationship among EF, GDP, EN, REN, POP, EPU, and GPR. FMOLS and DOLS estimators investigate the long-run relationship between the variables. Moreover, FMOLS and DOLS use non-parametric and parametric approach respectively to handle the endogeneity and serial correlation. Further, the DOLS approach is relatively better as it produces unbiased and efficient results even in the case of small sample and cross-sectional dependence [41]:

$$\hat{\beta}_{FMOLS} = [\frac{1}{N} \sum_{i=1}^{N} [\sum_{t=1}^{T} (X_{it} - \overline{X}_i)^2]^{-1} \times [(\sum_{t=1}^{T}(X_{it} - \overline{X}_i)\hat{Y}_{it} - T\hat{\Delta}_{[?]\mu})]] \tag{2}$$

$$\hat{\beta}_{DOLS} = [\frac{1}{N} \sum_{i=1}^{N} [\sum_{t=1}^{T} (X_{it}X'_{it})^{-1} (\sum_{t=1}^{T} X_{it}\,\hat{Y}_{it})]] \tag{3}$$

Equations (2) and (3) represent the FMOLS and DOLS estimators, where, *X* and *Y* are independent and dependent variable(s), respectively. A line of research reports that FMOLS and DOLS may give misleading results if panel sections are correlated [44]. To overcome this limitation, this study also applies augmented mean group estimator (AMG) [64] and [65] which gives efficient results even in case of aforementioned problem. AMG estimator is superior to FMOLS and DOLS as it is applicable even in case of non-stationary data. Thus, it is not necessary to check unit-root and co-integration before employing AMG estimator [21]. AMG consists of two-step procedure that is mentioned as follows.

In first step, we estimate Equation (1) by taking first difference of all the series and incorporating T − 1 period dummy:

$$\Delta EF_{it} = \beta_0 + \beta_1 \Delta GDP_{it} + \beta_2 \Delta EN_{it} + \beta_3 \Delta REN_{it} + \beta_4 \Delta POP_{it} + \beta_5 \Delta EPU_{it} + \beta_6 \Delta GPR_{it} + \sum_{t=2}^{T} \rho_t (\Delta D_t) + \varepsilon_{it} \tag{4}$$

In Equation (4), ΔD_t represents T − 1 period dummies at first difference. ρ_t refer to parameters that show period dummies.

In second step, we transform parameters (ρ_t) in new variable (τ_t) which shows the common dynamic process. The model is mentioned as follows:

$$\Delta EF_{it} = \beta_0 + \beta_1 \Delta GDP_{it} + \beta_2 \Delta EN_{it} + \beta_3 \Delta REN_{it} + \beta_4 \Delta POP_{it} + \beta_5 \Delta EPU_{it} + \beta_6 \Delta GPR_{it} + d_i(\tau_t) + \varepsilon_{it} \tag{5}$$

$$\Delta EF_{it} - \tau_t = \beta_0 + \beta_1 \Delta GDP_{it} + \beta_2 \Delta EN_{it} + \beta_3 \Delta REN_{it} + \beta_4 \Delta POP_{it} + \beta_5 \Delta EPU_{it} + \beta_6 \Delta GPR_{it} + \varepsilon_{it} \tag{6}$$

The group-specific model is initially altered with τ_t and then the average values of group-specific model parameters are calculated. For instance, the parameter of EPU can be calculated as $\beta_{5,\,AMG} = \frac{1}{N} \sum_{i=1}^{N} \beta_{5,\,i}$. AMG estimator considers the issues of heterogeneity and cross-sectional dependence. Moreover, AMG estimator produces authentic results when there is cross-sectional dependence in heterogeneous panel data [66].

To probe the causality between variables, we also employ Dumitrescu and Hurlin's [63] heterogeneous panel causality test (hereafter D-H test). This test is updated version of

panel granger causality and gives consistent results even in the presence of cross-sectional dependency [21]. The D-H test procedure is given as follows:

$$W_{N,T}^{HNC} = \frac{1}{N} \sum_{i=1}^{N} W_{i,t} \tag{7}$$

$$Z_{N,T}^{HNC} = \sqrt{\frac{N}{2K}} (W_{N,T}^{HNC} - K), \ N\,(0,\,1) \tag{8}$$

where, $W_{i,t}$ represents the Wald statistic. However, we can compute $W_{N,T}^{HNC}$ by averaging each Wald static for cross-sections. The null and alternative hypothesis of D-H test is reported as follows:

Hypothesis 3 (H3). *There is no homogenous causality.*

Hypothesis 4 (H4). *There is homogenous causality.*

5. Empirical Results

The empirical route employed in the current study is ordered as follows. First, we probe the cross-sectional dependence (CD) in our data to know whether shocks in one country may spillover to other countries as these shocks may produce misleading results (inconsistent parameters) if they are correlated with independent variables [67]. There are many CD tests in literature but the most widely used tests are Breusch-Pagan LM test, Pesaran LM test, and Pesaran CD test. We apply these three CD tests in this study and the results from these CD tests are illustrated in Table 4.

Table 4. Cross-sectional dependence test.

Model	Breusch-Pagan LM	Pesaran Scaled LM	Pesaran CD
EF = f (GDP, EN, REN, EPU, GPR, POP)	(26.11) [0.00] ***	(3.60) [0.00] ***	(2.84) [0.00] ***

Note: H_0 of all tests is "there is no cross-sectional dependence." (.) and [.] indicate test static and probability values respectively. *** represents level of significance at 1%.

As can be seen in Table 4 that null hypothesis can be rejected as the probability value is significant at 1% level of significance. Thus, we report that there is cross-sectional dependence. Second, we employ slope homogeneity test [68]. This test is based on $\hat{\Delta}$ and $\hat{\Delta}_{adj.}$ values. Results are posted in Table 5 which show that all slopes are heterogeneous except slope of GPR, which is homogenous.

Table 5. Results from homogeneity test.

Statistics	EF	GDP	EN	REN	POP	EPU	GPR
$\hat{\Delta}$	14.12 ***	14.28 ***	8.03 ***	2.60 ***	9.09 ***	2.73 ***	0.63
$\hat{\Delta}_{adj.}$	12.05 ***	15.37 ***	8.64 ***	3.25 ***	9.73 ***	2.93 ***	0.60

Note: *** indicates level of significance at 1%.

Third, we discern whether the data have stationary process to restrain from the spurious regression [69]. We use the LLC, IPS, PP-Fisher, and CIPS unit root tests for this purpose. It is worth mentioning that the CIPS unit root test [70] handles the issues of heterogeneity and cross-sectional dependence. Thus, the CIPS unit root test is relatively superior as compare to the LLC, IPS, and PP-Fisher tests. We present the unit root results in Table 6.

Table 6 illustrates the results from unit root tests. The findings from all unit root tests reveal that the null hypothesis of no unit root cannot be rejected at level. On the contrary, null hypothesis can be rejected at first difference. It implies that all variables are integrated at I (1).

Table 6. Unit root tests.

Variable	Level				First Difference			
	LLC	**IPS**	**PP-Fisher**	**CIPS**	**LLC**	**IPS**	**PP-Fisher**	**CIPS**
EF	(0.36)	(0.17)	(0.00) ***	−0.19	(0.09) *	(0.00) ***	(0.00) ***	−2.70***
EN	(0.95)	(0.90)	(0.00) ***	−0.90	(0.00) ***	(0.00) ***	(0.00) ***	−3.57***
EPU	(0.92)	(0.84)	(0.81)	−0.95	(0.00) ***	(0.00) ***	(0.00) ***	−3.21***
GDP	(1.00)	(1.00)	(0.02) **	−0.96	(0.00) ***	(0.00) ***	(0.00) ***	−2.98***
GPR	(0.21)	(0.14)	(0.08) *	−0.19	(0.00) ***	(0.00) ***	(0.00) ***	−2.66***
POP	(1.00)	(0.00) **	(0.00) **	−1.32	(0.00) ***	(0.00) ***	(0.00) ***	−2.83***
REN	(0.25)	(0.41)	(0.00) ***	−0.17	(0.00) ***	(0.00) ***	(0.00) ***	−2.65***

Note: (.) represents the probability value. *, **, *** indicate level of significance at 10%, 5%, and 1% respectively. The critical value of CIPS unit root test at 1% level of significance is −2.57.

Fourth, as the variables are stationary at first difference therefore we check whether the linear combination of these variables is stationary. If the linear combination of these variables is stationary, this implies that co-integration does exist. To probe the co-integration among the variables we employ Kao co-integration test. However, this test may give misleading results in the presence of heterogeneity and cross-sectional dependence. To resolve this limitation, we also apply Westerlund co-integration test which is consistent even if there is heterogeneity and cross-sectional dependence [41]. The results from the Kao test and Westerlund test are posted in Table 7.

Table 7. Co-integration results.

Test	Statistic	Probability
Kao test	−3.99	0.00 ***
Westerlund (2007) [71]		
P_t	−3.54	0.00 ***
P_a	−4.76	0.00 ***
G_t	−4.23	0.00 ***
G_a	−5.98	0.00 ***

Note: *** indicates level of significance at 1%. The null hypothesis of Kao test and Westerlund (2007) assumes no cointegration.

Table 7 shows the results from co-integration tests. The null hypothesis of no co-integration can be rejected as the probability values are significant at 1% level of significance. Thus, we conclude that co-integration (long-run relationships) exists among the variables. Fifth, we employ FMOLS, DOLS, and AMG estimators to probe the long-run relationship among variables. Table 8 reports the results from FMOLS, DOLS, AMG estimators.

Findings from FMOLS highlight that all the coefficients are statistically significant at a 1% level of significance. In detail, the coefficient of GDP is 0.31, which means that a 1% increase in GDP escalates the EF by 0.31%, thus implying that improvement in income level increases the ecological footprint of the panel of the emerging countries. These findings are in line with the findings of previous literature [41]. In addition, the coefficient of EN is 0.30, which translate that the EN increases the EF by 0.30% when EN increases by a 1%. There are several studies who report the similar findings [41]. For the renewable energy, the coefficient of REN is −0.32, thus, this posited that renewable energy consumption rather reduced pressure on the ecological footprint through a reduction in human ecological needs. This evidence is consistent with the previous studies [46]. Likewise, the coefficient of POP is 0.0 which shows that there is meagre or no effect of population on EF. However, the coefficient of EPU is 0.28, which concludes that an increase of 0.28% in EF is fostered by a 1% increase in EPU. Moreover, the coefficient of GPR is −0.29, which reports that 1% increase in GPR decreases the EF by 0.29%.

Table 8. Results from FMOLS, DOLS, and AMG estimators.

Variable	FMOLS	DOLS	AMG
GDP	0.31 (0.00) ***	0.19 (0.00) ***	0.32 (0.00) ***
EN	0.30 (0.00) ***	0.19 (0.00) ***	0.10 (0.00) ***
REN	−0.32 (0.00) ***	−0.23 (0.00) ***	−0.24 (0.00) ***
POP	0.13 (0.00) ***	0.15 (0.00) ***	−0.75 (0.13)
EPU	0.28 (0.00) ***	0.04 (0.00) ***	0.10 (0.00) ***
GPR	−0.29 (0.00) ***	−0.11 (0.00) ***	−0.18 (0.00) ***

Note: (.) represents probability value. *** indicate the level of significance at 1%.

Similarly, the results from DOLS conclude that all coefficients are statistically significant at 1% level of significance. In detail, GDP, EN, and POP escalate EF. On the contrary, REN decreases the EF. Further, the coefficient of EPU depicts that EPU increases the EF. On the other hand, the coefficient of GPR is negative, therefore, it could be concluded that GPR mitigates the EF.

Findings from the AMG estimator report that all coefficients are statistically significant except POP, which is statistically insignificant. Results from the AMG estimator also reveal that GDP and EN increase the EF. Further, REN plunges the EF, which is the same result from the previously expressed estimators. Next, the coefficient of EPU is 0.10 which shows that an increase in the level of uncertainty regarding the economic policy of the examined panel countries is responsible for more hazardous environmental damage. There are few possible reasons behind this result. For instance, EPU discourages innovations, R&D, and technology, which in turn increase environmental degradation. A similar finding has been reported in the case of the USA [7]. The coefficient of GPR depicts that a decrease of 0.18% in the EF is fostered by a 1% increase in the GPR. The same findings have been presented in case of top resource rich countries [8]. There are also few possible reasons behind these results. For instance, an increase in the GPR is responsible for a declining economic growth, which in turn mitigates the EF. This is because, rising political instability, civil unrest, and amid other states' and regional tensions is detrimental to sustainable economic growth. Additionally, GPR also reduces FPI, trade, and investment, which in turn reduces the environmental degradation (EF).

Since the FMOLS, DOLS, AMG estimators just report the long-run relationship, and do not explain the causality therefore we employ D-H causality test. As mentioned earlier, the D-H test produces consistent results in the presence of cross-sectional heterogeneity therefore it is being widely employed in recent studies [41]. Table 9 illustrates the results from the D-H test.

The findings from the D-H causality test reveal that bi-directional causality exists between GDP and EF, POP and EF, GDP and EN, POP and EN, REN and EN, GDP and EPU, POP and EPU, POP and GDP, and between REN and GDP. Based on these results, we report the following explanations:

- The two-way causality between GDP and EF indicates that GDP causes EF and vice-versa. More specifically, any attempt to boost GDP will increase the environmental degradation. On the other hand, the rise in environmental degradation affects the economic growth as well. These findings are in line with [62].
- The bi-directional causality between GDP and EN concludes that rise in non-renewable energy consumption leads to higher economic growth. Moreover, any attempt to increase GDP growth will escalate the non-renewable energy consumption as well. This conclusion is similar to [72].

- The two-way causality between REN and GDP implies that increase in renewable energy contributes to GDP growth, while rise in income encourages the use of renewable energy in these countries. This outcome is backed by [73].

Table 9. Results from D-H causality test.

Null Hypothesis:	W-Stat.	Z Bar-Stat.	Prob.
EN <≠> EF	6.03423	6.26138	0.00 ***
EF <≠> EN	1.72193	0.76134	0.44
EPU <≠> EF	1.03408	−0.11596	0.90
EF <≠> EPU	3.65599	3.22810	0.00 ***
GDP <≠> EF	4.35470	4.11926	0.00 ***
EF <≠> GDP	58.8704	73.6503	0.00 ***
GPR <≠> EF	1.31879	0.24717	0.80
EF <≠> GPR	0.96907	−0.19888	0.84
POP <≠> EF	7.80364	8.51815	0.00 ***
EF <≠> POP	46.8138	58.2729	0.00 ***
REN <≠> EF	1.48405	0.45794	0.64
EF <≠> REN	3.38019	2.87634	0.00 ***

Note: null hypothesis of D-H causality test assumes there is no causal relationship. *** indicate level of significance at 1%. Moreover, detailed results from D-H causality test will be available upon request.

6. Discussion

In this section, we briefly explain the results with their practical implications. The findings from FMOLS, DOLS, and AMG estimators reveal that GDP and EN escalates environmental degradation in the BRMCC countries. This infers that economic growth achieved by non-renewable energy consumption deteriorates environmental quality. These findings are in line with recent studies [74–76]. These countries consumed a very high share of non-renewable energy in their total energy consumption. They attained high economic growth at a cost of environmental degradation. On the other hand, REN plunges EF. The findings are backed by [11,44,77]. Some developed economies (e.g., Denmark, Austria, Switzerland, and Finland) expanded the use of renewables and had profoundly impeded environmental degradation. Hence, the BRMCC countries should also enlarge their renewable energy consumption. Incentives can be given to promote renewable energy consumption in order to achieve sustainable economic development.

Next, EPU is responsible for rising EF. This validates our first hypothesis that the consumption effect is greater than the investment effect. The result is consistent with [6–9]. Hence, the policy makers should mitigate the policies that related to uncertainty because they have both economic and environmental impacts. On the contrary, GPR plunges EF which accomplishes that the BRMCC countries can reduce EF at the cost of GPR. This validates the second hypothesis that the mitigating effect is stronger than the escalating effect. These findings are backed by [8,20]. GPR discourages economic growth and energy consumption, consequently it plunges environmental degradation. Therefore, the policy makers should be caution of using GPR as a tool to mitigate EF because it has negative economic and social effects.

Last but not least, the D-H causality test reports a two-way causality between GDP and EF which is consistent with [41]. This supports the feedback hypothesis and the policy makers should control EPU to achieve economic growth. Likewise, REN and GDP have a bi-directional causal relationship which implies that using REN is a way to achieve pollution free environment without losing economic growth (decoupling). Similar findings are observed by [44].

7. Conclusions

Since the turn of 21st century, the world is experiencing episodes of high economic policy uncertainty (EPU) and geopolitical risk (GPR). These two factors not only affect the socioeconomic indicators, but also the environmental quality. On this basis, the purpose of

this study is to investigate the impact of EPU, GPR, and energy consumption on ecological footprint (EF) in the BRMCC countries. In order to estimate the long-run relationships, we employ FMOLS, DOLS, and AMG estimators. We also use the D-H causality test to probe the causality between the variables.

The study finds that EPU escalates EF. This implies that EPU leads to environmental degradation in these countries. On the contrary, our study also finds that GPR decreases EF. This indicates that GPR ameliorates the environmental quality in the BRMCC countries. The findings also reveal that non-renewable energy escalates EF, whereas renewable energy decreases it. The implication of these findings is that while non-renewable energy deteriorates environmental quality; renewable energy upsurges environmental quality. Nevertheless, the D-H causality test concludes that there is bidirectional causality between GDP and EF, and between renewable energy and GDP. This expounds that economic growth is responsible for environmental degradation. On the other hand, environmental degradation affects the GDP as well. In addition, GDP causes renewable energy consumption and vice-versa.

Given these findings, related policies are put forward. First, policy makers should take measures to mitigate the EPU because EPU is responsible for environmental degradation. International organizations such as World Bank and IMF should guide the emerging countries to devise appropriate economic policies. In this regards, international conferences, summits, and trainings can be held. Second, the economic policies should be announced and implemented for a longer time span to impede the uncertainty. Moreover, the economic policies should be publicly announced, and should not have any associated implicit information.

Although GPR is a significant factor that mitigates environmental degradation, it cannot be used as an effective tool in controlling environmental degradation. Nonetheless, a strong economic policy could adequately serve as a cushion to balance the potential negative effects of GPR during periods of political instability and regional tensions. Furthermore, policy makers should put forward some alternatives on innovations and technological advancements that can help to improve environmental quality without poising adverse effect on GPR. In addition, these economies should further intensify their energy transition programs. This implies that, renewable energy utilization should be further promoted. As renewable energy leads to sustainable economic growth, policy makers should encourage its usage by giving subsidy to renewable products. Research grants for renewable energy should be awarded. Investment in renewable energy should be encouraged by rendering subsidized loans. Public awareness programs could be launched to encourage people to use renewables.

There are a few limitations of this study. First, a small data sample with respect to country and time period was used due to unavailability of more data. Moreover, due to the small dataset, several control variables are not added in the models, which may lead to issues of omitted variable bias. A for future research directions, researchers may consider the world uncertainty index as a proxy of EPU. Moreover, quantile-based estimation techniques could be used to present more comprehensive findings on the relationship between EPU, GPR, and EF. Finally, asymmetric modelling could also be employed to explore the positive and negative shocks of EPU and GPR on environmental degradation.

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