Re-evaluating the asymmetric economic policy uncertainty, conventional energy, and renewable energy consumption nexus for BRICS

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Abstract

Economic policy uncertainty has increased throughout the world since the previous few decades. Moreover, economic policy uncertainty significantly influences economic activities that may also produce a strong effect on energy consumption. The objective of the study is to investigate the effect of economic policy uncertainty on renewable and non-renewable energy consumption in the case of BRICS countries, for the period 1991–2019. The outcome of the panel NARDL-PMG modeling technique demonstrates that a positive shock in economic policy uncertainty exerts a negative impact on renewable energy consumption and positive impact on non-renewable energy consumption in the short-run and long-run. However, a negative shock in economic policy uncertainty has a positive impact on renewable energy consumption and negative impact on non-renewable energy consumption in the long run, while this effect becomes statistically insignificant in the short run. Numerical elements of long-run results infer that economic policy uncertainty is more influence on renewable energy compared to non-renewable energy consumption in BRICS in long run. On the basis of findings, the study suggests that the authorities should launch such programs that result in shrinking uncertainties linked with economic policy.

Keywords Economic policy uncertainty · Energy consumption · NARDL-PMG

Introduction

Since the last few decades, the menace of global warming has jeopardized the existence of all living creatures on the earth and the main cause behind this threat is the emissions of greenhouse gasses, particularly CO₂ that has the largest share among all the greenhouse gasses. The gravity of the problem has become more severe for the emerging and resourceful economies where the levels of economic uncertainties are also high. According to @@@Global Energy and CO₂ Status Report, in 2018, there was a record rise in CO₂ emissions that increased by 1.7% calculated almost as high as 33.1 Gt CO₂ (IEA 2019). Pollution fines

are significant tool to charitable donations of corporations (Wu et al. 2021; He et al. 2018a). BRICS economies are among the top countries that are the highest emitters of CO₂ in the world (Balsalobre-Lorente et al. 2019; Nathaniel et al. 2021a, b; He et al. 2018b). In 2018, the collective share of these economies in total CO₂ emissions of the world is 42%.¹ This contribution by BRICS economies is not surprising as they are the fastest-growing economies of the world (Su et al. 2021; Qin and Ozturk 2021); hence, their energy demand is also going up which is the main reason behind greenhouse gas emissions (Ozturk 2015). According to the BRICS energy report, in 2019, the energy consumed by these countries is one third of the world's total energy consumption, and this is expected to go up to 40% by the year 2040. Clearly, this is pertinent when one contemplates that though CO₂ discharges lessened in the developed economies, due to the use of clean energy, and came down from 40 to 25%, during 1990–2018, whereas, CO₂ emissions amplified in the BRICS economies, due to reliance on fossil fuels, from 27 to 42% in the same period (BP, 2019; IISD,

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¹ <https://www.ucsusa.org/resources/each-countrys-share-co2-emissions>

2019). Energy has become the lifeblood of economic growth (Rafindadi and Ozturk 2017; Ali et al. 2020). It is important to note that many researchers have declared energy as a primary determinant of CO₂ emissions and explored the energy-environment nexus (Ozturk 2010; Ozturk and Acaravci 2013; Dong et al. 2019; Baloch et al. 2021; Nathaniel et al. 2021a, b), but very few have included the variable of policy uncertainty while finding the determinants of energy demand.

Worldwide uncertainties have also made the global economic and political policies more volatile. Indeed, whatever the root causes of uncertainty is, it exerts some effects on economic affairs (Rodrik 1991; Blattman and Miguel 2010). For example, in 2003, global unrest was caused due to the second Gulf war and created a lot of uncertainties concerning the world economy (Rigobon and Sack 2005). Similarly, the COVID-19 pandemic has shocked the world, and its adverse impact on the world economy will be felt over a long period of time due to the uncertainty attached to it.² The impact of global uncertainty on business and economic activities, most of the time, is negative which in turn affects the decision-making of these entities (Tugcu et al. 2012). Since the uncertainties affect the production decisions of businesses and firms, hence, it can also influence the level of energy consumption and accordingly the CO₂ emissions (Ozturk and Bilgili 2015; Jiang et al. 2019; Ozcan and Ozturk 2019). The countries today are connected than ever before, hence, the impact of policy uncertainties with regards to economic decision-making in some economies can spread worldwide (Al Thaqeb and Algharabali 2019). On the other hand, the uncertainties in economic policies and decisions can impact energy consumption, positively and negatively, through direct government actions (Sharif et al. 2020).

Academics and legislators are both hands in gloves to see the impact of economic policy uncertainty on business and economic decision-making. In this context, monetary, fiscal, or administrative apprehensions have normally been linked to depressions by various economists not only in the past but in present times as well (Bernanke 1983; Rodrik 1991; Hassett and Metcalf 1999; Bloom 2009; Bachmann et al. 2013). A complete body of connected researches display that ambiguity in economic decisions has a hostile influence on economic actions (Jiang et al. 2020; Hu and Gong 2019).

Levenko (2020) confers uncertainty as a catalyst of domestic reserves, whereas Das and Manoharan (2019) emphasize the stock exchange, and Xu (2020) deliberates commercial invention. Recent studies on environment science claim that climate dimensions are significant

in economic and business decision-making (Brock and Hansen 2018; Contreras and Platania 2019; Workman et al. 2020). @@@The higher the level of uncertainty in the climate dynamics the chances for an economy to converge to an advanced steady-state will become grim (Golub et al. 2020). Certainly, Guo et al. (2019) do contend that uncertainties, if over and underestimated, have consequences for energy and environmental policymaking. This is not @@@startling since policy indecision is projected to have a noteworthy impact on business fiscal strategies, asset-building plans and also on customer expenses. Moreover, Istiak and Alam (2019) observed that policy indecision exerted an asymmetric impact on inflationary anticipation, while Istiak and Alam (2019) noticed the same effects for bilateral relations between Mexico and the USA, and Hassan et al. (2021) confirmed for trade volumes. However, the literature is lacking on the impact of economic policy uncertainty on energy consumption, while this study fills the gap.

Therefore, our primary focus in this study is to analyze the link between economic policy uncertainty and energy consumption (renewable and non-renewable energy consumption). The BRICS economies are chosen as a sample because they are the fastest-growing economies and their energy demand is rising due to an enormous increase in social and economic activities. Besides, the level of economic uncertainties is high in these economies as compared to developed economies (Ozturk et al. 2010; Adams et al. 2020). Previously, all the studies have included the symmetric assumption with regards to the variable of economic policy uncertainty; however, in this study, we have relied on the asymmetric assumption. Lei et al. (2021) noted that economic policy uncertainty is non-linear, significantly influencing the renewable energy consumption in china. While Zhang et al. (2021) infer that economic policy uncertainty has non-linear negative impact on renewable energy consumption in BRICS, this infers that role of economic policy uncertainty on renewable and non-renewable energy is yet to be unleashed in energy literature even though, in recent periods. This study is also contributed into literature by updating the policy insights for BRICS nations. In the symmetric assumption, the positive and negative change moves in the opposite direction with the same magnitude, while in the asymmetric assumption, the positive and negative change can move in the same or opposite direction with significantly different magnitudes. This study measures the positive and negative shocks impacts on energy sector. This study fills a gap in the literature adopting positive and negative shocks of economic policy uncertainty and energy consumption in BRICS but also reduces the ambiguity in literature. Economic shocks, such as the 1997 Asian financial crisis, 2008 global financial crisis, and even the COVID-19 pandemic, have considerable influences on energy consumption. Such type of study is more important in literature of energy

² For more detail see Baker et al. (2020), Altig et al. (2020), and Bakas and Triantafyllou (2020).

consumption. The study also helps explain the internal and external mechanism of economic policy uncertainty affecting the energy consumption. To that end, we apply the panel NARDL-PMG technique.

The remainder of the study is organized as follows. Next, we will discuss the data and estimation technique is discussed in section two. In section three, we shed light on the results and finally conclude the study in section four.

Model and methods

The basic aim of this study is to analyze the relationship between economic policy uncertainty and renewable and non-renewable energy consumption in BRICS economies. The studies of Anser et al. (2021) and Sohail et al. (2021) have to lead us towards the following base model.

$$RE_{it} = \alpha_0 + \alpha_1 EPU_{it} + \alpha_2 GDP_{it} + \alpha_3 FDI_{it} + \alpha_4 Trade_{it} + \mu_{it} \quad (1)$$

$$NRE_{it} = \alpha_0 + \alpha_1 EPU_{it} + \alpha_2 GDP_{it} + \alpha_3 FDI_{it} + \alpha_4 Trade_{it} + \mu_{it} \quad (2)$$

where renewable energy (RE) and non-renewable energy (REC) consumption are a function of economic policy uncertainty (EPU), gross domestic product (GDP), foreign direct investment (FDI), trade openness (Trade), and a random error term (μ). GDP, FDI, and trade are key factors of energy consumption of each economy (Keho 2016; Ozturk 2017; Usman et al. 2021). Therefore, we have included GDP, FDI, and trade variables in energy consumption model to reduce the omitted variables problem. Subscript “ t ” represents the time dimension and “ i ” represents the country. The expected signs of the independent variables can either be positive or negative (Sohail et al. 2021). The model described above is a long-run model; however, our interest is in both the short- and long-run results. Hence, in the next step, we will reshape model (3) into the error correction format as specified underneath:

$$\begin{aligned} \Delta RE_{it} = & \gamma + \sum_{p=1}^{n1} \gamma_{1p} \Delta RE_{it-p} + \sum_{p=0}^{n2} \gamma_{2p} \Delta EPU_{it-p} \\ & + \sum_{p=0}^{n3} \gamma_{3p} \Delta GDP_{it-p} + \sum_{p=0}^{n4} \gamma_{4p} \Delta FDI_{it-p} \\ & + \sum_{p=0}^{n5} \gamma_{5p} \Delta Trade_{it-p} + \pi_1 REC_{it-1} \\ & + \pi_2 EPU_{it-1} + \pi_3 GDP_{it-1} + \pi_4 FDI_{it-1} + \pi_5 Trade_{it-1} + \mu_{it} \end{aligned} \quad (3)$$

$$\begin{aligned} \Delta NRE_{it} = & \gamma + \sum_{p=1}^{n1} \gamma_{1p} \Delta NRE_{it-p} + \sum_{p=0}^{n2} \gamma_{2p} \Delta EPU_{it-p} \\ & + \sum_{p=0}^{n3} \gamma_{3p} \Delta GDP_{it-p} + \sum_{p=0}^{n4} \gamma_{4p} \Delta FDI_{it-p} \\ & + \sum_{p=0}^{n5} \gamma_{5p} \Delta Trade_{it-p} + \pi_1 NRE_{it-1} \\ & + \pi_2 EPU_{it-1} + \pi_3 GDP_{it-1} + \pi_4 FDI_{it-1} + \pi_5 Trade_{it-1} + \mu_{it} \end{aligned} \quad (4)$$

After redesigning the model, the subsequent Eq. (4) is dubbed panel ARDL-PMG forwarded by Pesaran et al. (1999, 2001). Once estimated, this equation gives us both the short- and long-run results. The estimated coefficients of the first-differenced (Δ) variables illustrate the short-run results, while, the long-run results can be traced from the estimates—normalized on. The long-run results need to fulfill another condition called co-integration before we make a decision whether our long-run results are valid or not. To that end, we generate a residual series by using Eqs. (3) and (4) and called this series ECM. Next, we adjust the lagged value of the ECM, represented by ECM_{t-1} , in place of the linear relationship of lagged level variables. If the estimate attached to ECM_{t-1} is negatively significant, we can say that our results are co-integrated, i.e., valid. Moreover, this method can estimate the mixtures of the variables $I(0)$ and $I(1)$ because it has the power to look after the integrating properties of the variables; hence, pre-unit root testing is not a mandatory condition in this method which is a major advantage of this method over others.

To achieve our goal of analyzing the asymmetric impact of EPU on renewable energy and non-renewable energy consumption, we restructure our main variable, i.e., EPU, and break it into positive (EPU^+) and negative (EPU^-) shocks with the help of partial sum procedure. For other applications of the same procedure, see Ullah et al. (2021) and Ullah and Ozturk (2020). Mathematically, we can illustrate the partial sum procedure as shown below:

$$EPU^+_{it} = \sum_{n=1}^t \Delta EPU^+_{it} = \sum_{n=1}^t \max(\Delta EPU^+_{it}, 0) \quad (5a)$$

$$EPU^-_{it} = \sum_{n=1}^t \Delta EPU^-_{it} = \sum_{n=1}^t \min(\Delta EPU^-_{it}, 0) \quad (5b)$$

where EPU^+ represents the positive changes in the series and EPU^- represents the negative changes in the series. After breakdown of the EPU, next, we put these partial sum variables in the place of the original EPU variable in Eq. (3). Consequently, the equation will take the following form:

Table 1 Variables definitions and data description

Variables	Symbol	Definitions	Mean	Std. Dev
Renewable energy consumption	RE	Renewable energy is measured in quad BTU from the sum of wind energy, solar energy, nuclear energy, and biofuel energy	2.41	2.86
Non-renewable energy consumption	NRE	Non-renewable energy is measured in quad BTU from the sum of coal, natural gas, and petrol	25.5	30.1
Economic policy uncertainty	EPU	The index is calculated on the basis of no. of “uncertainty” related words in economic intelligence unit (EIU)	3.43	3.25
GDP growth	GDP	GDP per capita growth (annual %)	3.25	2.67
Foreign direct investment	FDI	foreign direct investment, net inflows (BoP, current US\$)	23.1	2.00
Trade openness	Trade	Trade (% of GDP)	42.2	15.6

$$\begin{aligned}
\Delta RE_{it} = & \alpha_0 + \sum_{k=1}^n \beta_{1k} \Delta RE_{it-k} + \sum_{k=0}^n \beta_{2k} \Delta EPU^+_{it-k} \\
& + \sum_{k=0}^n \delta_{3k} \Delta EPU^-_{it-k} + \sum_{k=0}^n \beta_{4k} GDP_{it-k} \\
& + \sum_{k=0}^n \delta_{5k} FDI_{it-k} + \sum_{k=0}^n \beta_{6k} Trade_{it-k} \\
& + \omega_1 RE_{it-1} + \omega_2 EPU^+_{it-1} \\
& + \omega_3 EPU^-_{it-1} + \omega_4 GDP_{it-1} + \omega_5 FDI_{it-1} \\
& + \omega_6 Trade_{it-1} + \mu_{it}(6)
\end{aligned}$$

$$\begin{aligned}
\Delta NRE_{it} = & \alpha_0 + \sum_{k=1}^n \beta_{1k} \Delta NRE_{it-k} + \sum_{k=0}^n \beta_{2k} \Delta EPU^+_{it-k} \\
& + \sum_{k=0}^n \delta_{3k} \Delta EPU^-_{it-k} + \sum_{k=0}^n \beta_{4k} GDP_{it-k} \\
& + \sum_{k=0}^n \delta_{5k} FDI_{it-k} + \sum_{k=0}^n \beta_{6k} Trade_{it-k} + \omega_1 NRE_{it-1} \\
& + \omega_2 EPU^+_{it-1} + \omega_3 EPU^-_{it-1} \\
& + \omega_4 GDP_{it-1} \\
& + \omega_5 FDI_{it-1} + \omega_6 Trade_{it-1} + \mu_{it}(5)
\end{aligned}$$

@@@Equations 5 and 6 can now be called panel NARDL-PMG proposed by Shin et al. (2014). If we compare both versions of ARDL, i.e., linear and non-linear, we can see that both look identical except the inclusion of partial sum variables in the non-linear model. Hence, both the linear and non-linear models are subject to the same OLS technique and diagnostic tests (Shin et al. 2014). We run the Hatemi-J (2012) nonlinear causality test to scrutinize the causal relationship between economic policy uncertainty and renewable energy and non-renewable energy consumption for BRICS during the period 1991–2019.

Data

For empirical exercise, annual data over the period ranging from 1991 to 2019 are used for BRICS economies. Data on renewable energy consumption (quad BTU) and non-renewable energy consumption (quad BTU) are gathered from the @@@Energy Information Administration (EIA), whereas economic policy uncertainty is index of number of “uncertainty” that come from “Worlduncertaintyindex.com.” While GDP per capita growth (annual %), FDI net inflows (BoP, current US\$), and trade (% of GDP) are obtained from World Bank, data on FDI has been converted into log form in order to make standardize the data uniformly. @@@Table 1 contains descriptive statistics for the renewable energy consumption, non-renewable energy consumption, EPU, GDP, FDI, and trade data pertaining to panel of BRICS economies. The mean of RE, NRE, EPU, GDP per capita, FDI, and trade is 2.41 quad BTU, 25.5 quad BTU, 3.43, 3.25%, 23.1 current US\$, and 42.2%, respectively, while the standard deviation are 2.86 quad BTU, 30.1 quad BTU, 3.25, 2.67%, 2.00 current US\$, and 15.6%, respectively. The pattern of economic policy uncertainty in BRICS is also reported in Fig. 1.

Empirical results and discussion

Before estimating panel symmetric and asymmetric models, it is imperative to confirm the stationary properties of all the variables. For panel unit root testing, we have adopted three tests, i.e., LLC, IPS, and ADF. The findings of these three tests demonstrate that few variables are stationary at level and few are stationary at I(1); however, none of the variables is I(2). These results fulfill the prerequisite of applying the ARDL-PGM and NARDL-PMG approaches. The outcomes of the panel unit root tests are given in Table 2.

Fig. 1 Pattern of economic policy uncertainty in BRICS

Table 2 Panel unit root testing

	LLC		IPS		ADF		
	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)	
RE	2.364	−1.587*	I(1)	−0.074	I(1)	0.016	−7.861*** I(1)
NRE	−0.39	−2.031**	I(1)	−0.452	I(1)	−0.477	−6.755*** I(1)
EPU	0.118	−4.843***	I(1)	−2.231**	I(0)	−1.925**	I(0)
GDP	−2.924***		I(0)	−3.157***	I(0)	−4.371***	I(0)
FDI	−2.994***		I(0)	−3.008***	I(0)	−4.016***	I(0)
Trade	−2.625***		I(0)	−2.738***	I(0)	−3.242***	I(0)

* p value < 0.10 ** p value < 0.05 *** p value < 0.01.

Table 3 delivers the outcomes of coefficient estimates of both the renewable energy consumption and non-renewable energy consumption models. The long-run ARDL-PMG estimate of the economic policy uncertainty in the renewable energy consumption model is negative and significant implying that a 1% upsurge in economic policy uncertainty leads to 0.834% reduction in renewable energy consumption in BRICS countries. There is no long-run association between economic policy uncertainty and non-renewable energy consumption as the long-run ARDL-PMG coefficient estimate of the economic policy uncertainty

in the non-renewable energy consumption is insignificant. The short-run findings of ARDL-PMG demonstrate that economic policy uncertainty has a significant negative impact on renewable energy consumption and a significant positive impact on non-renewable energy consumption. The usefulness of ARDL-PMG results is confirmed from the findings of certain diagnostic tests given in panel C. The overall goodness of both models is confirmed from a significant coefficient estimate of log-likelihood ratio. The long-run cointegration among the variables is confirmed through ECM test of cointegration and the

Table 3 Long- and short-run coefficient estimates of renewable and non-renewable energy consumption

Variable	RE		NARDL-PMG		NRE		NARDL-PMG	
	ARDL-PMG				ARDL-PMG			
	Coefficient	t-Stat	Coefficient	t-Stat	Coefficient	t-Stat	Coefficient	t-Stat
Long-run								
EPU	−0.834*	1.853			0.642	0.937		
EPU_POS			−2.192*	1.925			1.951*	1.775
EPU_NEG			−4.041**	1.987			2.001*	1.722
GDP	0.102	0.297	−0.444	1.252	0.781**	2.416	0.036	0.127
FDI	−2.165**	2.093	−2.996	1.515	2.290***	3.485	3.060***	3.695
Trade	7.501***	2.685	2.031**	2.163	2.914	0.773	10.50***	4.070
Short-run								
D(EPU)	−0.030*	1.701			0.126**	2.129		
D(EPU(-1))	0.015	0.774						
D(EPU_POS)		−0.026*	1.842			0.483*	1.817	
D(EPU_POS(-1))		0.038	1.075			0.200	1.218	
D(EPU_NEG)		0.005	0.280			−0.158	1.070	
D(EPU_NEG(-1))		0.010	0.330			−0.308	1.277	
D(GDP)	0.015	1.370	0.002**	2.334	0.021	0.782	0.099**	2.071
D(GDP(-1))	−0.028	0.964	−0.037	0.951			−0.053	0.584
D(FDI)	0.141**	2.299	0.194*	1.851	0.915	0.808	0.421*	1.900
D(FDI(-1))	0.071	0.955	0.056	0.808			2.762	1.156
D(Trade)	0.222	0.938	0.254	1.210	0.241	0.482	0.946	0.850
D(Trade(-1))	0.301	1.416	0.285	1.153			−0.450	0.563
C	−1.107	0.977	1.000	0.959	−3.406*	1.705	−3.823**	1.981
Diagnostics								
Log-likelihood	155.9		165.1		284.3		328.5	
ECM(-1)	−0.224**	1.969	0.159*	1.905	−0.281*	1.826	−0.322*	1.732
Kao-Cointegration	2.755**		5.365***		3.023**		6.565***	
Wald-LR-EPU			4.945***				5.655***	
Wald-SR-EPU			1.255				0.324	

* p value < 0.10 ** p value < 0.05 *** p value < 0.01.

Kao-Cointegration test. Coefficient estimates of ECM in both models are statistically significant and hold a negative sign as required for convergence and Kao-cointegration coefficient estimates in both models are also statistically significant.

The study also tries to investigate how renewable and non-renewable energy consumption responds to positive and negative shocks in the economic policy uncertainty. The long-run NARDL-PMG model results show that positive shocks in economic policy uncertainty exert a significant and negative impact on renewable energy consumption and a significant and positive impact on non-renewable energy consumption. The coefficient estimates of economic policy uncertainty infer that a percent increase in economic policy uncertainty lead to 2.192% reduction in renewable energy consumption and 1.951% upsurge in non-renewable energy consumption in the long-run. The negative shocks in economic policy uncertainty positively affect renewable energy consumption and negatively affect non-renewable energy consumption.

This finding is also consistent with Sohail et al. (2021), who noted that monetary policy uncertainty has negative effects on renewable energy consumption in short and long run. Economic policy uncertainty has negative effects on energy sector's renewable energy investment and consumption. Economic policy uncertainty has to impact financial development, investment, household saving and consumption decisions, firm innovations, tourism, and bank stability, green economic growth (Al-Thaqeb and Algharabali 2019), which in turn negatively affect renewable energy consumption. Economic policy uncertainty hinders renewable energy consumption due to the usage of other sources of energy that are more affordable. Policymakers adopt less effective renewable energy policies in an uncertain situation in any economy. Total costs of vehicles depends upon on energy consumption travel time (Li et al. 2020). For Pakistan, economy and energy consumption are stimulating the CO₂ emission (Shaheen et al. 2020).

Firms are more likely to deploy conventional cheap energy sources for the production process which in turn economic policy uncertainty negatively affects renewable energy consumption. Sohail et al. (2021) noted that policy uncertainty harmfully affects renewable energy investment and renewable consumption, which they indicate as “consumption effect.” Economic policy uncertainty has dynamic impacts on energy consumption, as Pirgaip and Dinçergök (2020) reported a dynamic links economic policy uncertainty and energy consumption. This also means that economic policy uncertainty inactivate a demand shock for energy consumption which in turn negatively affect renewable energy consumption.

An increase in economic policy uncertainty has prevented renewable energy use by increasing the non-renewable energy use in BRICS economies. A similar finding is also noted by Pirgaip and Dinçergök (2020) for G7 economies. Findings infer that economic policy uncertainty has adverse effects on economic activity which may result in reduced renewable energy consumption. Findings infer that economic policy uncertainty force to non-renewable energy instead of reducing renewable energy consumption. Findings also reported that economic policy uncertainty has a harmful impact on the green energy side as compared to the dirty energy side in BRICS. Economic policy uncertainty has also a direct and indirect effect on energy consumption in BRICS. Thus our finding implies that economic policy uncertainty is a key asymmetric variable of renewable and non-renewable energy consumption in BRICS economies.

This finding is also supported by Shafiullah et al. (2021), who noted that economic policy uncertainty significantly hurt the enterprises’ decision-making and thus reduces the renewable energy consumption. Economic policy uncertainty decreases firms short-term and long-term firm investment behavior by decreasing the clean energy consumption. Also, economic policy uncertainty increase the prospect of bankruptcy, which results in increased financing costs, and, thus, enterprises’ decrease renewable energy consumption, while our finding also infers that economic policy uncertainty has relatively large impact on renewable energy consumption compared to non-renewable energy consumption.

The long-run findings of other control variables reveal that GDP has no significant impact on renewable and non-renewable energy consumption. Foreign direct investment also has no significant impact on renewable energy consumption, but it exerts a significant positive impact on non-renewable energy consumption. Trade exerts a positive effect on renewable and non-renewable energy consumption.

The short-run coefficient estimates of NARDL-PMG model are explained in the same manner as we have already interpreted in the ARDL-PMG model. Just like the symmetric model, we also want to check in the asymmetric model whether short-run impacts survive in the long run or not. In

the short-run, the positive shock in economic policy uncertainty mitigates renewable energy consumption; however, it escalates non-renewable energy consumption. The coefficient estimates reveal that due to a 1% upsurge in economic policy uncertainty, renewable energy consumption decreases by 0.026% and non-renewable energy consumption increases by 0.483% in the BRICS countries. The negative shocks in economic policy uncertainty have no significant impact on renewable and non-renewable energy consumption in the short run revealed by statistically insignificant coefficient estimates of economic policy uncertainty. GDP and FDI have significant positive impact on renewable and non-renewable energy consumption in the short run. But, there is no significant association between trade and renewable and non-renewable energy consumption in the panel of BRICS countries in the short run.

In Panel C, outcomes of various diagnostic tests are described that confirm the reliability of our findings. The coefficient estimates of log-likelihood ratio in both models are statistically significant that confirms the overall goodness of the models. The long-run cointegration among the variables is also confirmed through statistically significant coefficient estimates of ECM test. The coefficient estimates of ECM is -0.159 in the renewable energy consumption model and -0.322 in non-renewable energy consumption model, which states that in the renewable energy consumption model, almost 16% convergence will be attained in 1 year, and in non-renewable energy consumption model, 32% convergence towards stability will be achieved in period of 1 year. Kao-cointegration coefficient estimates are also statistically significant confirming the existence of long-run cointegration in both models. Wald test also supports the findings by revealing that long-run asymmetries exist among variables in both models in only long run.

Finally, the results of the causality tests are reported in Table 4, confirming the bi-directional causality between the $EPU_POS \rightarrow RE$, whereas, evidence of uni-directional causality is found between $EPU_NEG \rightarrow RE$, $EPU_POS \rightarrow NRE$, and $EPU_NEG \rightarrow NRE$.

Conclusion and policy implications

One important factor that exerts a significant impact on energy consumption is economic policy uncertainty. The consequence of economic policy-related uncertainty to economic decisions is greater in today’s integrated world. Overall, economic policy uncertainty also exerts a significant effect on energy policies and climatic changes. These uncertainties may arise due to the political instability, economic situation, and the financial crisis. The basic objective of the study is to investigate symmetric and asymmetric impacts of economic policy uncertainty on renewable and

Table 4 Panel asymmetric causality test

Null hypothesis:	W-Stat	Zbar-Stat	Prob	Decision	Null Hypothesis:	W-Stat	Zbar-Stat	Prob	Decision
EPU_POS → RE	4.588	2.164	0.031	Yes	EPU_POS → NRE	4.241	1.848	0.065	Yes
RE → EPU_POS	5.599	3.084	0.002	Yes	NRE → EPU_POS	3.256	0.951	0.342	No
EPU_NEG → RE	4.709	2.274	0.023	Yes	EPU_NEG → NRE	6.168	3.602	0.000	Yes
RE → EPU_NEG	2.579	0.335	0.737	No	NRE → EPU_NEG	2.278	0.062	0.951	No
GDP → RE	1.533	-0.614	0.540	No	GDP → NRE	2.739	0.496	0.620	No
RE → GDP	2.024	-0.161	0.872	No	NRE → GDP	4.972	2.548	0.011	Yes
FDI → RE	3.079	0.808	0.419	No	FDI → NRE	4.474	2.091	0.037	Yes
RE → FDI	1.767	-0.398	0.690	No	NRE → FDI	2.514	0.288	0.773	No
Trade → RE	2.435	0.216	0.829	No	Trade → NRE	2.773	0.527	0.598	No
RE → Trade	1.589	-0.562	0.574	No	NRE → Trade	4.125	1.770	0.077	Yes
EPU_NEG → EPU_POS	3.179	0.881	0.378	No	EPU_NEG → EPU_POS	3.179	0.881	0.378	No
EPU_POS → EPU_NEG	19.94	16.14	0.000	Yes	EPU_POS → EPU_NEG	19.94	16.14	0.000	Yes
GDP → EPU_POS	0.528	-1.531	0.126	No	GDP → EPU_POS	0.528	-1.531	0.126	No
EPU_POS → GDP	2.124	-0.079	0.937	No	EPU_POS → GDP	2.124	-0.079	0.937	No
FDI → EPU_POS	0.717	-1.359	0.174	No	FDI → EPU_POS	0.717	-1.359	0.174	No
EPU_POS → FDI	1.386	-0.750	0.453	No	EPU_POS → FDI	1.386	-0.750	0.453	No
Trade → EPU_POS	1.188	-0.931	0.352	No	Trade → EPU_POS	1.188	-0.931	0.352	No
EPU_POS → Trade	2.514	0.276	0.782	No	EPU_POS → Trade	2.514	0.276	0.782	No
GDP → EPU_NEG	0.858	-1.231	0.218	No	GDP → EPU_NEG	0.858	-1.231	0.218	No
EPU_NEG → GDP	2.091	-0.109	0.913	No	EPU_NEG → GDP	2.091	-0.109	0.913	No
FDI → EPU_NEG	2.729	0.471	0.637	No	FDI → EPU_NEG	2.729	0.471	0.637	No
EPU_NEG → FDI	1.589	-0.566	0.572	No	EPU_NEG → FDI	1.589	-0.566	0.572	No
Trade → EPU_NEG	1.727	-0.440	0.660	No	Trade → EPU_NEG	1.727	-0.440	0.660	No
EPU_NEG → Trade	2.652	0.402	0.688	No	EPU_NEG → Trade	2.652	0.402	0.688	No
FDI → GDP	2.297	0.089	0.929	No	FDI → GDP	2.297	0.089	0.929	No
GDP → FDI	5.965	3.462	0.001	Yes	GDP → FDI	5.965	3.462	0.001	Yes
Trade → GDP	2.107	-0.086	0.932	No	Trade → GDP	2.107	-0.086	0.932	No
GDP → Trade	1.932	-0.246	0.806	No	GDP → Trade	1.932	-0.246	0.806	No
Trade → FDI	2.841	0.589	0.556	No	Trade → FDI	2.841	0.589	0.556	No
FDI → Trade	3.888	1.552	0.121	No	FDI → Trade	3.888	1.552	0.121	No

* p value < 0.10 ** p value < 0.05 *** p value < 0.01.

non-renewable energy consumption in BRICS countries. The study has used ARDL-PMG and NARDL-PMG techniques for empirical analysis for annual data ranging from 1991 to 2019. After careful investigation, the study claims that there is no previous study done to investigate the impact of economic policy uncertainty on renewable and non-renewable energy consumption.

The long-run findings of ARDL-PMG determine that economic policy uncertainty has a significant negative effect on renewable energy consumption; however, it exerts no significant impact on non-renewable energy consumption. The short-run outcomes of ARDL-PMG approach show that economic policy uncertainty has a negative impact on renewable energy consumption and a positive impact on non-renewable energy consumption. The long-run and short-run linear effects are also maintained in non-linear empirical analysis. The findings of NARDL-PMG infer that positive changes

in economic policy uncertainty have negative effects on renewable energy consumption and positive effects on non-renewable energy consumption in the long run and short run. Similarly, the negative changes in economic policy uncertainty also have a positive impact on renewable energy consumption and a negative effect on non-renewable energy consumption in the long run, but, the effect is statistically insignificant in the short run.

The authorities and policymakers must explore effective economic policies that increase the usage of clean energy. The BRICS authorities must deploy additional funds from foreign and domestic investments. Also, local and foreign investors can be inspired to renewable energy projects by donating funds and exempt the taxes that discourage investments in clean energy in a certain situation. The government should retain the consistency of economic policies especially clean energy policies based on the full concern

for the economic environment. Maintaining stable economic policies, especially policies in the energy sector, could encourage its realization of carbon emission reduction targets. The empirical findings call for vital changes in clean energy policies to accommodate economic policy uncertainties, and economic policies must be dynamic in nature of consequences. Government authorities must prioritize their aims in policies for a healthy environment along with economic activities.

The analysis of economic policy uncertainty and energy consumption may be an important theme for other high pollutant economies. We leave this prospect for future empirical studies. Authors should also use a similar econometric approach for better empirical findings.

Authors' contributions This idea was given by Qingrui Zeng. Qingrui Zeng and Xiaofang Yue analyzed the data and wrote the complete paper.

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Availability of data and materials The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethical approval Not applicable

Consent to participate I am free to contact any of the people involved in the research to seek further clarification and information.

Consent to publish Not applicable

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