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RESEARCH ARTICLE

# Economic policy uncertainty and $CO_2$ emissions: a comparative analysis of developed and developing nations

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## Abstract

Energy consumption is essential for economic growth; however, its consumption also increases $CO_2$ emissions, which contributes to climate change and environmental degradation. However, both environmental sustainability and sustainable development can be achieved by clean energy (CE) consumption since it consists of noncarbohydrates energy sources that seldom or do not cause $CO_2$ emissions. Therefore, the current study considers economic policy uncertainty (EPU) to study the impacts of CE on $CO_2$ emissions that control economic growth (GDP) and urbanization in both developed and developing nations. The findings from ARDL show that EPU significantly increases $CO_2$ emissions in both the long and short run for both developing and developed nations. While CE and urbanization contribute to improving environmental quality. Economic growth increases $CO_2$ emissions. The results could have a few significant practical impacts on economic policies across which policymakers could try to reduce policy uncertainty by participating in and organizing international treaties and summits. Additionally, international organizations could organize programs to reduce EPU. The role of political stability can be effective in reducing EPU in these countries. Moreover, these nations should introduce environmentally friendly innovation and clean energy technologies and give tax releases on the import and use of CE products while increasing R&D budgets.

**Keywords** Clean energy consumption · Economic policy uncertainty · Economic growth · $CO_2$ emissions · Sustainable development goals

## Introduction

In recent times, greenhouse gas emissions appeared as the biggest contributor to global warming and climate change. So, policymakers these days are largely concerned with the increasing levels of carbon emissions. For sustaining the intergenerational equity, the depletion of natural resources, energy-led economic growth trajectory, and global consumption pattern are causing difficulty. Therefore, the basics of sustainable development are harmed. To deal with this global challenge, sustainable development goals (SDGs) have been introduced by the United Nations in 2015. According to these SDGs, countries around the globe will have to fulfill their developmental plans by the end of 2030. The goal of SDGs is to maintain the global balance by resetting the prevailing economic growth path. Among the 17 SDGs, SDGs 7 and 13 deal with clean and green energy production and climate action, respectively, and are important for environmental sustainability.

The need for commercial energy is escalating with an expansion in industrial activities and population growth. In the production of commercial energy, the major contributor is fossil fuel. The ambient amount of air pollution is aggravated by the burning of fossil fuels raising climatic issues (Balsalobre-Lorente et al. 2021; Al Mulali et al 2015; Clercq and De 2019; Mehmood 2021;Cheng et al. 2021). SDG 7, i.e., clean and affordable energy, should be accomplished to address SDG 13. Hence, to tackle climatic issues, it is

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necessary to discover and develop clean energy (CE) solutions. This argument encourages the fundamental principle of this study.

These days, debates over climatic issues and their mitigation policies involve the Paris Climate Change Agreement. It illustrates the vital role being portrayed by the United Kingdom (UK) in rebuilding climatic stability, after the removal of the USA from the COP-21. Though, with the European and other developed nations, the importance of the UK is relatively weak in processing the climatic shift concerns. The UK emphasized their breakdown in managing the climate change concerns during the group of seven (G7) Presidency of the Climate and Clean Air Coalition in 2019. Although the policies regarding air quality in the UK abide by the European Union directives, they are turning out to be futile (CCAC 2021). This emerged through the legislative argument on the energy bill, which is intended to net zero emissions by 2050 (E&T 2019). The ecological safety procedures were also confronted by the Yellow Vest protest movement, due to this environment policy of uncertainty generated in the pro-ecological policy for France (Clercq 2019). This shows the importance of effective decision-making of government institutions for environmental protection. Environmental quality is linked with economic policies and economic policies have a fundamental role in shaping the climate of any nation. To measure the economic policy uncertainty, an index has been formed.

Theoretically, Baker et al. (2016) conceptualized the term "policy uncertainty." This index measures the risk of government policies that are undefined for the near future. This index is based on the number of newspaper articles, which are containing the term uncertainty in any country. According to Jiang et al. (2019), a rise in policy uncertainty can distract the emphasis of policymakers to other important matters than ecological sustainability. This can badly influence ecological consequences and policies.

In a few decades, the economic development around the globe has increased tremendously and has had a massive impact on ecological degradation. According to Tiba and Omri (2017), the linkage between energy, income, and ecology has urged policy experts and academia to have an extensive investigation of their causal relationship. Energy consumption boosts gross domestic product (GDP) that upsurges carbon emissions and ecological risks and stimulates climate change by global warming. Significant increases in carbon emissions are linked with an increase in energy consumption from fossil fuels (Adewuyi and Awodumi 2017). To protect the planet, carbon emissions need to be taken seriously as they are the key contributor to ecological degradation and global warming (Bilgili et al. 2016). The correlation between economic growth and ecological performance is interpreted as a tradeoff; after the surge in energy consumption, it was observed that sustainable economic growth should be ensured without any devastation to the ecosystem (e.g., water pollution, loss of biodiversity, deforestation, and climate change).

These days, the major concern of several countries is the accomplishment of the SDGs as they cater to the social, economic, and ecological aspects. The global impact of environmental issues which includes climate change, global warming, and air pollution casts a negative impact on economic agents. Recently, many research studies have been directed to explore the contributing factors of $CO_2$ emissions and how to combat these through various actions and solutions. In this regard, this work contributes to the ongoing discussion about environmental policy. For this purpose, this work aims to answer the following research questions: (1) How does economic policy uncertainty impact $CO_2$ emissions? (2) How do renewable energy, population, and GDP contribute to $CO_2$ emissions in the presence of EPU? (3) Is there any difference regarding the nexus of EPU-$CO_2$ emissions in developed and developing countries?

The structure of this work is as follows: the literature is in the second section, data and methodology, results and discussion, and conclusion are in the third, fourth, and fifth sections respectively.

## Literature review

Several studies have investigated the associations between energy use, economic growth, and environmental quality. These research works found contradictory results.

For example, Adams et al. (2020) suggest that the countries having high geopolitical risk and policy uncertainty are predominantly prone to ecological issues. Studies also reveal that economic complexity may affect the ecological performance and environmental degradation of a country (Doğan et al. 2019, 2021; Chu 2020; Boleti et al. 2021). Sharif et al. (2017a) analyzed the impacts of electricity consumption on economic growth. They found that electricity consumption is increasing the economic growth in Singapore. Godil et al. (2021) analyzed the impacts of renewable energy and technological innovations on transport-related $CO_2$ emissions. They found that renewable energy and innovations are lowering the emissions in China. In a study by Sharif et al. (2020b), the scholars investigated the impacts of renewable and non-renewable energy on ecological sustainability in Turkey. They found that renewable energy lowers the EF but non-renewable energy is contributing to more EF. Khan et al. (2019) conducted a study to read the associations between economic, social, and green logistics. They found that terrorism, political instability, and natural disasters are drivers of economic and environmental problems. Suki et al. (2020) investigated the EKC hypothesis in Malaysia. They found that overall and economic globalization are contributing to environmental degradation but political and social globalization are improving it. Sharif et al. (2017b) found that tourism is contributing to economic growth in the USA. Sharif et al. (2020a) investigated the role of tourism, economic growth, and globalization on $CO_2$ emissions in Malaysia. They found that economic growth and globalization are degrading the air quality but tourism is improving it.

Many studies have been done regarding the root causes of carbon emissions and ecological footprint and their linkages with energy consumption-ecological deprivation (Yao et al. 2019; Wang et al. 2020; Sharif et al. 2020c; Nathaniel et al. 2021; Pata 2021; Ahmad et al. 2021). Nevertheless, the effect of geopolitical risk, economic complexity, and economic policy uncertainty on energy consumption-ecological deprivation has not been explored significantly. Literature suggests that global uncertainties are driven by economic and political policy instability around the globe. Researchers conclude that economic outcomes will surely be affected by uncertainty while uncertainty could be either in trade, conflict/war, political or social (Blattman and Miguel 2010; Guidolin and la Ferrara 2010). For instance, according to Rigobon and Sack (2005), in 2003, the second Gulf War created economic uncertainties. Also, economic uncertainties are induced globally due to the outbreak of novel coronavirus (Baker et al. 2020; Bakas and Triantafyllou 2020; Altig et al. 2020; Le et al. 2021; Tiwari et al. 2021). Uncertainty influences the economic representatives in terms of their activities and decision-making (Bernanke 1983; McDonald and Siegel 1986; Dixit and Pindyck 1994; Carroll 1996; Bloom et al. 2001; Bansal and Yaron 2004). The influence of economic policy uncertainty in recent years, and especially in advancing macroeconomic installs, has been widely debated among practitioners, academics, and policymakers. Therefore, policy uncertainty will affect the activities and decisions of economic representatives. According to Jiang et al. (2019), ecological issues (pollution) impact the operational decisions of individuals/corporations so there is a possibility that policy uncertainty can create an impact on carbon emissions. According to Al-Thaqeb and Algharabali (2019), during times of high uncertainty, corporations act conservatively; therefore, they slow down their investments (employment and production). Hence, it also affects the population and economy, moreover, its effect is not limited to the local host but spills over to other countries as well. Furthermore, Jiang et al. (2019) believe that policy uncertainty influences carbon emissions through government policies and ordinances that can inspire or hinder environmental decay.

Few studies validate the relationship between economic activities and policy uncertainty. A study conducted in the USA suggests that capital investment and productivity are depleted due to policy uncertainty (Kang et al. 2014; Gulen and Ion 2016). Studies suggest that the jolts of policy uncertainty reduce inflation and escalate the unemployment rate (Leduc and Liu 2016). In addition, market integration and instability increase with the increase in policy uncertainty (Pástor and Veronesi 2012) also reduces the prices of stocks (Ko and Lee 2015). Now, evolution in climate science suggests that in the formulation of economic policies, climate change dynamics play a vital role (Sheehan and Sheehan 2008; Stern 2018; Hussain et al. 2020; Mehmood et al. 2021). According to Golub (2020), uncertainty about climate policy decreases the possibility that the economy unites in a highly stable state. A study conducted on Turkey by Sahinoz and Erdogan Cosar (2018) shows that extreme economic uncertainties negatively influence economic growth, consumption, and investment in the country. Responses to inflation expectation are disproportionate to the shock of policy uncertainty, depending on whether the shocks occur in a pre-financial crisis or post and whether the shocks are positive or negative (Istiak and Alam 2019). Nevertheless, very few studies have been conducted to investigate how carbon emissions are integrated with economic policy uncertainty. Therefore, this study has been carried out to bridge this gap which comprehensively deals with the impact of economic policy uncertainty integrated with carbon emissions in developed and developing countries.

The rest of the paper is designed as follows. Data and methodology are summarized in the "Data and methodology" section. Empirical findings are discussed in "Results and discussions." "Conclusion and policy recommendations" discusses conclusions and policy implications.

## Data and methodology

This research paper investigates the factors affecting economic policy uncertainties (EPU) in developed and developing countries, i.e., the USA, the UK, China, Pakistan, and India. Particularly, this investigation analyses the interaction effects of EPU and CE, spanning the period from 2000 to 2021 for the USA, the UK, China, and India, and 2010 to 2021 for Pakistan due to data availability. The annual dataset of EPU has been acquired from Economic policy uncertainty indices (https://www.policyuncertainty.com/) while other study variables have been acquired from World Bank data indicators (WDI) as shown in Table 1. Following Shahbaz et al. (2013), annual time series has been transformed into quarterly data for detailed and robust analysis. Figure 1 shows the EPU for the USA, UK, China, Pakistan, and India illustrating the decreasing trend of EPU for the USA and the UK, whereas the EPU shows an increasing trend for Pakistan, China, and India.

The autoregressive distributed lag (ARDL) approach is preferred over other approaches of Johansen and Juselius (2009) due to their advantages. This approach can be applied to time

**Table 1** Variables and data source

| Indicators | Symbol | Source |
|---|---|---|
| $CO_2$ emission | EC | WDI |
| Economic policy uncertainty | EPU | Economic policy uncertainty indices |
| Renewable energy | CE | WDI |
| Urban population | UP | |
| Gross domestic product | GDP | |

series having mixed order integrations. Furthermore, ARDL is appropriate for even small datasets. For robust results, the lag values can be incorporated as well Mehmood and Tariq (2020). In this research study, other variables are also incorporated. The novelty of this is to analyze the interactive effect of EPU and CE and their impact on carbon emissions. The calculation of this study is a little facilitated in comparison to prior studies.

The equation is as follows:

$$nEC_t = \alpha_0 + \alpha_1 \ln EPU_t + \alpha_2 \ln CE_t + \alpha_3 \ln UP_t + \alpha_4 \ln G_t + \mu_t \quad (1)$$

In Eq. 1, $\alpha_0$ is the constant term whereas the coefficients of variables are represented by $\alpha_1$, $\alpha_2$, $\alpha_3$,and $\alpha_4$ while the error correction term is represented by $\mu_t$, whereas LNEC, LNEPU, LNCE, LNUP, and LNG represent the logarithmic form of emissions of carbon dioxide (EC), economic policy uncertainty (EPU), clean energy (CE), urban population (UP), and economic growth (G), respectively.

The following mathematical equation will be used for long-run analysis:

$$\ln EC_t = \alpha_0 + \sum_{n=1}^{p} \partial_n lnEC_{t-n} + \sum_{o=1}^{q1} \delta_o lnEPU_{t-o} + \sum_{p=1}^{q2} \varphi_p lnCE_{t-p} + \sum_{r=1}^{q3} \in_r lnUP_{t-r} + \sum_{s=1}^{q4} \varnothing_s lnG_{t-s} + \mu_t \quad (2)$$

The vector error correction-based equation for short-run analysis is as follows:

$$\Delta(lnEC)_t = \alpha_0 + \sum_{n=1}^{p} \partial_n \Delta(lnEC_{t-n}) + \sum_{o=1}^{q1} \delta_o \Delta(EPU_{t-o}) + \sum_{p=1}^{q2} \varphi_p \Delta(lnCE_{t-p}) + \sum_{r=1}^{q3} \in_r \Delta(lnUP_{t-r}) + \sum_{s=1}^{q4} \varnothing_s \Delta(lnG_{t-s}) + \varepsilon_t \quad (3)$$

The change operator is represented by$\Delta$; $\vartheta_{zt-1}$ represents the error correction term (ECT) which is used for the calculation of the disequilibrium extent of the data.

## Results and discussions

Before the long- and short-run analyses, it is necessary to perform a unit root test. Hence, the unit root test has been performed with structural breaks. The findings of the unit root test are shown in Table 2. It is observed that the country under study shows mixed order integration at a level, while all the variables of all the countries are integrated at first difference. Next, the ARDL technique is applied to understand the long-run coefficient values as this technique is most appropriate for mixed order integration. ARDL technique gives some benefits to other econometric approaches. First, it is appropriate for the time series to have mixed order of integration. Second, it gives robust outcomes for small sample series.

Table 3 shows that all the selected variables for Pakistan are cointegrated at 1%, while for India, they are cointegrated at 2.5%. The co-integration existence in the model is demonstrated by the significance of the *F*-statistics. Diagnostic tests have shown that the model is free from endogeneity, heteroscedasticity, residual autocorrelation, and misallocation problems. In addition, a normal distribution is observed in residuals while both CUSUM and CUSUMSQ are stable. These are the obligatory conditions for the application of the long-run estimation technique. As these conditions are fulfilled, we can successfully run the long-run estimation model.

Table 4 shows the results of the long-run analysis. The empirical results indicate that GDP boosts the $CO_2$ emissions in all selected countries. For 1% increase in GDP causes a 0.22%, 0.56%, 0.88, 0.04%, and 0.16% upsurge in $CO_2$ emissions in the UK, the USA, Pakistan, China, and India, respectively. The result implies that a rise in the economy in these countries is achieved at the cost of environmental quality. The outcomes are supported by Mehmood et al. (2022b) for India and Pakistan, Tariq et al. (2022) for South Asia, and Xue et al. (2022) for France. However, our results are inconsistent with Li et al. (2022) for South Asian countries, Umar et al. (2020) for China, Doğan et al. (2021) for developed countries, and Zameer et al. (2020) for India. CE can mitigate the negative impacts of GDP on environmental quality. Similarly, the negative and statistically significant coefficient value of CE at a 1% level for all selected countries indicates that CE can significantly mitigate $CO_2$ emissions. For every 1% increase in CE decreases $CO_2$ emissions by 0.22%, 0.23%, 0.33%, 0.73%, and 1.4% in USA, UK, Pakistan, China, and India, respectively. This implies that a rise in

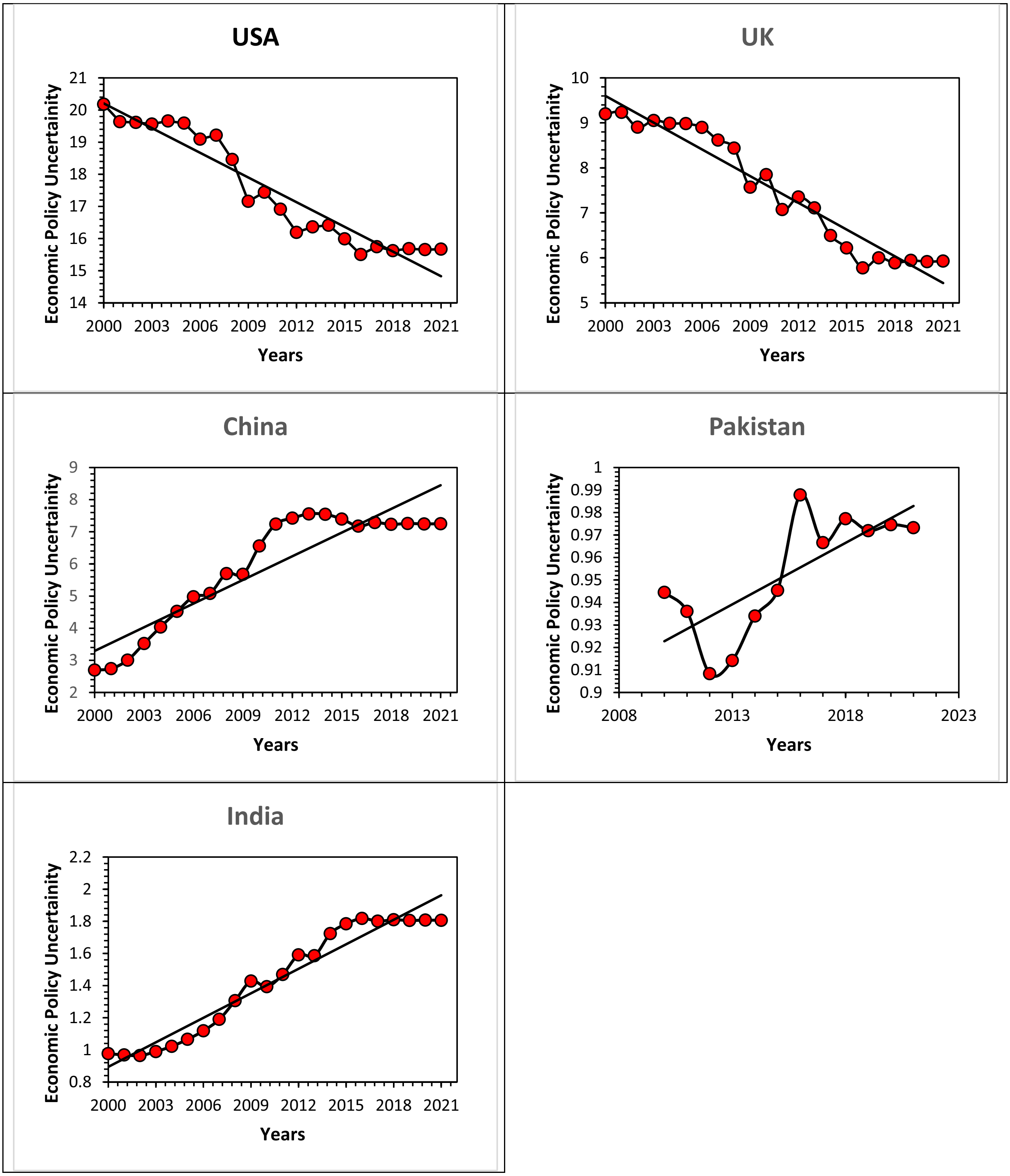


**Fig. 1** EPU for the USA, UK, China, Pakistan, and India

CE improved the environmental quality. This verdict is in line with Mehmood et al. (2022a) for G-11 countries and Al-Mulali et al. (2014) for Vietnam. However, the results are inconsistent with Sinha and Shahbaz (2018) for India and Nathaniel and Iheonu (2019) for Africa.

The empirical results show that the coefficient value of EPU is positive and statistically significant. A 1% increase

**Table 2** Unit root test

| Country | Variable | Unit root (level) | | Unit root (first difference) | |
|---|---|---|---|---|---|
| | | *T*-statistic | Break year | *T*-statistic | Break year |
| USA | LNEC | – 4.01 | 2007Q4 | – 12.05*** | 2009Q1 |
| | LNEPU | 0.75 | 2007Q4 | – 10.17*** | 2020Q1 |
| | LNCE | – 5.85*** | 2005Q4 | – 10.78*** | 2001Q1 |
| | LNUP | – 1.99 | 2008Q4 | – 7.51*** | 2021Q2 |
| | LNG | – 2.75 | 2009Q4 | – 10.53*** | 2003Q1 |
| UK | LNEC | – 2.72 | 2008Q4 | – 10.82*** | 2009Q1 |
| | LNEPU | – 3.38 | 2006Q4 | – 10.42*** | 2016Q1 |
| | LNCE | – 3.21 | 2003Q4 | – 10.79*** | 2002Q1 |
| | LNUP | – 10.45*** | 2020Q4 | – 12.32*** | 2002Q1 |
| | LNG | – 2.47 | 2012Q4 | – 13.16*** | 2020Q1 |
| China | LNEC | – 4.19* | 2002Q4 | – 11.05*** | 2003Q1 |
| | LNEPU | – 3.59 | 2015Q4 | – 10.13*** | 2013Q1 |
| | LNCE | – 4.80 | 2002Q4 | – 10.42*** | 2003Q1 |
| | LNUP | – 8.34*** | 2020Q4 | – 12.33*** | 2001Q1 |
| | LNG | – 2.88 | 2019Q4 | – 12.11*** | 2001Q1 |
| Pakistan | LNEC | – 3.45 | 2015Q4 | – 8.76*** | 2016Q1 |
| | LNEPU | – 2.99 | 2016Q4 | – 7.83*** | 2015Q1 |
| | LNCE | – 5.80*** | 2013Q4 | – 7.04*** | 2012Q1 |
| | LNUP | – 1.99 | 2014Q4 | – 13.37*** | 2021Q2 |
| | LNG | – 2.41 | 2012Q4 | – 8.10*** | 2012Q1 |
| India | LNEC | – 2.72 | 2008Q4 | – 10.83*** | 2009Q1 |
| | LNEPU | – 3.38 | 2006Q4 | – 10.43*** | 2016Q1 |
| | LNCE | – 3.21 | 2003Q4 | – 10.79*** | 2002Q1 |
| | LNUP | – 10.45*** | 2020Q4 | – 12.33*** | 2002Q1 |
| | LNG | – 2.47 | 2012Q4 | – 13.16*** | 2020Q1 |

**Table 3** ARDL bound test results

| Years Break year | USA | UK | China | Pakistan | India |
|---|---|---|---|---|---|
| *F*-stat | 1.16 | 1.66 | 1.50 | 69.43 | 4.16 |
| $R^2$ | 0.99 | 0.98 | 0.99 | 0.98 | 0.99 |
| Adj-$R^2$ | 0.99 | 0.98 | 0.98 | 0.99 | 0.99 |
| D.W test | 1.96 | 1.93 | 1.82 | 0.91 | 1.74 |
| $X^2$-NORMAL | 106.82 | 141.39 | 197.18 | 106.2 | 74.66 |
| $X^2$-ARCH | 1.14 | 0.55 | 0.28 | 0.12 | 0.28 |
| $X^2$-RAMSAY | 3.60 | 6.746 | 4.64 | 4.68 | 4.75 |
| CUSUM | Stable | Stable | Stable | Stable | Stable |
| CUSUM-sq | Stable | Stable | Stable | Stable | Stable |

in EPU increases 0.05%, 0.07%, 0.09%, 0.02%, and 0.05% $CO_2$ emissions in the USA, the UK, Pakistan, China, and India, respectively. This reveals that an increase in EPU increases environmental degradation. Our empirical results are supported by Xue et al. (2022) for France but contradict the Nathaniel and Iheonu (2019) for the USA. Moreover, a rise in UP improves the environmental quality. The coefficient value of UP is negative and statistically significant at

**Table 4** Long-run analysis

| Country | Variable | Co-efficient | *T*-statistic | Prob-value |
|---|---|---|---|---|
| USA | LNCE | – 0.22*** | – 3.64 | 0.00 |
| | LNEPU | 0.05*** | 3.01 | 0.00 |
| | LNG | 0.56*** | 4.01 | 0.00 |
| | LNUP | – 7.07*** | – 4.26 | 0.00 |
| UK | LNCE | – 0.23*** | – 3.64 | 0.00 |
| | LNEPU | 0.07*** | 4.08 | 0.00 |
| | LNG | 0.22* | 1.69 | 0.09 |
| | LNUP | – 0.12** | – 2.22 | 0.05 |
| China | LNCE | – 0.73*** | – 9.64 | 0.00 |
| | LNEPU | 0.02* | – 1.69 | 0.06 |
| | LNG | 0.04* | – 1.71 | 0.08 |
| | LNUP | – 0.61*** | – 3.01 | 0.00 |
| Pakistan | LNCE | – 0.33** | – 2.89 | 0.03 |
| | LNEPU | 0.09*** | 3.09 | 0.00 |
| | LNG | 0.88*** | 6.25 | 0.00 |
| | LNUP | 3.27*** | – 6.78 | 0.00 |
| India | LNCE | – 1.41*** | – 8.03 | 0.00 |
| | LNEPU | 0.05*** | 5.40 | 0.00 |
| | LNG | 0.16** | 2.87 | 0.03 |
| | LNUP | 0.74** | – 2.58 | 0.03 |

1%. This estimation indicates that every 1% increase in UP will lead to a decrease in $CO_2$ emissions by 7.07%, 0.12%, 0.61%, and in the USA, the UK, and China respectively but UP increases the carbon emissions in Pakistan, and India by 3.27% and 0.74% respectively. This implies that UP improves environmental quality in developed nations but it is not sustainable in developing countries. The findings are supported by Mehmood et al. (2021) for SAARC countries Charfeddine and Ben Khediri (2016) for UAE, and Ahmed et al. (2019) for Indonesia. However, our estimate is inconsistent with Chen et al. (2021) for 110 economies and Al-Mulali and Ozturk (2015) for MENA countries. The ecological modernization theory that claims urban sustainability is associated with a high urbanization level also supports our findings (Poumanyvong and Kaneko 2010). Efficient productivity and resource efficiency is achieved with a rise in urbanization. Public services like water supply, waste management, sanitation, and many others are relatively less expensive to construct and run in highly urbanized areas. Moreover, modernization is also encouraged by urbanization leading to efficient technology, energy efficiency, and innovation (Ahmed and Wang 2019). The empirical findings of the short-run analysis are reported in Table 5. The empirical findings of the short-run analysis are quite similar to the long-run analysis. In the short run, CE and UP are reducing the $CO_2$ emissions in these countries. Moreover, a negative and statistically significant coefficient value of the ECT for all selected countries validates the stability of our model.

**Table 5** Short-run analysis

| Country | Variable | Co-efficient | *T*-statistic | Prob-value |
|---|---|---|---|---|
| USA | ΔLNEPU | 0.05*** | 5.40 | 0.00 |
| | ΔLNCE | − 0.22*** | − 4.03 | 0.00 |
| | ΔLNUP | − 7.07*** | − 5.33 | 0.00 |
| | ΔLNG | 0.56*** | 5.05 | 0.00 |
| | $ECM^{-1}$ | − 0.11*** | − 3.72 | 0.00 |
| UK | ΔLNEPU | 0.15*** | 5.03 | 0.00 |
| | ΔLNCE | − 0.20*** | − 5.64 | 0.00 |
| | ΔLNUP | − 7.07*** | − 4.26 | 0.01 |
| | ΔLNG | 0.56*** | 4.01 | 0.00 |
| | $ECM^{-1}$ | − 0.12*** | − 2.95 | 0.00 |
| China | ΔLNEPU | 0.57*** | 5.91 | 0.00 |
| | ΔLNCE | − 0.73*** | − 3.79 | 0.00 |
| | ΔLNUP | − 0.61*** | − 3.01 | 0.00 |
| | ΔLNG | 0.71*** | 3.03 | 0.00 |
| | $ECM^{-1}$ | − 0.20*** | − 3.09 | 0.00 |
| Pakistan | ΔLNEPU | 0.01*** | 3.99 | 0.00 |
| | ΔLNCE | − 1.60*** | − 5.45 | 0.00 |
| | ΔLNUP | 3.27*** | − 8.89 | 0.00 |
| | ΔLNG | 0.56*** | 9.40 | 0.00 |
| | $ECM^{-1}$ | − 0.79*** | − 2.62 | 0.01 |
| India | ΔLNEPU | 0.05*** | 5.54 | 0.00 |
| | ΔLNCE | − 1.41*** | − 3.03 | 0.00 |
| | ΔLNUP | 0.78** | − 2.5 | 0.04 |
| | ΔLNG | 0.56*** | 5.05 | 0.00 |
| | $ECM^{-1}$ | − 0.55*** | − 5.17 | 0.00 |

## Conclusion and policy recommendations

The current study has analyzed the effect of clean energy and economic policy uncertainty on $CO_2$ emissions in developed and developing countries, i.e., the USA, the UK, Pakistan, China, and India, following the ARDL approach. The yearly data was transformed into quarterly data for in-depth analysis. The unit root test with structural breaks validates mixed order of integration for both developed and developing countries. The ARDL estimates indicated that economic growth and economic policy uncertainty degrade the environmental quality of sample countries. However, clean energy and urbanization are environmentally friendly and contribute to improving the environmental quality of the selected countries. Urbanization is not friendly in Pakistan and India. This indicates that Pakistan and India need to improve their urban settlements. For this purpose, clean energy sources should be deployed. Moreover, green areas need to be enhanced in urbanized areas.

Based on these outcomes, a few policy implications can be deduced. Initially, policies should be transparent and clear, with government officials should try to reduce any economic policy uncertainty through international treaties and summits. Additionally, international organizations, i.e., the World Bank, the WTO, and UNO should introduce programs to reduce economic policy uncertainty. Moreover, political uncertainties also contribute to increasing the level of $CO_2$ emissions, and policymakers should take initiative to shrink the policy uncertainty level. This might involve a discussion among the government and the citizens so that the existing frictions regarding the environmental policies' socioeconomic effect can be mitigated. Effective communication among parties also contributes to reducing the level of economic policy uncertainty. Moreover, clean energy sources should be preferred in urban communities. Urban policies need to be revised by policymakers. Technologies should be used effectively for clean energy production. For this purpose, Pakistan and India need to learn from the USA, China, and the UK how they have settled their urban population. The fundamental role of carbon emissions is the energy utilization from fossils. Pakistan and India need to replace their non-renewable energy sources with renewable energy sources. These sources do not consume fossil fuels to generate energy. Therefore, attention should be to enhancing the imports of clean energy sources. The fraction of clean energy to the total energy expenditure is enhancing air quality. This indicates that these territories need to spend more on clean energy sources as it will enhance the air quality. Governments should give tax releases on clean energy use. R&D budgets should upsurge. Moreover, projects and grants for introducing innovation, and clean energy technologies should be provided. Subsidies for the import of clean energy products should be provided.

Future works can study the other kind of uncertainties in terms of risk, misspecification, and ambiguity and quantify them suitably and their differential impacts, if any, to propose evidence-enlightened policy. Moreover, future work can be done for other groups of countries or individual countries by adopting robust econometric methodologies. Future research work can be conducted comparative research work for the panel data of developing and developed nations.

**Author contribution** Munawar Iqbal conducted the analyses and wrote the manuscript. Zia ul Haq contributed to the analysis and writing of the manuscript, and Sohail Chand guided and supervised the whole research work.

**Data availability** Not required

## Declarations

**Ethical approval** Not required

**Consent to participate** All authors participated in this research.

**Consent to publish** Not applicable

**Competing interests** Not required

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