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Economic Policy Uncertainty, Renewable Energy Consumption and Environmental Sustainability in China

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ABSTRACT

Climate change, global warming and environmental degradation have become the serious threat for the planet. Climate change cause earthquakes severs storms, food security and uneven rainfall; CO2 emissions are major component of climate change. The literature on impact of economic policy on climate change has attained the great attention of policy makers and research now a day. This paper seeks out the impact of EPU, foreign direct investment, urbanization and renewable energy consumption on the environmental sustainability. The study employs Autoregressive distributed lag (ARDL) model to analyze the data from China during 1995 to 2021. The empirical findings revealed that EPU, Urbanization and FDI have positive impact on CO2 emissions, while renewable energy consumption has negative impact on CO2 emissions in China.

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1. Introduction

This planet is facing the risk of global warming and environmental deterioration; the main culprit behind these aforementioned problems is GHGs; the most determinative gas among all GHGs is co2, which accounts for 76% share of total GHGs (Syed, Bhowmik, Adedoyin, Alola, & Khalid, 2022). The risk of climate crises is multifarious and associated with various environmental threats, including biodiversity damage, creation of waste, and surging water and air contamination (Zhang et al., 2023). Past research has highlighted the dire need to mitigate co2 emanation to protect human life (Nathaniel, Alam, Murshed, Mahmood, & Ahmad, 2021; Wang, Liu, Zhong, & Lobonţ, 2022). Gradually, industrial firms turn their focus from low co2 to low cost of production due to the rapid increase in population around developing countries; it is predicted that the demand for coal, oil, gas, nuclear and renewable energy will skyrocket in future to fulfil growing population needs (Nathaniel et al., 2021). 85% of energy is associated with fossil fuels, 57 percent of the total of co2 ejections (A. Amin & Dogan, 2021).

In the 5th IPCC review article, it was determined by the global community that global temperature should not surge above 2C by the completion of the twenty-first century (IPCC, 2014). Perceiving transformation of the climate as a possible danger to the environment and economic and social stability, in 2015, world leaders met in Paris to adopt an agreement aimed at combating climate change. As per the terms of this agreement, the vast majority of economies are bound to take strategies to mitigate co2 emanations and limit global warming to well below 2C and make efforts to decrease temperature below 1.5C further (Bouyghrissi et al., 2022; Rehman, Ma, Ozturk, Murshed, & Dagar, 2021; Ullah, Ozturk, Usman, Majeed, & Akhtar, 2020). To take advantage of favourable economic conditions, many developing nations are accelerating their GDP and increasing domestic production, both increasing CO2 emanations (IPCC, 2019).

Economic policy uncertainty means the uncertainty affiliated with the public policies which affect an economy of business (N. Amin & Song, 2023; Pirgaip & Dinçergök, 2020). Numerous researchers have worked on the association between EPU and co2 emanation with different results; economic policy uncertainty and co2 release are firmly associated with each other. Further, EPU affects co2 discharge in rapid and slow growth periods (Jiang et al., 2019; Wang et al., 2022). EPU infuriates co2 outflow in economies with enormous resources but crises prone (catastrophe change) (Wang et al., 2022). EPU can upset the ecosystem across a triad of channels. Firstly, high EPU distracts government attention from environmental problems, adversely affecting environmental regulation implementation. Secondly, EPU deteriorates the economic performance of enterprises; Thirdly, due to high EPU, the government may relax the environmental regulations, which cause a reduction in the firm's commitment to control carbon emanations (Chu & Le, 2022; Jiang et al., 2019).

EPU is the main reason behind the decrease in energy utilization and GDP expansion, ultimately leading to co2 discharge (Adedoyin & Zakari, 2020; Anser, Alharthi, Aziz, & Wasim, 2020). While EPU boosts energy consumption and causes co2 ejection (Anser et al., 2020; Danish, Ulucak, & Khan, 2020). EPU is linked to weaknesses in fiscal, monetary, and various related strategies (Syed & Bouri, 2022). Over the last two decades, EPU has risen in developed and underdeveloped countries (Huang, Ali, & Solangi, 2023). Economic policy uncertainty constrained policymakers' emphasis on environmental or ecological sustainability, which can adversely affect the ecological consequences and policies (Iqbal, Chand, & Ul Haq, 2023; Jiang et al., 2019). Uncertainty plays a vital role in determining climate and environmental strategies globally (Benlemlih & Yavaş, 2023). Currently, one research explored the correlation between environment and EPU and demonstrated two potential factors (i) ramification on consumption and (ii) influence on investment (Wang et al., 2022).

It is globally observed that as countries start getting more developed, people prefer to move to developed areas, which is the main reason behind environmental degradation (Mahmood, Alkhateeb, & Furqan, 2020). Urbanization accelerates the population swarming and economic affairs in the urban core (Hussain, Li, & Sattar, 2022). Urbanization boosts GHGs emissions and leads to Global warming (Hussain et al., 2022; Jiang et al., 2019). It is predicted that around 64% of the people living in developing countries will be moved to urban areas by 2050 (Abbasi, Parveen, Khan, & Kamal, 2020). That is why urbanization may become a crucial cause of high co2 emanations (Anser et al., 2020). Urbanization adversely affects the environment, human health, sanitation and deforestation (Abbasi et al., 2020). The indispensable affiliation between population factors and co2 outflow has been a debating point for researchers in less developed economies (Li, Zhou, & Zhang, 2022).

Urbanization accelerates the energy demand, use of more energy results in high co2 emanation and deteriorates the surroundings (Musah, Kong, Mensah, Antwi, & Donkor, 2021). Urbanization is the major element to accelerate crime, poverty, the spread of diseases and environmental deterioration (Ali, Law, & Zannah, 2016). The reason behind rapid urbanization is the search for better economic opportunities and safer living conditions. As urbanization improves output, it boosts economic activities and generations' wealth to reshape arts, science, politics and other professions (Ali et al., 2016). The economies are more unified globally than ever before; As globalization revealed more positive than negative influences, especially with regard to eradicating poverty and income inequality in developing countries, still its consequences on the environment is not without cost. Anthropogenic activities adversely affect the environment and badly affect planet habitants' health (Mahmood et al., 2020; Mehmood & Mansoor, 2021).

FDI is a catalyst for energy utilization and co2 emanations in host countries, attracting foreign investment due to the lax environment (Hao & Chen, 2023). FDI enhance environmental quality by using efficient technological innovations; it works as a "Magic Wound" for the country's economic progress. In comparison, it has some adverse effects, As it increases demand for energy utilization for sustainable development, which in turn skyrockets the co2 emanations (Luo, Guo, Ali, & Zhang, 2022; Mukhtarov, Aliyev, Mikayilov, Ismayilov, & Rzayev, 2021). The PHH declares the positive affiliation between FDI and the environment (Solarin & Al-Mulali, 2018). The harmful impact of FDI on ecosystems has been demonstrated by prior research. According to the pollution halo hypothesis, the transmission of eco-friendly technologies from developed to developing countries may scale down the co2 outflow (Solarin & Al-Mulali, 2018). Due to globalization and trade openness, FDI amplified significantly in the late 1980s (Luo et al., 2022). FDI displays three crucial impacts on the destination country's political, social and economic (Balli, Sigeze, Ugur, & Çatık, 2021). In spite of helping to enhance the host country's economic progress, FDI also intensifies environmental deterioration (Balli et al., 2021).

According to the international energy association, Energy utilization accounts for 75% of GHGs discharge worldwide (IEA, 2015). Energy is essential for sustainable economic and industrial development; however, it is directly affiliated with co2 emanations. To avoid any calamity, co2 outflow must be taken into account (N. Amin & Song, 2023). Renewable energy utilization was 18.5% in 2105; this percentage must be increased for sustainable environmental quality and reduction in co2 ejection (A. Amin & Dogan, 2021; Rehman et al., 2021). At recent, it has become a surpassing challenge for all countries to mitigate the co2 release, sustain economic progress and convert NRE utilization into renewable energy deploy. Policies to diversify fuel sources and using renewable energy sources instead of fossil fuels are at the top of the list for the 21st century (Nathaniel et al., 2021). Large-scale usage of natural resources and energy globally causes environmental deterioration, which is the major cause of diseases like malaria. Energy utilization is regarded as the appropriate agent to catalyze economic expansion, also responsible for environmental destruction (Nathaniel et al., 2021). Immense utilization of natural materials is responsible for the irreversible deterioration of the biosphere and destroys the world's social and economic development goals. It is widely accepted that the unlimited burning of fossil fuel energy is the prime motive of climate change risk, which has become a hot debate in environmental and economic sustainability (Hao & Chen, 2023).

2. Literature Review

Syed et al. (2022) investigated the alliance between EPU, trade openness, renewable energy, industrial production index and co2 exhalation via the bootstrap ARDL approach. The study data collected in the US during 1985 to 2019. The research outcomes unflod a positive association of EPU, tradeand industrial production index with co2 discharge in the long run, while renewable energy displayed inverse affiliation with co2 emanations. Wang et al. (2022) scrutinized the nexus between EPU, GDP, energy prices, and co2 radiations by utilizing ARDL. Researchers gathered data using the United States from 1960 to 2016. The empirical results showed a positive association of EPU and GDP with co2 outpouring. At the same time, energy prices adversely influenced co2 ejection. A. Amin and Dogan (2021) scrutinized the association between energy structure, real income, energy intensity, population, EPU, and co2 emissions by applying the dynamic ARDL technique. The information gathered from China during the years 1980 and 2016. The estimated outcomes of the survey exhibited the positive ramifications of EPU, energy intensity, GDP, and population on co2 ejection, whereas energy structure negatively influenced carbon emissions. Zhang et al. (2023) inquired about the alliance between ecological innovation, RNE transition, globalization, EPU, and co2 emissions by adopting ARDL and gradual shift causality. From 1990 to 2019, the study used information acquired in the United States. The empirical findings confirmed the co-integration between variables. The estimated results showed that EPU, renewable energy transition,and energy intensity negatively influenced carbon emissions, while globalization positively influenced the co2 discharge.

Khan, Ali, Dong, and Li (2021) investigated the alliance between EPU, GDP, reusable energy, trade, FDI, and co2 emanation by applying FMOLS, Dumitrescu- Hurlin panel causality estimators. The survey analyzed data of four East Asian economies over the period 1997 to 2020. The study's empirical findings confirmed positive EPU, trade, and GDP reverberations on co2 ejection. In comparison, FDI and renewable energy unfavorably influenced co2 outflow in the four East Asian countries. The empirical findings of Dumitrescu- Hurlin Panel causality confirmed the two-way causality between co2 ejection and EPU, co2 discharge and energy deploy, co2 exuding and GDP. Anser et al. (2020) demonstrated the affinity between co2 exhalation, GDP, population, EPU, and energy employed by adopting the PMG-ARDL estimation technique. The study obtained data from the top 10 ten Co2 emanations countries from 1990 to 2015. An empirical assessment of the study revealed positive convergence of EPU, GDP, and population on co2 release, whereas GDP2 and energy consumption adversely affected the carbon emissions.

Iqbal et al. (2023) analyzed the affiliation between EPU, urban population, GDP, renewable energy, and CO2 via the ARDL model. The research utilized data of developed and developing countries during 2000 to 2021 for India, UK, and USA. For Pakistan, 2010 to 2021, due to the availability of data. The estimated results demonstrated a positive reverberations of EPU and GDP on co2 discharge. At the same time, energy consumption negatively influenced carbon emissions; in the long term, the urban population displayed a constructive association in the case of India and Pakistan, while the urban population negatively effected the ecosystem in the case of the USA, UK, and China. Shabir, Ali, Hashmi, and Bakhsh (2022) conducted the causal linkage between EPU, trade, GDP, FDI, energy utilization, and co2 ejections by employing panel VECM and the Granger causality method. Information was compiled from 24 developed and developing countries since 2001 to 2019. The empirical findings demonstrated the adverse impressions of EPU, GDP, energy, and trade on co2 ejections; on the contrary, FDI positively influenced co2 emissions in the long run.

Chu and Le (2022) inspected the bond between EPU, renewable energy, energy intensity, and carbon emissions by applying FMOLS, fixed effects model with Driscoll and KRAY methods. The investigation assessed information from the G7 countries from 1997 to 2015. The empirical estimations of the analysis exhibited a beneficial influence of energy intensity on carbon release, while EPU and renewable energy negatively influenced the co2 exhalation. Syed et al. (2022) assessed the causal union between EPU, Geopolitical risk, renewable energy, urbanization, GDP, non-renewable energy, and co2 exhalation by utilizing Panel quantile regression AMG and CCEMG estimation techniques. The study obtained data from BRICS economies from 1990 to 2015. Different techniques showed different results. The estimated results of AMG demonstrated that non-renewable energy, GDP, and urbanization positively influenced the Co2 emanation. In contrast, renewable energy, EPU, and geopolitical risk inferred a negative impact on carbon emissions. According to CCEMG estimations, the results are the same as AMG outcomes. The findings of panel quantile regression confirmed the heterogeneous results of EPU and geopolitical risk on co2 emissions. EPU negatively influenced co2 emissions in the low and middle quantiles but positively in the high quantile, and geopolitical risk influenced vice versa.

Huang et al. (2023) explored the correlation between GDP, EPU, renewable energy usage, FDI, and environmental quality by utilizing panel data analysis techniques, including PCSE and GLS. The study attained data from 19 developed and under developed countries over the years 2001 to 2019. The estimated outcomes of the analysis showed a detrimental impact reverberations of EPU and GDP on the environment, while renewable energy positively converged co2 ejection. Ayhan, Kartal, Kılıç Depren, and Depren (2023) demonstrated the affinity between EPU, GDP, energy consumption, and political stability on co2 discharge by applying QQR and QR models. The inquiry fetched data from G-7 economies during 1997 to 2021. The factual outcomes displayed adverse consequences of EPU on co2 ejection in Japan, Italy, and the USA, but in case of France, the UK, and Germany, it showed mixed results. The empirical evidence confessed the adverse influence of energy utilization on co2 outflow.

Mahmood et al. (2020) documented the affiliation between urbanization, industrialization, and co2 outpouring via ARDL and NARDL estimation techniques. The paper piled up data from Saudi Arabia from 1968 to 2014. Positive results were found in the study's empirical analyses for both industrialization and urbanization on co2 discharge in the long run. Cheng and Hu (2022) investigated the causal linkage between urbanization, urban sprawl, and co2 ejection by utilizing expand the STIRPAT model. The paper applied the OLS, static spatial panel, and Dynamic spatial panel models. The study obtained data from China from 1997 to 2018. The statistical estimation showed a positive association between urbanization sprawl, urbanization, and co2 discharge. Ali et al. (2016) evaluated the coalition between urbanization, trade, GDP, energy, and co2 outflow by utilizing ARDL techniques. The assessment accumulated data in Nigeria from 1971 to 2011. Different variables react differently. The long-run analysis disseminated that urbanization positively influenced co2 release; on the other hand, trade openness displayed negative consequences on co2 leakage; in comparison, GDP and energy utilization unfold the positive ramifications on co2 emanations.

Liu and Bae (2018) examined the association between real GDP, energy intensity, industrialization, urbanization, renewable energy utilization, and co2 emanations via the ARDL and VECM models. The survey took information from China since 1970 to 2015. The estimated study results unveiled the positive impact of industrialization, urbanization, energy intensity, and real GDP on co2 outpouring, while renewable energy exerted negative consequences on co2 radiations. Musah et al. (2021) demonstrated the correlation between GDP, urban population, and renewable energy through different econometric techniques, including CADF and Westerlund and Edgerton bootstrap co-integration, Driscoll-kraay co-integration. The review obtained data from West Africa for the period spanning 1990 to 2018. The investigated findings uncovered the favorable consequences of GDP, and urbanization on the environment, while renewable energy utilization adversely affected the co2 emanation in West Africa. Hussain et al. (2022) inspected the collaboration between GDP, urbanization, non-renewable energy, and co2 ejection by executing FMOLS and panel quantile regression (PQR). The assessment investigated the data gathered from Africa varies from 1996 to 2019. The empirical evidence reported that urbanization and non-renewable energy enhanced co2 outflow in Africa, while GDP followed the EKC. Li et al. (2022) verified the causal association between population size, GDP, low carbon innovation, FDI, financial development, industrial development, and co2 emissions by applying panel ARDL, CCEMG, and AMG econometric techniques. The study estimated data from 285 cities in China from 2003 to 2018. The empirical outcomes of the study revealed that low carbon innovation, GDP, FDI, FD, and industrial development positively influenced carbon emissions. At the same time, population size negatively influenced carbon emissions.

Mosikari and Eita (2020) reviewed the affiliation between energy use, GDP, population size, and co2 outflow by using the PSTR estimation approach. The study analyzed data from 29 selected African countries for 2005-2019. The estimated results confirmed that energy consumption and GDP positively influenced carbon emissions, whereas urbanization negatively affected carbon emissions. Anwar et al. (2021) verified the affinity among renewable energy, FD, GDP, urbanization, and co2 discharge by employing FMOLS, FE-OLS, and DOLS. The research accumulated data from 15 Asian countries to investigate the union from 1990 to 2014. The investigated conclusions unfold the positive collision between FD, urbanization, and GDP, but renewable energy demonstrated a negative affiliation with the environmental quality. Abbasi et al. (2020) estimated the interconnection between FD, urbanization, co2 emanation, trade, GDP, and energy consumption, exerting FMOLS and VECM. The research acquired data from 8 Asian economies over the period 1982 to 2017. The experimental analysis indicated a positive influence of GDP, FD, urbanization, and energy utilization on co2 discharge, while trade openness negatively influenced the co2 release in 8 selected Asian economies. Salahudin et al. discovered the collaboration between urbanization, globalization, GDP, energy poverty, and co2 radiations by adopting second-generation panel regression and cross-sectional dependence approaches. The research assembled data from 44 African nations duration 1984 to 2016. The verifiable outcomes confirmed that GDP and urbanization displayed positive impressions on co2 outflow, while energy exhibited adverse sequel on co2 discharge.

Anser et al. (2020) empirically analyzed the union between GDP, urbanization, population size, and co2 leakage by adopting Driscoll and Kraay methodology. The analysis piled up data from SAARC countries during 1994 to 2013. The verifiable outcomes confirmed the supportive collision of population size and GDP on residential carbon ejections, but urbanization confirmed the existence of EKC. Mahmood et al. (2020) focused on the interconnection of urbanization, GDP, trade, and co2 discharge by executing the ARDL method. The investigation piled up data from East Asian and Pacific countries from 1982 to 2014. The interpretation of the calculation announced that urbanization lessens the co2 in Japan, China, Mongolia, and Hong Kong, while urbanization positively influenced the co2 emanation in Macao, Singapore, and South Korea. GDP positively influenced the environment in Hong Kong, China, Japan, Singapore, and Mongolia; on the other hand, GDP negatively affected Macao and South Korea. While trade openness negatively affected in China, Japan, Hong Kong, and Mongolia, in contrast, GDP positively impacted on co2 emanations in Macao and South Korea.

Nathaniel et al. (2021) indicated the causal linkage between FDI, crude oil consumption, GDP, and co2 emissions, through ARDL and NARDL. The study obtained data of India for the years spanning from 1990 to 2020. The estimated results of ARDL exhibited the positive influence of GDP, FDI, and prices of crude oil on co2 emissions in India, while the results of NARDL showed a positive association between GDP and co2 emissions, as well as FDI and crude oil price, inferred positive sequel on co2. Rehman et al. (2021) unfolded the alliance between tourism, FDI, GDP, electricity utilization, and CO2 by applying ARDL apporach. The interpretation fetched information from Bangladesh during 1990 to 2019. The empirical results revealed that GDP, electricity usage, and FDI positively influenced the environment, but tourism negatively influenced environmental quality. Wang et al. (2022) probed the alliance between GDP, FDI, technological advancement, energy intensity, and co2 emissions by using the quantile regression technique. Research looked at information from 28 different Chinese provinces between the years 2000 and 2018. The estimated findings of the study revealed the negative result of FDI and energy intensity on co2 transmissions; on the contrary, GDP and urbanization positively affected the environmental quality.

Luo et al. (2022) looked into the affiliation between NRE utilization, GDP, RE usage, FDI, and co2 discharge by utilizing AMG, and MG estimation techniques. The study estimated the figures from India, China, and Singapore from 1980 to 2020. The study's empirical analysis confirmed the positive influence of non-renewable energy consumption and FDI on co2 emanation, while renewable energy consumption negatively influenced carbon emissions. Balli et al. (2021) probed the union between energy use, FDI, GDP, and carbon emanations via pooled mean group and CCE-MG techniques. The study attained data from APEC countries over the years 1981 to 2021. The estimation analysis exerted the positive influence of energy utilization on co2 outflow; meanwhile, FDI inferred a negative influence on co2 emissions. GDP showed mixed results different results for different countries. Mozhid et al. (2022) evaluated the affiliation among GDP, FDI, energy, and co2 emissions through the ARDL technique. The study analyzed the facts from SAARC countries for the time 1980 to 2016. The analysis revealed the positive impact of GDP and energy exercise on co2 emissions in the long run. FDI showed an adverse influence in India, Pakistan, and Srilanka and a positive impact in Bangladesh and Nepal. The GDP^2 exerted a harmful after math on co2 emissions.

Solarin and Al-Mulali (2018) inquired causal linkage between urbanization, GDP, energy application, FDI, and co2 emanation by employing CCEMG and AMG. The investigation collected statistics from 20 countries for 1980 to 2016. The empirical outcomes of the analysis revealed a positive association between GDP, energy consumption, urbanization, and environmental quality. FDI showed a negative influence on developed and a positive for developing economies. Wang et al. (2022) indicated the alliance between GDP, energy usage, FDI, and co2 ejection via the panel ARDL method. The inquiry analyzed data taken from newly industrialized countries from 1990 to 2016. The paper's factual analysis confirmed the positive affect of trade openness, FDI, and energy utilization on carbon outflow, while GDP adversely affected co2 emissions. Mukhtarov et al. (2021) explored the nexus between FDI, GDP, and co2 release via STSM structural time series modeling approach. The research gathered data from Azerbaijan during 1996 to 2013. The empirical estimation showed a positive sequel of FDI on co2 transmissions till 2006; after that, FDI exerted a negative influence on environmental quality. On the contrary, GDP positively impacted co2 emissions for the entire duration. Edmund NtomUdemba (2019) experimented with the tie among FDI, tourist arrivals, energy, and co2 outpouring by adopting the ARDL. The survey attained information from China covering the period 1995 to 2016. The experimented results showed a positive impact of FDI, tourist arrival, and use of energy on co2 ejection.

Usman, Akadiri, and Adeshola (2020) conducted the association among renewable energy, globalization, FD, real output, and ecological footprint using different estimation techniques like the structural break co-integration test and ARDL model. The paper assembled figures from the USA since 1985 to 2014. The estimated calculations of the experiment showed a positive after math of FD and globalization on the environment, whereas GDP and renewable energy negatively influenced the atmosphere in the long run. Zaidi, Danish, Hou, and Mirza (2018) analyzed the affiliation between non-renewable energy, renewable energy, GDP, and co2 outpouring via the ARDL model. The study collected figure from Pakistan from 1970 to 2016. The observed outcomes of research revealed the positive sequel of GDP and non-renewable energy on co2 outflow; at the same time, renewable energy negatively influenced the co2 emissions in the long run in Pakistan. Apergis, Kuziboev, Abdullaev, and Rajabov (2023) scrutinized the correlation between renewable and NRE and co2 discharge by employing the ARDL. The research analyzed statistics from Uzbekistan from 1985 to 2020. The empirical outcomes documented the negative influence of renewable energy consumption on co2 outflow in the long run and short run; also, non-renewable utilization positively influenced the co2 outflow.

Saqib (2022) evaluated the connection between renewable energy, FD, NRE, GDP, and co2 emissions through CIPS and ADF unit root test, Westerlund co-integration test, and AMG techniques. The research gathered data from 13 Asian developing economies from 1995 to 2020. Predicted findings from the research indicated the favorable influence of GDP, and non-renewable energy on co2 ejection, while RE negatively influenced co2 emissions; financial development showed significantly unfavorable results. The causality test inferred the bidirectional causality between the study variables. Hao and Chen (2023) scrutinized the association between renewable energy, GDP, FDI, green innovation, trade openness, inflation rate, financial innovation, and co2 emissions by employing different econometric techniques including OLS, DOLS, FMOLS and ARDL. The survey analyzed the data from E7 countries since 1990 to 2020. Empirical findings of the analysis revealed the positive influence of GDP, FDI, inflation rate, and government final consumption expenditures on the environment. On the other hand, renewable energy, green innovation, financial innovation, and trade openness negatively influenced carbon emissions. A. Amin and Dogan (2021) examined the affiliation between trade openness, GDP, renewable energy consumption, non-renewable energy utilization, urbanization, and co2 emissions via the dynamic common correlated effect CS-ARDL technique and DH panel causality test. The study collected data from South and East Asian countries over the period spanning from 2000 to 2018. The analysis indicated that GDP, NRE, trade, and urbanization positively influenced carbon outflow, but renewable energy utilization negatively affected the Co2 emanation.

Nathaniel et al. (2021) established the nexus between RE, GDP, and co2 outflow by adopting second-generation econometric techniques, including AMG and CCEMG. The study utilized data on G7 countries spanning from 1990 to 2017. AMG and CCEMG indicated a favorable effect of GDP on co2 emissions, whereas renewable energy, the square of GDP, and non-renewable energy negatively influenced the carbon emissions. (2022) scrutinized the linkage between GDP, FDI, renewable energy, FD, and carbon discharge using the ARDL model. The survey analyzed the data of Morocco spanning from 1980 to 2017. The empirical estimations of the study displayed positive consequences of GDP, FD, and FDI on co2 ejection in the long term, but GDP2 and renewable energy negatively influenced the co2 emissions. Çıtak, Uslu, Batmaz, and Hoş (2020) probed the association between natural gas, renewable energy, population, and co2 outflow by using a non-linear ARDL model. The paper obtained figures from the USA during the period 1997 to 2017. The positive advantages of using renewable energy sources were validated by the study's empirical findings and natural gas, on co2 ejection. Long-term positive causation between natural gas use and carbon outflow was also found.

3. Methodology

The present study employed China data from 1995 to 2021. The dependent variable are CO2 and ecological footprint.The major independent variable of current study is economic policy uncertainty (EPU). Data on EPU are obtained from policy uncertainty.com. Data on FDI, urbanization and renewable energy consumption are fetched from WDI. Table A describes the variables.

Table 1: Variables Description

Variables	Symbol	Measurement	Data Source
Carbon emission	CO_2	CO_2 emissions (kt)	WDI
Ecological footprint	EF	Ecological Footprint (gha per person)	https://data.footprintnetwork.org/?ga
Economic policy uncertainty	EPU	Average of News_Based_Policy_Uncert_Index	https://www.policyuncertainty.com/
Foreign direct investment	FDI	Foreign direct investment, net inflows (% of GDP)	WDI
Urbanization	URB	Urban population (% of total population)	WDI
Renewable energy	RNE	Renewable energy consumption (% of total final energy consumption)	WDI

Before we present the ARDL technique, we examine the effect of EPU on CO2 emissions and ecological footprint. Our study consists of two models. Model A represents the effect of EPU on CO2 ,and model B represents the effect of EPU on EF along with other variables.

$$CO_2 = f\,(EPU, URB, RNE, FDI) \qquad (A)$$

$$EF = f\,(EPU, URB, RNE, FDI) \qquad (B)$$

The Econometric Equation of the study for both models is given below;

$$CO_{2t} = \varphi_0 + \varphi_1 EPU_t + \varphi_2 URB_t + \varphi_3 RNE_t + \varphi_4 FDI_t + \mu_t \;\ldots\ldots\ldots(1A)$$

$$EF_t = \varphi_0 + \varphi_1 EPU_t + \varphi_2 URB_t + \varphi_3 RNE_t + \varphi_4 FDI_t + \mu_t \;\ldots\ldots\ldots(1B)$$

Where CO2 is carbon emissions, EF demonstrates ecological footprint, EPU indicates economic policy uncertainty, FDI shows foreign direct investment, URB displays urbanization and RNE shows renewable energy. The expected signs of co-efficient of EPU for co2 are positive but negative for EF, sign of FDI is positive for CO2 emanations and negative for EF, furthermore sign of urbanization is positive for CO2 but negative for EF, Additionally, sign of RNE is negative for both CO2 and ecological footprint which implies that renewable energy plays crucial role in mitigating CO2 emissions. The ARDL representation is specified as follows

$$\Delta CO_{2t} = \varphi_0 + \sum_{i=1}^{l} \varphi_{1i} \Delta CO_{2t-1} + \sum_{i=0}^{p} \varphi_{2i} \Delta EPU_{t-i} + \sum_{i=0}^{q} \varphi_{3i} \Delta URB_{t-i} + \sum_{i=0}^{r} \varphi_{4i} \Delta RNE_{t-i} + \sum_{i=0}^{s} \varphi_{5i} \Delta FDI_{t-i}$$
$$+ \alpha_1 CO_{2t-1} + \alpha_2 EPU_{t-1} + \alpha_3 URB_{t-1} + \alpha_4 RNE_{t-1} + \alpha_5 FDI_{t-1} + \mu_t \text{..........................}(2A)$$

$$\Delta EF_t = \varphi_0 + \sum_{i=1}^{l} \varphi_{1i} \Delta EF_{2t-1} + \sum_{i=0}^{p} \varphi_{2i} \Delta EPU_{t-i} + \sum_{i=0}^{q} \varphi_{3i} \Delta URB_{t-i} + \sum_{i=0}^{r} \varphi_{4i} \Delta RNE_{t-i} + \sum_{i=0}^{s} \varphi_{5i} \Delta FDI_{t-i}$$
$$+ \alpha_1 EF_{t-1} + \alpha_2 EPU_{t-1} + \alpha_3 URB_{t-1} + \alpha_4 RNE_{t-1} + \alpha_5 FDI_{t-1} + \mu_t \text{..........................}(2B)$$

Error correction Term

$$\Delta CO_{2t} = \varphi_0 + \sum_{i=1}^{l} \varphi_{1i} \Delta CO_{2t-1} + \sum_{i=0}^{p} \varphi_{2i} \Delta EPU_{t-i} + \sum_{i=0}^{q} \varphi_{3i} \Delta URB_{t-i} + \sum_{i=0}^{r} \varphi_{4i} \Delta RNE_{t-i} + \sum_{i=0}^{s} \varphi_{5i} \Delta FDI_{t-i} + \lambda ECT - 1 + vt_t \quad (3A)$$

$$\Delta EF_t = \varphi_0 + \sum_{i=1}^{l} \varphi_{1i} \Delta EF_{t-1} + \sum_{i=0}^{p} \varphi_{2i} \Delta EPU_{t-i} + \sum_{i=0}^{q} \varphi_{3i} \Delta URB_{t-i} + \sum_{i=0}^{r} \varphi_{4i} \Delta RNE_{t-i} + \sum_{i=0}^{s} \varphi_{5i} \Delta FDI_{t-i} + \lambda ECT - 1 + vt_t \quad (3B)$$

Where CO2, EPU, FDI, URB and RNE represents carbon emanations, Economic policy uncertainty, foreign direct investment, urbanization and renewable energy consumption respectively. Moreover, i and t are symbols of lags and time period respectively; i=1,2….5.

Pesaran, Shin, and Smith (2001) propose two tests to determine the co-integration in ARDL approach. The F-statistics andt-statistics, however two critical values are recommended by (Pesaran et al., 2001) i-e upper and lower bound criteria. It is assumed that upper and lower critical bound values should follow the F-statistics values. The value of F-statistics must be higher than upper critical bound. If the value of F-statistics is lower than upper or lower bound value, then it means results are not conclusive.

4. Empirical Results and Discussion

Table 1 is the demonstration of variables and their estimates. The table manifest that FDI has (3.247080) mean value, urbanization has (46.48833) mean value, CO2 mean value (7064677); EF mean value (2.649634); EP mean value (95.19278) and RNE has mean value (18.86996). Other estimates like Jarque-bera, Skewness, Kurtosis, Probability are also mentioned in table 2.

Table 2: Descriptive statistics

	CO2	EF	EP	FDI	RNE	URB
Mean	7064677.	2.649634	95.19278	3.247080	18.86996	46.48833
Median	7199605.	2.716984	84.17336	3.487419	14.88000	46.53900
Maximum	11297320	3.550194	193.9879	4.880863	30.54000	62.51200
Minimum	3070505.	1.634705	36.83881	1.310716	11.34000	30.96100
Std. Dev.	3046420.	0.740627	45.21646	1.134401	7.443012	10.00435
Skewness	-0.114827	-0.191547	0.886541	-0.314120	0.597934	0.015471
Kurtosis	1.402502	1.383620	2.730169	1.849390	1.609197	1.708029
Jarque-Bera	2.930333	3.104375	3.618710	1.933412	3.784987	1.878914
Probability	0.231039	0.211784	0.163760	0.380334	0.150696	0.390840
Sum	1.91E+08	71.54012	2570.205	87.67116	509.4890	1255.185
Sum Sq. Dev.	2.41E+14	14.26176	53157.74	33.45850	1440.359	2602.265
Observations	27	27	27	27	27	27

All variables are transformed into logarithm form. The reliability of co-integration relies on the stationarity of series. The present study conduct unit root test. Augmented Dickey fuller and Philips Perron test are indicated in table 3. All variables are held constant at first difference. To utilize the ARDL technique it is compulsory that all variables should be integrated at first difference or mixed order. Our data fulfill the requirement of stationarity, we apply the ARDL technique.

Table 3: Unit root test

Variable	ADF		PP	
	Level	First Difference	Level	First Difference
CO2	-1.054	-5.370***	-1.551	-6.532***
EF	-0.162	5.543***	-0.263	-5.555***
EP	-2.320	-5.438***	-2.402	-6.396***
URB	-0.022	-7.426***	-0.160	-7.663***
RNE	-0.689	-5.838***	-0.760	-5.844***
FDI	-1.698	-6.102***	-1.254	-6.181***

The following table 4 reports that existence of co-integration in both models as it is mentioned through F-bound test results.

Table 4: Bound Test Estimation

F-statistics	K	Range	Critical values	
			I(0) bound	I(1) bound
		Model.1		
5.819	4	10%	2.45	3.52
		5%	2.86	4.01
		1%	3.74	5.06
		Model 2		
5.0829	4	10%	2.45	3.52
		5%	2.86	4.01
		1%	3.74	5.06

We use the ARDL approach in present study (Table 5). The findings of analysis depicted that all variables are statistically significant for model A, while for model B ecological footprint, all variables are significant expect renewable energy consumption. The value of economic policy uncertainty is 0.0533 which mentions that a 1% upsurge in EPU, lessen the carbon emissions by 0.0533, in contrast, the value of EPU for ecological is 0.153 which depicts that 1% rise in EPU rises the CO2 emanations by 0.153%. The value of urbanization is 0.176 for CO2 model which indicates that rise in urbanization mitigate CO2 discharge by 0.176%, Moreover the value of urbanization for EF is 0.082, demonstrating that 1% upsurge in urbanization, upswing the ecological footprint by 0.082%. The value of renewable energy -0.257 illustrates that 1% increase in renewable energy, escalates the CO2 emanations, Additionally, the value of renewable energy for ecological footprint is 0.405 presenting that 1% rise in renewable energy decrease 0.405% ecological footprint. The findings revealed the value of FDI is 0.044, which means that 1% extension in FDI, causes the 0.044% expansion of CO2, while the value of FDI for ecological footprint 0.081 displays that 1% rise in FDI leads to 0.044% growth in ecological footprint.

Table 5: Long run estimations (ARDL)

Variables	Coefficient	[S.E]	{T-st}
	Model 1		
LEP	0.0533**	[0.0234]	{2.2741}
LURB	0.1764***	[0.0320]	{5.5111}
LRNE	-0.2576***	[0.0359]	{-7.1678}
LFDI	0.0443***	[0.0115]	{3.8476}
C	14.5566***	[0.3130]	{46.5046}
	Model 2		
LEP	0.1532**	[0.0668]	{2.2908}
LURB	0.0821	[0.1001]	{0.8195}
LRNE	-0.4059***	[0.1374]	{-2.9543}
LFDI	0.0812 **	[0.0391]	{2.0748}
C	5.8638***	[1.2149]	{4.8262}

Short Run			
MODEL 1 CO2	**Coefficient**	**[S.E]**	**{T-ST}**
D(LEP)	0.0380**	[0.0164]	{2.3065}
D(LURB)	0.1255***	[0.0282]	{4.4524}
D(LRNE)	-0.1833***	[0.0496]	{-3.6958}
D(LFDI)	0.0315***	[0.0123]	{2.5604}
CointEq(-1)	-0.7117***	[0.1461]	{-4.8706}
MODEL 2			
D(LEP)	0.0449***	[0.0168]	{2.665}
D(LURB)	0.1821***	[0.0535]	{3.3985}
D(LURB(-1))	0.1128*	[0.0638]	{1.7672}
D(LRNE)	0.0485	[0.0552]	{0.8793}
D(LRNE(-1))	0.0683	[0.0487]	{1.4003}
D(LFDI)	0.1745***	[0.0440]	{3.9592}
D(LFDI(-1))	0.1529***	[0.0471]	{3.2424}
CointEq(-1)	-0.2930***	[0.0799]	{-3.6667}

Note: *** indicates 1% level of significance; ** indicates 5% level of significance; * indicates 10% level of significance. Square brackets [ ] values show the standard errors and { } value demonstrates t-statistics.

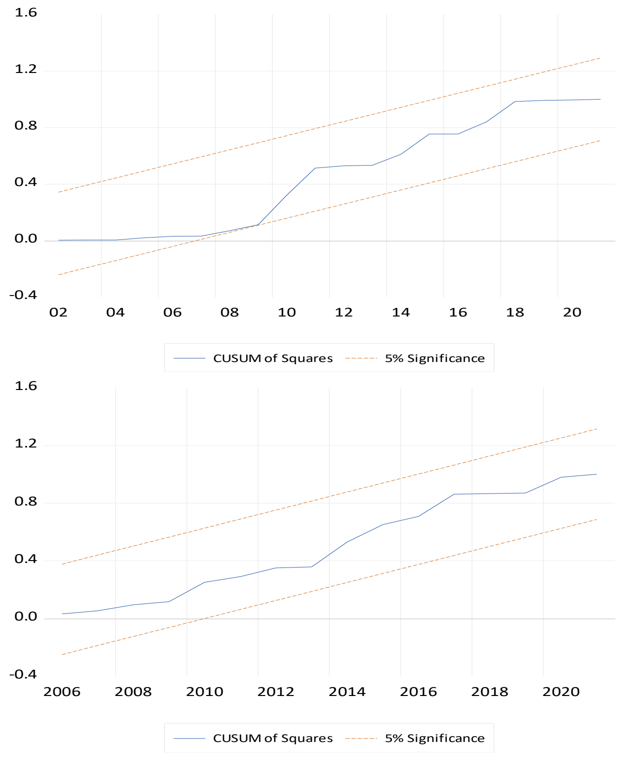
Table 5: Diagnostic Test (ARDL)

	Model. 1	**Model. 2**
R^2	0.931	0.978
Adj R^2	0.918	0.965
Durbin-Watson	2.143	2.20
LM test	2.224(0.130)	0.875(0.435)
Jarque-Bera	0.352(0.838)	0.284(0.867)
Hetero	1.720(0.166)	0.306(0.975)
Ramsey reset	0.933(0.360)	1.853(0.191)

Note: The values in ( ) are p-values.

Figure 1: CUSUM & CUSUMQ (Model 1)

Figure 2: CUSUM & CUSUMQ (Model 2)



5. Conclusion

The study evaluates the impact of EPU, FDI, URB, RNE on CO2 and ecological footprints by covering the period 1995 to 2021 from China. For this purpose, we used ARDL technique to examine the short and long run association between the study variables. Our study makes a unique endeavor to determine the impact of economic policy uncertainty on ecological footprint and CO2 emissions in China.The long run outcomes of the autoregressive distributed lag (ARDL) displays significant positive association of EPU, urbanization and FDI with CO2 emanation, while

RNE shows negative association with Co2.However, EPU, urbanization, FDI and RNE indicates significant connection with ecological footprint.

In present times, EPU have escalated rampantly and affected both the environment and economy. The government of China should reduce uncertainty in economic policy by endowing economic policy. The government should make strict regulations about monetary policy, interest and tax system to stabilize the economy. The government should make policies for consistent economic and environmental conditions. The actualfindings of our research indicate negative association between renewable energy consumption and CO2 emissions. The government should adopt the green renewable energy projects. The government should launch the awareness programs to motive the people of the country to adopt renewable energy instead of traditional energy. Importance of renewable energy consumption should be the part of curriculum and household. Wide awareness should be promoted nationwide. Our results display positive relationship between FDI and CO2 emissions. Government should adopt strict policy about the use of eco-friendly and green investment to abate the CO2 emissions. Pollution Halo hypothesis should be practiced. Urbanization is found positively associated with CO2 emissions in China.

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