International Journal of Energy Economics and Policy

ISSN: 2146-4553

available at http: www.econjournals.com

International Journal of Energy Economics and Policy, 2023, 13(6), 234-243.

Does Renewable Energy Transition in the USA and China Overcome Environmental Degradation?

Abdul Hayy Haziq Mohamad[1,2], Muhamad Rias K. V. Zainuddin[3], Rossazana Ab-Rahim[1]*

[1]Faculty of Economics and Business, Universiti Malaysia Sarawak, Malaysia, [2]School of Business and Management, University of Technology Sarawak, Malaysia, [3]Faculty of Business, Economics and Social Development, University Malaysia Terengganu, Malaysia. *Email: arrossazana@unimas.my

Received: 08 July 2023 **Accepted:** 14 October 2023 **DOI:** https://doi.org/10.32479/ijeep.14840

ABSTRACT

The use of fossil energy highly contributes to the CO_2 emissions. Compared to other countries, China and the USA were responsible for approximately half of the global CO_2 emissions in 2022. The SDG7 agenda, which aims to preserve the use of renewable energy, has made people aware of the need to switch from fossil-based to renewable energy sources by 2030. Thus, this paper aims to analyze the implications of fossil and renewable energy consumption on environmental degradation in the USA and China. This study uses the linear and nonlinear autoregressive distributed lag (ARDL) model to examine the cointegration of the fossil and renewable energy toward the CO_2 emissions from 1985 to 2021. The estimation results for USA using linear ARDL shows that fossil energy lead to higher CO_2 emissions, meanwhile renewable energy reduces the CO_2 emissions. Similar finding in the nonlinear ARDL, most of the models for China and the USA found significant impact of renewable energy consumption, where higher renewable energy transition contributes in lowering environmental degradation. This provide justification for policymakers in both countries to continue their efforts in renewable energy transition to archive the SDG7 agenda in 2030.

Keywords: Carbon Emission, Energy Consumption, Kuznets Curve, Renewable Energy
JEL Classifications: Q35, Q40, Q45

1. INTRODUCTION

Global warming refers to the steady rise in average Earth-atmosphere temperatures. It causes sea level rise, more severe weather, and ecosystem changes. Through a process known as the greenhouse effect, specific gases in Earth's atmosphere (also called greenhouse gases) trap heat from the sun and maintain a habitable climate. Earth's average temperature would be around −18°C (0°F) without the greenhouse effect, making it too cold for most living forms to survive. Human actions such as burning fossil fuels and clearing forests have led to a dramatic increase in atmospheric concentrations of greenhouse gases, particularly carbon dioxide (CO_2) (McJeon et al., 2021). Global warming is a phenomenon where the Earth's temperature rises due to an intensified greenhouse effect brought on by an increase in greenhouse gas concentration. You et al. (2021) have stated that CO_2 is the primary cause of global climate change.

The world is moving toward heavy industry and technology. As a result, global competition is continually increasing economic growth and escalating energy consumption, leading to more CO_2 emissions, according to Appiah et al. (2018) and Su et al. (2021). Li et al. (2018) stated that the consumption of fossil fuels, particularly coal-fired power production, is the main source of CO_2. Several policies have been presented to reduce and prevent increasing temperatures due to the uncontrollable CO_2 emission in the past. The Sustainable Development Goals (SDGs) is one of the most potential policies to ensure that the world has a healthy ecosystem in the long term. The United Nations General Assembly adopted the SDGs in 2015 as part of the 2030 Agenda for Sustainable

This Journal is licensed under a Creative Commons Attribution 4.0 International License

Development. By 2030, the SDGs aim to end poverty, safeguard the environment, and secure peace and prosperity for all people. Sustainable policies may include measures to reduce greenhouse gas emissions, protect natural resources, promote renewable energy, improve access to education and healthcare, and ensure fair and equitable distribution of resources.

The greenhouse effect must be addressed and the impacts of climate change must be mitigated by reducing greenhouse gas emissions and switching to renewable energy sources. Sustainable Development Goal 7 (SDG7) is one of the 17 global objectives set up in 2015 by the United Nations General Assembly as part of the 2030 agenda for Sustainable Development. SDG7 aims to ensure that everyone has access to energy that is inexpensive, trustworthy, environmentally friendly, and modern. The SDG7 objectives are as follows:

1. Guarantee universal availability of affordable, dependable, and modern energy services by 2030
2. Significantly increase the proportion of renewable energy in the worldwide energy mix by 2030
3. Double the pace of improvement in energy efficiency at the global level by 2030
4. Enhance international collaboration by 2030 to make it easier for people to access clean energy research and technology, such as improved and cleaner fossil fuel technology, renewable energy, and energy efficiency, and also encourage spending on energy infrastructure and clean energy technology.

The excessive demand for energy for household use and heavy industrial needs is one of the greatest obstacles to achieving the SDG7 agenda. Rapid economic development has highlighted the problem of global climate change, and carbon dioxide emissions have exacerbated the situation. According to the SDGs report of 2022, there has been a notable increase in the global electricity access rate, which has risen from 83% in 2010 to 91% in 2020. The number of individuals without electricity decreased from 1.2 billion to 733 million throughout this time.

The use of electricity is a critical necessity that cannot be avoided. Therefore, countries with large populations, such as China, India, the USA, Indonesia, and Pakistan, should adopt more sustainable energy use to manage carbon emissions that are far too high each year. Figure 1 shows a comparison of the use of electricity derived from fossil fuels, specifically from oil, coal, and natural gas. China consumed the most electricity from fossil resources among the five largest population nations, followed by the USA and India. Meanwhile, Indonesia and Pakistan have the lowest consumption of electricity from fossil fuels. China has an increasing trend from 2011 to 2021, but the USA has a nearly static trend in the use of fossil fuel electricity.

According to a report published by the Center in 2020, China's energy resource endowment is composed of coal (58%), oil (20%), gas (8%), hydro (8%), nuclear (2%), and renewable resources (5%) (Center, 2020). Zhao et al. (2021) reported that China is the largest population with the highest CO_2 emissions. China's economic growth is heavily dependent on the use of non-renewable energy sources, and from 1978 to 2017, its energy consumption rose from 397.1 million tons to 3.1 billion tons oil equivalent (Lei et al., 2022). This rise is equivalent to 5.4% annually on average, but the global average for this time period was closer to 2.8% (BP Statistical Review of World Energy, 2018).

Figure 2 compares CO_2 emissions in the world and China from 2019 to 2021. Wu et al. (2022) reported that both China and the USA are responsible for nearly half of global carbon emissions. Another study reported that China and the USA emit 44% of CO_2 annually (Xu et al., 2022). It is critical to remember that the Chinese economy is still rapidly expanding and has plenty of room to expand. As a result, there will be an even greater demand for per capita energy consumption. Policymakers in China must consider alternative energy sources in light of this development if the country's energy needs are to be met in the future. On the other hand, the USA, as the world's largest economy, urgently needs to reduce its use of fossil fuels to achieve the goal of a sustainable and green environment.

Although the use of electricity from fossil sources is high, there are efforts from all over the world to adapt to clean energy sources. Inglesi-Lotz (2016) reported that renewable energy sources are rising in developed and emerging countries to enhance new energy resources and reduce CO_2 emissions. Most of the developed countries replace fossil source such as coal to less polluting fuels (Nejat et al., 2015; Li et al., 2022). The transformation to a clean energy source country not only has a great impact on the environment (Bhutta et al., 2022; Xia and Wang, 2020) but also has a positive impact on the economy because many investors choose to invest in sustainable industries (Hysa et al., 2020; Zhou et al., 2022). The EIA report stated that there has been a significant surge in the consumption of renewable energy sources, with an annual increase of 3.0% (Apergis and Payne, 2010).

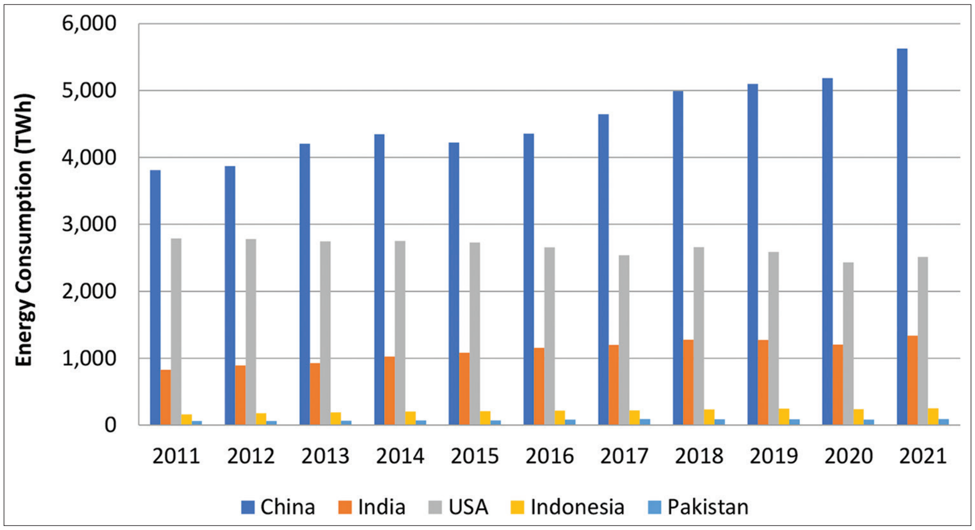
This paper aims to analyze the implications of non-renewable and renewable energy consumptions on environmental degradation for the USA and China. This study contributes the body of knowledge by evaluating the renewable energy by sources, namely, hydro, solar, and wind energy. The findings of this study will shed light on whether renewable energy consumption significantly helps to reduce carbon emission in both countries.

2. LITERATURE REVIEW

Studies comparing China and the USA in relation to CO_2 emissions have recently gained much attention among researchers. Some studies directly focus on the impact of CO_2. Shui and Harriss (2006) studied the effects of the USA and China trade on national and world emissions of CO_2 from 1997 to 2003. In their study, Xu et al. (2022) compared the trade effects between the USA and China and analyzed the spatial characteristics of CO_2 emissions in greater detail. From 2001 to 2018, Zhang et al. (2022) compared the carbon abatement in commercial buildings between China and the USA.

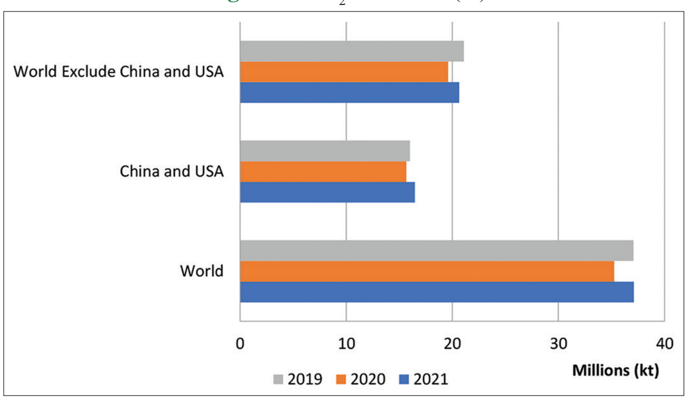
In their study, Dai et al. (2021) examine the effect of China-US trade on CO_2 emissions across 189 countries, with a greater emphasis on 26 specific sectors. The study is based on annual

Figure 1: Electricity from fossil resources



Source: Our World in Data (2023)

Figure 2: CO_2 emissions (kt)



Source: Our World in Data (2023)

data from 1996 to 2015 and concludes that there are countries in Europe, Africa, and Asia that experience negative effects from CO_2 emissions. Furthermore, China is one of the most important economic generators in the world, but it has high CO_2 emissions from its manufacturing sector. In contrast, the USA has high CO_2 emissions from its service sector. A comparison of CO_2 emission intensities between these two countries was conducted for the years 2002, 2005, and 2007 using an input-output analysis based on the "emergy/dollar ratio." The study shows that there has been a gradual decrease in CO_2 emissions in China's exports to the USA due to the development of green technology (Du et al., 2011).

Li et al. (2020) compared the amount of CO_2 emissions from 1993 to 2013 that were caused by final consumption in both countries. The study discovered that both domestic and foreign countries contributed to final consumption, resulting in CO_2 emissions. Both countries have also recognized that their CO_2 emissions are high on an annual basis and have implemented environmental policies. Carbon reduction policies in the USA and China have been compared, and the USA has begun to drastically reduce carbon emissions. On the other hand, China policy is still in the relative carbon emission reduction phase, which is the lowering of carbon emission intensity. The increase in CO_2 emissions continues, but at a slower rate than before. The study also included that the reasons were unavoidable because China has the world's largest population (Wu et al., 2022).

During the COVID-19 pandemic, comparisons regarding the forecasting of CO_2 emissions and the share of renewable energy in primary energy consumption were made between China and the USA. The nonlinear gray model was used to make a prediction until 2025, and the results have a positive impact on achieving the SDG7 goal in the future (Sahin, 2022). Khochiani and Nademi (2020) compared the three most polluting countries, including the USA and China, by using the wavelet coherence approach to determine the nexus between CO_2 emissions, energy consumption, and economic growth. The study conducted between 1971 and 2013 in China showed that there is a strong significant correlation between CO_2 emissions and Gross domestic product (GDP) in the short term horizon. This is almost similar to the USA, as there was a positive correlation in all frequencies between GDP and CO_2 emissions.

Several studies also focus on the element of renewable energy in China. Lei et al. (2000) studied the use of renewable and non-renewable energy in terms of the asymmetric impacts in China from 1990 to 2019. The results show that, in China, positive and negative shocks to bank deposits and general money have a significant growing influence on the use of renewable energy over the long term. Destek and Aslan (2017) also used the bootstrap panel causality study on renewable and non-renewable energy consumption and economic growth in 17 emerging nations, including China, from 1980 to 2012. During that time period, China continued to consume a large amount of non-renewable energy than renewable energy. The study by Zhao et al. (2020) using time series econometric techniques determined that from 1980 to 2016, the trade openness factor was the cause of massive non-renewable energy consumption.

Jiang et al. (2022) conducted the nonlinear autoregressive distributed lag (NARDL) approach to analyze the asymmetric effect of renewable energy consumption in China. The study found that a decrease in the use of renewable energy may lead to an increase in CO_2 emissions because most people in China do not have a choice but to depend on non-renewable energy. Ali et al. (2022) conducted an empirical study on carbon emissions in China from 1990 to 2019 using dynamic autoregressive distributed lag (ARDL). Results showed that there is a strong correlation in the long and short term between the consumption of renewable and non-renewable energy and CO_2 emissions. Moreover, Abbasi et al. (2022) analyzed the data using dynamic ARDL and obtained a similar finding. From 1980 to 2018, China's fossil fuel energy was a major contributor to CO_2 emissions. However, adopting renewable energy is the appropriate strategy to achieve sustainability goals.

Empirical studies on renewable energy have also been conducted to prove its great sustainable effect in the USA. Dabboussi and Abid (2022) analyzed, using a threshold approach, that renewable energy consumption has a positive impact on economic growth. Emirmahmutoglu et al. (2021) analyzed the relationship between renewable and non-renewable energy consumption and the US real GDP using the Toda-Yamamoto approach. Another study also used a similar method to analyze the consumption of renewable energy and trade policy in the USA. The results determined that there was a positive impact on the US GDP due to renewable energy (Usman et al., 2020). The past studies in the literature have done many comparisons between two biggest world trade countries. However, there is still a lack of studies that directly compare the impacts of fossil and renewable resources between China and the USA, especially on the renewable energy by sources.

3. DATA AND METHODOLOGY

The study aims to examine whether ARDL bound test in the long-run cointegrate exists among the CO_2 emissions per capita, GDP per capita, GDP per capita square, population, foreign direct investment (FDI), and electricity from fossil and renewable sources. The study also identifies the segment of renewable energy (hydro, solar, and wind) that can impact the degradation of CO_2 emission. This empirical analysis uses annual data from 1985 to 2021 (37 years) to examine the renewable energy model and electricity based on hydro power. However, separation of renewable energy for segment energy such as solar and wind are suffocated of data. Thus, in certain models, this study is only using 31 observations from 1990 to 2021. All data are transformed into natural log to standardize the data distribution.

The model coefficients are β_0–β_6, where time is calculated through t. To identify interactions among variables, we will first establish the ARDL approach developed by Pesaran et al. (2001). To avoid the heteroscedasticity issue and generate more accurate estimates, all the variables in equation are transformed into their logarithmic forms. This study aims to determine the long-run ARDL cointegration only. In the direction of encountering relationships for variables, the specification of an ARDL model (long-run) was characterized as follows:

$$\begin{aligned}\Delta \ln CO2_t &= c_1 + \sum_{i=1}^{p}\alpha_{1i}\Delta \ln CO2_{t-i} + \sum_{i=0}^{q}\alpha_{2i}\Delta \ln GDP_{t-i} \\ &+ \sum_{i=0}^{r}\alpha_{3i}\Delta \ln GDP^2_{t-i} + \sum_{i=0}^{s}\alpha_{4i}\Delta \ln POP_{t-i} + \sum_{i=0}^{k}\alpha_{5i}\Delta \ln FDI_{t-i} \\ &+ \sum_{i=0}^{l}\alpha_{6i}\Delta \ln FOS_{t-i} + \sum_{i=0}^{m}\alpha_{7i}\Delta \ln RE_{t-i} + \beta_1 \ln GDP_{t-1} \\ &+ \beta_2 \ln GDP2_{t-1} + \beta_3 \ln POP_{t-1} + \beta_4 \ln FDI_{t-1} \\ &+ \beta_5 \ln FOS_{t-1} + \beta_6 \ln RE_{t-1} + \varepsilon_t \end{aligned} \quad (1)$$

Where CO_2 is CO_2 emissions per capita (mt), GDP is gross domestic product per capita ($), GDP^2 is the square term of GDP, POP is the total population, FDI is foreign direct investment ($), FOS is fossil energy consumption (exajoules), and RE is renewable energy consumption (exajoules). As an extension from existing studies, this study evaluates the impact of renewable energy by sources on the carbon emission. This is done by substituting the RE variables with solar, wind, and hydro. The process is repeated to obtain the coefficients for each renewable energy source. The comparisons between China and the USA as both are closely comparable nations, and these countries not only have great economic power but also contribute to the largest CO_2 emissions in the world. Therefore, this study is using CO_2 per capita as the dependent variable, to clarify of the impact toward CO_2 emission from both of the countries, and include the population variable as independent as for reason both countries are among top three largest global population in the world.

Gross domestic product (GDP) per capita and GDP per capita square are important independent variables to be selected to this model, since both countries have enormous national income and by using the GDP per capita square to able the capture of the nonlinear relationship in Kuznets theory. In early 1950, an economist named Simon Kuznets initially suggested the Kuznets curve, commonly referred to as the environmental Kuznets curve (EKC) (Kuznets, 1962). EKC was familiar among the environmental study to analyze the inverted U-shape between pollution and economic factors (Ahmad et al., 2021). The FDI is representing the element to use the nonlinearity for the ARDL model, and there have been several studies that indicate the same variable to analyze the NARDL of FDI toward the CO_2 emissions (Abid et al., 2022; Haug and Ucal, 2019). The NARDL is enabled to FDI because it has been the positive and negative effect toward the CO_2 emission.

However, in this study, FDI remain natural, while the focus of study are the sustainable factors that indicate the renewable electricity resource, solar, hydro, and wind that are in positive and negative impacts. The fossil electricity resource is also an independent variable used to analyze the effect to CO_2 emission. Many previous studies showed that electricity from the source of fossil is greatly polluting the environment and releasing a lot of CO_2 emissions (Ullah et al., 2022; Ali et al., 2021).

The long-run relationship can be examined using various methods, such as the Pedroni test (2004) used by Prohl and Schneider (2006) or the Johansen cointegration test (Johansen, 1988). However, this paper uses the bound test in ARDL and NARDL models to analyze the impact of renewable and non-renewable energy consumption to sand fossil electricity resources toward the CO_2 emissions. Pesaran and Shin (1996) reported that there are many accurate issues among researchers on the Johansen cointegration method. Therefore, the ARDL cointegration technique was created to gain more accurate result of the long-run relationship. The ARDL approach requires that all variables must be stationary at I(1) and/or I(O) for the unit root test (Pesaran and Shin, 1996; Pesaran et al., 2001). The ARDL model for this study is as follows:

The nonlinear ARDL is an extension to the ARDL technique where Granger and Yoon (2002) develop the concept of "hidden cointegration," wherein cointegrating relationships between the positive and negative components of the underlying variables can be identified (Shin et al., 2014). Shin et al. (2014) approach will be used to decompose the variables as electricity power source (hydro, solar, and wind) with positive and negative shocks ($RE^{\pm}$; $HYDRO^{\pm}$; $SOLAR^{\pm}$; $WIND^{\pm}$) being taken into consideration. The variables are as follows:

$$\mathrm{FOS}^{+}=\sum_{i=1}^{t}\Delta\mathrm{FOS}^{+}{}_{i}=\sum_{i=1}^{t}\max(\Delta\mathrm{FOS}^{+}{}_{i},0) \tag{2}$$

$$\mathrm{FOS}^{-}=\sum_{i=1}^{t}\Delta\mathrm{FOS}^{-}{}_{i}=\sum_{i=1}^{t}\min(\Delta\mathrm{FOS}^{-}{}_{i},0) \tag{3}$$

$$\mathrm{RE}^{+}=\sum_{i=1}^{t}\Delta\mathrm{RE}^{+}{}_{i}=\sum_{i=1}^{t}\max(\Delta\mathrm{RE}^{+}{}_{i},0) \tag{4}$$

$$\mathrm{RE}^{-}=\sum_{i=1}^{t}\Delta\mathrm{RE}^{-}{}_{i}=\sum_{i=1}^{t}\min(\Delta\mathrm{RE}^{-}{}_{i},0) \tag{5}$$

$$\mathrm{SOLAR}^{+}=\sum_{i=1}^{t}\Delta\mathrm{SOLAR}^{+}{}_{i}=\sum_{i=1}^{t}\max(\Delta\mathrm{SOLAR}^{+}{}_{i},0) \tag{6}$$

$$\mathrm{SOLAR}^{-}=\sum_{i=1}^{t}\Delta\mathrm{SOLAR}^{-}{}_{i}=\sum_{i=1}^{t}\min(\Delta\mathrm{SOLAR}^{-}{}_{i},0) \tag{7}$$

$$\mathrm{WIND}^{+}=\sum_{i=1}^{t}\Delta\mathrm{WIND}^{+}{}_{i}=\sum_{i=1}^{t}\max(\Delta\mathrm{WIND}^{+}{}_{i},0) \tag{8}$$

$$\mathrm{WIND}^{-}=\sum_{i=1}^{t}\Delta\mathrm{WIND}^{-}{}_{i}=\sum_{i=1}^{t}\min(\Delta\mathrm{WIND}^{-}{}_{i},0) \tag{9}$$

$$\mathrm{HYDRO}^{+}=\sum_{i=1}^{t}\Delta\mathrm{HYDRO}^{+}{}_{i}=\sum_{i=1}^{t}\max(\Delta\mathrm{HYDRO}^{+}{}_{i},0) \tag{10}$$

$$\mathrm{HYDRO}^{-}=\sum_{i=1}^{t}\Delta\mathrm{HYDRO}^{-}{}_{i}=\sum_{i=1}^{t}\min(\Delta\mathrm{HYDRO}^{-}{}_{i},0) \tag{11}$$

Based on Shin et al. (2014), this study substitutes Eqs. (2) and (11) into the ARDL equation to estimate the nonlinear ARDL for fossil energy. The nonlinear equation is as follows:

$$\begin{aligned}\Delta\ln CO2_t &= c_1+\sum_{i=1}^{p}\alpha_{1i}\Delta\ln CO2_{t-i}+\sum_{i=0}^{q}\alpha_{2i}\Delta\ln GDP_{t-i}\\ &+\sum_{i=0}^{r}\alpha_{3i}\Delta\ln GDP^2_{t-i}+\sum_{i=0}^{s}\alpha_{4i}\Delta\ln POP_{t-i}+\sum_{i=0}^{k}\alpha_{5i}\Delta\ln FDI_{t-i}\\ &+\sum_{i=0}^{l}\alpha_{6i}\Delta\ln FOS_{t-i}+\sum_{i=0}^{m}\alpha_{7i}\Delta\ln RE^{+}_{t-i}+\sum_{i=0}^{n}\alpha_{8i}\Delta\ln RE^{-}_{t-i}\\ &+\beta_1\ln GDP_{t-1}+\beta_2\ln GDP2_{t-1}+\beta_3\ln POP_{t-1}+\beta_4\ln FDI_{t-1}\\ &+\beta_5\ln FOS^{+}_{t-i}+\beta_6\ln FOS^{-}_{t-i}+\beta_6\ln RE^{+}_{t-i}+\beta_7\ln RE^{-}_{t-i}+\varepsilon_t\end{aligned} \tag{12}$$

Based on this latest equation, the study can identify the asymmetric effects in renewable energy consumption changes. Similarly, to obtain the asymmetric effects of renewable energy by sources, this study substitutes (4) to (11) into the linear ARDL to obtain the nonlinear equation for each renewable energy source. Table 1 shows the detailed description for each variable used in this study and also the respective data sources.

4. RESULTS AND DISCUSSION

Prior to the ARDL estimations, this study conducted unit root test as a preliminary test to ensure all variables are stationary either in level or first differences. Table 2 shows the results from the unit root test using Phillips-Perron (PP) for China and the USA. For the USA, almost all the variables in the first difference are significant at 1% except for the population and solar variables. The population are significant 1% at the levels, and also the same the solar variable at 10% significancy. China in the levels is having 2 significant at 5% for wind and population variables, and having all variables are significant a first different except for population, thus enabling the estimation for bootstrap ARDL test, as all variables are significant at levels and/or first difference (Pesaran et al., 2001).

Table 3 indicates eight models of ARDL for China and the USA. This paper prior toward the linear ARDL in the long-run context as the issues was to look forward for the SDG7 agenda to intensify the renewable and clean energy in 2030. China linear ARDL models resulting splendid for the GDP and GDP2, and almost all the models are significant except for hydro (Model 4). The U-shape of EKC is accurate to the theory with results as the GDP all are in positive values and GDP2 are relatively negative. These results are continuously to the other researchers as before, Shahbaz et al. (2017), conducted the cointegration of ADRL bound test for CO_2 emissions in China from the impact of the globalization has identify the exist of U-shape of the Kuznets curve in short and long-run cointegration.

Similar results also happened to the USA models, however, by comparing to the USA only have solar (Model 2) to gaining significant to the U-shape of EKC. A previous study also showed that the inverted U-shape of Kuznets curve existed toward the pattern of USA economic growth (Aslan et al., 2018). The USA is among the Organization for Economic Cooperation and Development countries that have inverted U-shape Kuznets (Maneejuk and Yamaka, 2022); thus, this paper also indicates that

Table 1: Variables description

Short form	Variables description	Data sources
CO_2	CO_2 emissions Per Capita (mt)	Our World in Data
GDP	Gross Domestic Product Per Capita ($)	World Bank
GDP2	Gross Domestic Product Per Capita Square ($)	World Bank
POP	Population (total)	World Bank
FDI	Foreign Direct Investment ($)	World Bank
FOS	Fossil Energy Consumption (exajoules)	Our World in Data
RE	Renewable Energy Consumption (exajoules)	Our World in Data
SOLAR	Solar Energy Consumption (exajoules)	BP World Energy
WIND	Wind Energy Consumption (exajoules)	BP World Energy
HYDRO	Hydro Energy Consumption (exajoules)	BP World Energy

Source: World Bank (2023); BP World Energy (2023)

Table 2: Unit root results

Variables	China		USA	
	Level	First difference	Level	First difference
LCO2	−1.6907	−2.9929**	0.5588	−6.0728***
LGDP	−0.9295	−2.7146*	−1.5034	−5.1491***
LGDP2	−2.0733	−2.8694*	−1.4106	−5.2134***
LPOP	−3.8681**	−0.4113	−4.0492***	−0.3802
LFDI	−1.4597	−4.3101***	−3.0373**	−8.8331***
LFOSSIL	−0.6215	−3.8365***	−2.833*	−5.5933***
LRE	−1.9539	−6.843***	−2.833*	−5.5933***
LSOLAR	−1.5765	−3.1069**	−1.6654*	−1.9607
LWIND	−3.6513**	−4.515***	0.1181	−3.7614***
LHYDRO	−1.928	−6.9269***	−2.9298*	−8.024***

(*) Significant at 10%; (**) Significant at 5%; (***) Significant at 1%

the income of the USA has impact the CO_2 emissions and closely tandem with the Kuznets theory.

The population for the ARDL are all significant for China and the USA, however report as negative impact toward CO_2 emissions, which are not usually toward the most previous researches (Ahmed et al., 2017; Hashmi and Alam, 2019; Rahman et al., 2020). However, the Organization of Islamic Cooperation countries found that population does not affect the CO_2 emissions in the long-run (Shaari et al., 2020). Mamipour et al. (2019) also found that the population in Iran has a negative effect toward the CO_2 emissions.

The significant FDI for the USA are showing negative values, while China has a positive impact to the CO_2 emissions. This indicates that the USA is more aware of the incoming of the sustainable investment that is reflex the negative impact for USA (Model 2) toward the CO_2 emissions. Compared to China (Models 1 and 4), are showing the FDI has causing the increasing of CO_2 emissions. Wang et al. (2022) reported that the main source of environmental damage in China is the inflow of FDI from 1980 to 2019. Other researchers also reported that the FDI inflow to China will highly contribute to the CO_2 emissions leading to environmental pollution (Rahman et al., 2019; Zheng and Sheng, 2017).

Hassan et al. (2021) reported that the CO_2 emissions are the by-product of fossil fuel, coal, and natural gas, which cause high damage to the environment. In Pakistan, proven that CO_2 emissions were strongly contributed by the fossil-based energy likely coal and oil resources (Rahman and Ahmad, 2019). Indeed, this paper finds that both countries are having significant and positive impact for the consumption based on fossil for all of the models. By comparing China is more polluted as report with 0.9161 (Model 1), while the USA (Model 4) with the amount of 0.8307. Hu and Wu (2013) also reported that China still heavily relies on fossil fuels to meet energy consumption for households and heavy industry. Other studies showed that China's heavy industries and rapid development led to high energy consumption and drive toward increasing CO_2 emissions (Zhang et al., 2019).

For the renewable energy consumption, we can clarify that the USA (Model 1) is the only significant model with −0.1055, indicating that renewable energy can reduce the CO_2 emissions in the USA. On the other hand, China resulting unexpected impact to the CO_2 emissions for the linear ARDL as there are three of the significant (Model 1, 2, and 4) are report to be positive value (0.2992, 0.0737 and 0.2148). However, previous studies also have similar results. Maji and Adamu (2021) reported that although several studies showed that renewable energy consumption plays a significant role to reduce the CO_2 emissions, the case is different in Nigeria.

Other countries in the Middle East and North Africa countries also found that the renewable energy does not significantly improve the environmental quality (Nathaniel et al., 2020). In some cases, there is a possibility that the renewable energy is negatively correlated with the CO_2 emissions (Ponce and Khan, 2021). Overall, Table 3 shows that there are strong cointegrations of fossil and renewable resources toward the CO_2 emissions. The F-statistics for all the models are significant, and most of the CUSUM and CUSUM square are stable and the normality test also conducted, resulting a normal distribution.

Similar with the linear ARDL, the nonlinear ARDL also focus on the long-run relationships. Firstly, the F-statistics shown are for the bound test results that show that all variables in the model have long-run relationship. The estimation results for nonlinear ARDL provide consistent results for the GDP and GDP^2 as all models have positive coefficients for the former and negative coefficients for the latter. This is consistent with the EKC hypothesis, where economic growth at first leads to higher environmental degradation and till one point, increase in economic growth will decrease the environmental degradation, thus creating an inverted U-shaped curve.

All models show that the population has negative and significant impact on the carbon emission in both countries. Although it contradicts most previous studies, we can explain the relationship

Table 3: Long-run estimation results for linear ARDL

Variable	CHINA				USA			
	Model 1	Model 2	Model 3	Model 4	Model 1	Model 2	Model 3	Model 4
ln GDP	1.2654**	8.7338***	3.3068**	0.1125	21.9588*	35.0198**	21.3848	7.2012
ln GDP^2	−0.0950**	−0.4433***	−0.1428**	−0.0174	−0.9894	−1.5863**	−0.9567	−0.2963
ln POP	−5.6120***	−21.1413***	−10.8087***	−4.5464***	−1.885***	−2.5905***	−2.3456***	−2.7645***
ln FDI	0.0274**	−0.0386	−0.0118	0.0408***	−0.0183	−0.0296**	−0.0149	−0.0165
ln FOS	0.9161***	0.4878***	0.6757***	0.8348***	0.4021**	0.6556***	0.6362***	0.8307***
ln RE	0.2992***				−0.1055**			
ln SOLAR		0.0737***				0.0044		
ln WIND			−0.0158				−0.0101	
ln HYDRO				0.2148***				−0.0622
Constant	105.8953***	401.0952***	206.0560***	88.5484***	−84.1321	−144.1461*	−75.283	7.8361
F−statistics	8.5572***	15.7953***	3.0746*	8.2821***	15.4540***	13.6519***	3.9857**	9.5794***
Normality	1.3188	0.8714	0.4071	0.6655	3.0700	3.9951	2.0443	4.4557
LM	2.8221*	3.1433*	3.8385**	5.7795**	3.3557*	2.7280*	2.0824	6.5675***
BPG	0.5741	0.9235	0.5459	0.5273	0.4686	0.4186	1.1430	0.2943
RESET	0.0039	5.9906**	4.5352**	0.0704	3.6967*	5.4257**	18.4949***	4.5358**
CUSUM	Stable	Stable	Stable	Not stable	Stable	Stable	Stable	Stable
$CUSUM^2$	Stable	Not Stable	Stable	Stable	Stable	Stable	Stable	Stable
CointEq(−1)*	−1.0386***	−1.7182***	−1.0911***	−1.1091***	−0.5597***	−0.6377***	−0.9031***	−0.6998***

*, **, and *** denotes significant level at 10%, 5% and 1%, respectively

Table 4: Long-run estimation results for non-linear ARDL

Variable	China				USA			
	Model 1	Model 2	Model 3	Model 4	Model 1	Model 2	Model 3	Model 4
ln GDP	4.3437***		4.3954*	1.4119*	28.2022***	31.9576***	42.4959***	30.8674***
ln GDP^2	−0.2570***		−0.2269**	−0.112**	−1.2685***	−1.4388***	−1.929***	−1.3922***
ln POP	−8.8500***		−12.1338***	−7.7333***	−0.822**	−1.973***	−1.6147***	−0.7286**
ln FDI	−0.0045		0.0224	0.0592***	−0.033***	0.0029	0.0017	−0.0233***
ln $FOSSIL^+$	1.3407***		0.9621***	1.0684***	0.0419	0.0202	0.3281***	−0.0978
ln $FOSSIL^-$	−3.6675***		−3.0113*	−3.8707**	0.8257***	0.4107***	0.5468***	0.6673***
ln RE^+	−0.0552				−0.0377			
ln RE^-	4.5033***				0.125**			
ln $SOLAR^+$						−0.0088**		
ln $SOLAR^-$						0.5616***		
ln $WIND^+$			−0.0068				−0.0318***	
ln $WIND^-$			−0.0058				0.5929**	
ln $HYDRO^+$				0.2215***				−0.048
ln $HYDRO^-$				−1.832**				0.0805**
Constant	167.1832***		233.2865***	156.016***	−136.5601***	−135.7605***	−199.3972***	−152.9532***
F-statistics	8.1274***		3.9173***	6.4104***	7.6036***	36.4581***	14.0876***	7.8695***
Normality	3.6028		6.6460**	0.9610	1.2239	0.3148	0.6284	1.8999
LM	5.1514**		9.2925**	18.4105***	7.6238**	15.2975***	0.7747	5.4592**
BPG	0.3878		0.7056	1.0244	1.4833	1.1667	11.2621***	0.6838
RESET	1.4848		23.4276***	1.7857	0.4124	1.0052	0.8883	1.6180
CUSUM	Stable		Stable	Stable	Stable	Stable	Stable	Stable
$CUSUM^2$	Stable		Stable	Stable	Stable	Stable	Stable	Stable
CointEq(−1)*	−1.0386***		−1.8582***	−2.1066***	−2.3435***	−2.1693***	−2.5065***	−2.2822***

*, **, and *** denotes significant level at 10%, 5% and 1%, respectively

based on increased awareness throughout time that led to lower carbon emission (Wu et al., 2021). The FDI have mixed impact, where for China (Model 4), we can see positive impact of FDI on carbon emission, while for the USA, we found negative impact (Models 1 and 4). The positive implications are consistent with Salahuddin et al. (2018) and Khan et al. (2020), while Abdo et al. (2020) and Nguyen et al. (2020) found negative impact. The economic intuitions behind this foreign investment in China are not green investment, while the opposite is true for the USA.

For the energy indicators as shown in Table 4, the nonlinear ARDL applied in this study found interesting results. Increases in the non-renewable energy consumptions (fossil) lead to higher carbon emission for China (Models 1, 3, and 4) and the USA (Model 3). On the other hand, reduction in the fossil energy consumption causes lower carbon emissions in China (Models 1, 3, and 4). However, contradicting results are obtained for the USA (all models) where positive relationships are found between reduction in the fossil energy consumption and carbon emission. We can support our findings based on the study by Solaymani (2019) among the seven top carbon emitters including the USA, found that USA still fail to reduce the CO_2 emissions in term of carbon from transportation sector.

For the renewable energy, both countries found no significant impact of aggregated renewable energy (Model 1) on carbon emissions. Meanwhile, reduction in renewable energy consumption led to higher carbon emission. The positive signs are consistent with Dong et al. (2019) and Xinmin et al. (2022) studies. The specific renewable energy sources for the USA highlight clearly that renewable energy transition does significantly reduce carbon emission in the USA as higher renewable energy decreases carbon emission and reduction in renewable energy consumption increases carbon emissions.

On the other hand, China found inverse relationship for hydro energy consumption. This means that the current hydro energy consumptions in China do not lead to lower carbon emissions in China. This might be due to high carbon emission during the current industrialization era. Moreover, China is now focusing more on the solar energy in the renewable energy that led to strong cointegration toward the environmental degradation (Crijns-Graus et al., 2020; Li and Huang, 2020; Zhang et al. 2020). This study is unable to estimate the nonlinear ARDL for solar energy in China due to the lack of variation in solar energy and hence unable to capture the positive and negative changes. Last but not the least, this study also conducted few diagnostic checking to evaluate the model used in this study. Overall, this study concludes that there are no issues in terms of the data distribution, parameter stability, and error term distribution.

5. CONCLUSION

The global take the energy crisis and climate change as serious issues to overcome, especially in countries with large populations like China and the USA. Both countries hold the record as the highest CO_2 emissions (Wu et al., 2022) and as having the major role in global manufacturing (Goldstein, 2022). Most countries also depend on China and the USA to gain the economic scale, meaning both countries are strongly oriented with the heavy industries. Thus, these countries definitely need a lot of electricity supply sources.

Many parties are concerned about this issue because China and the USA continue to rely on fossil-based energy sources to meet domestic demands. The use of fossil energy will of course release CO_2 and cause pollution to the environment. As a result, the UN has established an agenda of SDG7, which is critical to the long term viability of clean energy consumption. This paper concludes that it is possible to achieve the long-run goal in 2030. In the linear ARDL examine fossil energy will enhance the CO_2 emissions, and the renewable model for the USA defines that renewable energy will reduce the CO_2 emissions.

This study also found that China ARDL model is not having positive effect to reduce the CO_2 emissions. However, in the nonlinear ARDL, most of the models for China and the USA have records to have significant and positive impacts on environmental degradation. There are strong efforts from both countries to transform the energy supply to renewable energy, and many renewable energy policies will gain more benefits to sustain the environment and enhance the economic growth (Hou et al., 2021; Wei et al., 2022). Thus, this concludes that China and the USA are moving forward to sustainable energy in the future.

This paper only aims to focus on fossil and renewable energy consumption. This study has limitation, which did not include nuclear power for comparison. Whether nuclear energy is sustainable or not remains a debate. Due to the possibility of severe radioactive consequences in the event of a nuclear reactor accident, such as the Chernobyl disaster in Russia in 1986, its position as environmentally friendly also remains a debate (Berger, 2010; Ludovici et al., 2020). However, nuclear energy is considered clean energy because it does not emit CO_2 (Lau et al., 2019; Zhan et al., 2021). Since both countries are also producing the electricity from nuclear energy, there is still room for improvement for this paper. Hence, it is more appropriate to evaluate both countries' performance to determine how well positioned they are to meet the SDG7 goals by 2030.

REFERENCES

Abbasi, K.R., Awan, A., Bandyopadhyay, A., Rej, S., Banday, T.P. (2023), Investigating the inverted N-shape EKC in the presence of renewable and nuclear energy in a global sample. Clean Technologies and Environmental Policy, 25(4), 1179-1194.

Abdo, A.B., Li, B., Zhang, X., Lu, J., Rasheed, A. (2020), Influence of FDI on environmental pollution in selected Arab countries: A spatial econometric analysis perspective. Environmental Science and Pollution Research, 27, 28222-28246.

Abid, A., Mehmood, U., Tariq, S., Haq, Z.U. (2022), The effect of technological innovation, FDI, and financial development on CO_2 emission: Evidence from the G8 countries. Environmental Science and Pollution Research International, 29, 11654-11662.

Ahmad, M., Muslija, A., Satrovic, E. (2021), Does economic prosperity lead to environmental sustainability in developing economies? Environmental Kuznets curve theory. Environmental Science and Pollution Research, 28(18), 22588-22601.

Ahmed, K., Rehman, M.U., Ozturk, I. (2017), What drives carbon dioxide emissions in the long-run? Evidence from selected South Asian countries. Renewable and Sustainable Energy Reviews, 70, 1142-1153.

Ali, M.U., Gong, Z., Ali, M.U., Wu, X., Yao, C. (2021), Fossil energy consumption, economic development, inward FDI impact on CO_2 emissions in Pakistan: Testing EKC hypothesis through ARDL model. International Journal of Finance and Economics, 26(3), 3210-3221.

Ali, U., Guo, Q., Kartal, M.T., Nurgazina, Z., Khan, Z.A., Sharif, A. (2022), The impact of renewable and non-renewable energy consumption on carbon emission intensity in China: Fresh evidence from novel dynamic ARDL simulations. Journal of Environmental Management, 320, 115782.

Apergis, N., Payne, J.E. (2010), Renewable energy consumption and economic growth: Evidence from a panel of OECD countries. Energy Policy, 38(1), 656-660.

Appiah, K., Du, J., Poku, J. (2018), Causal relationship between agricultural production and carbon dioxide emissions in selected emerging economies. Environmental Science and Pollution Research, 25, 24764-24777.

Aslan, A., Destek, M.A., Okumus, I. (2018), Bootstrap rolling window estimation approach to analysis of the environment Kuznets curve hypothesis: Evidence from the USA. Environmental Science and Pollution Research, 25, 2402-2408.

Berger, E.M. (2010). The Chernobyl disaster, concern about the environment, and life satisfaction. Kyklos, 63(1), 1-8.

Bhutta, U.S., Tariq, A., Farrukh, M., Raza, A., Iqbal, M.K. (2022), Green bonds for sustainable development: Review of literature on development and impact of green bonds. Technological Forecasting and Social Change, 175, 121378.

BP Statistical Review of World Energy. (2018), BP Statistical Review of World Energy 2018: Two Steps Forward, One Step Back. Available from: https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/energy-economics/statistical-review/bp-statsreview-2018-full-report.pdf [Last accessed on 2023 Mar 15].

BP World Energy. (2023), Statistical Review of World Energy. Available from: https://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy.html [Last accessed on 2023 Mar 15].

Center, B.P. (2020), Annual Energy Outlook 2020. Vol. 12. Washington, D.C: Energy Information Administration. p1672-1679.

Crijns-Graus, W., Wild, P., Amineh, M.P., Hu, J., Yue, H. (2022), International comparison of research and investments in new renewable electricity technologies: A focus on the European union and China. Energies, 15(17), 6383.

Dabboussi, M., Abid, M. (2022), A comparative study of sectoral renewable energy consumption and GDP in the US: Evidence from a threshold approach. Renewable Energy, 192, 705-715.

Dai, F., Yang, J., Guo, H., Sun, H. (2021), Tracing CO_2 emissions in China-US trade: A global value chain perspective. Science of the Total Environment, 775, 145701.

Destek, M.A., Aslan, A. (2017), Renewable and non-renewable energy consumption and economic growth in emerging economies: Evidence from bootstrap panel causality. Renewable Energy, 111, 757-763.

Dong, K., Dong, X., Dong, C. (2019), Determinants of the global and regional CO_2 emissions: What causes what and where? Applied Economics, 51(46), 5031-5044.

Du, H., Guo, J., Mao, G., Smith, A.M., Wang, X., Wang, Y. (2011), CO_2 emissions embodied in China-US trade: Input-output analysis based on the emergy/dollar ratio. Energy Policy, 39(10), 5980-5987.

Emirmahmutoglu, F., Denaux, Z., Topcu, M. (2021), Time-varying causality between renewable and non-renewable energy consumption and real output: Sectoral evidence from the United States. Renewable and Sustainable Energy Reviews, 149, 111326.

Goldstein, J. (2022), Wither the trade regime? International Studies Review, 24(2), viac019.

Granger, C.W.J., Yoon, G. (2002), Hidden Cointegration. U of California, Economics Working Paper No. 2002-02.

Hashmi, R., Alam, K. (2019), Dynamic relationship among environmental regulation, innovation, CO_2 emissions, population, and economic growth in OECD countries: A panel investigation. Journal of Cleaner Production, 231, 1100-1109.

Hassan, A., Ilyas, S.Z., Jalil, A., Ullah, Z. (2021), Monetization of the environmental damage caused by fossil fuels. Environmental Science and Pollution Research, 28, 21204-21211.

Haug, A.A., Ucal, M. (2019), The role of trade and FDI for CO_2 emissions in Turkey: Nonlinear relationships. Energy Economics, 81, 297-307.

Hou, F., Su, H., Li, Y., Qian, W., Xiao, J., Guo, S. (2021), The impact of foreign direct investment on China's carbon emissions. Sustainability, 13(21), 11911.

Hysa, E., Kruja, A., Rehman, N.U., Laurenti, R. (2020), Circular economy innovation and environmental sustainability impact on economic growth: An integrated model for sustainable development. Sustainability, 12(12), 4831.

Inglesi-Lotz, R. (2016), The impact of renewable energy consumption to economic growth: A panel data application. Energy Economics, 53, 58-63.

Jiang, Y., Batool, Z., Raza, S.M.F., Haseeb, M., Ali, S., Zain Ul Abidin, S. (2022), Analyzing the asymmetric effect of renewable energy consumption on environment in STIRPAT-Kaya-EKC framework: A NARDL approach for China. International Journal of Environmental Research and Public Health, 19(12), 7100.

Johansen, S. (1988), Statistical analysis of cointegration vectors. Journal of Economic Dynamics and Control, 12(2-3), 231-254.

Khan, Z.U., Ahmad, M., Khan, A. (2020), On the remittances-environment led hypothesis: Empirical evidence from BRICS economies. Environmental Science and Pollution Research, 27, 16460-16471.

Khochiani, R., Nademi, Y. (2020), Energy consumption, CO_2 emissions, and economic growth in the United States, China, and India: A wavelet coherence approach. Energy Environment, 31(5), 886-902.

Kuznets, S. (1962), Inventive activity: Problems of definition and measurement. In: The Rate and Direction of Inventive Activity: Economic and Social Factors. USA: Princeton University Press. p19-52.

Lau, L.S., Choong, C.K., Ng, C.F., Liew, F.M., Ching, S.L. (2019), Is nuclear energy clean? Revisit of environmental Kuznets curve hypothesis in OECD countries. Economic Modelling, 77, 12-20.

Lei, W., Ozturk, I., Muhammad, H., Ullah, S. (2022), On the asymmetric effects of financial deepening on renewable and non-renewable energy consumption: Insights from China. Economic Research-Ekonomska Istraživanja, 35(1), 3961-3978.

Li, J., Huang, J. (2020), The expansion of China's solar energy: Challenges and policy options. Renewable and Sustainable Energy Reviews, 132, 110002.

Li, X., Liao, H., Du, Y.F., Wang, C., Wang, J.W., Liu, Y. (2018), Carbon dioxide emissions from the electricity sector in major countries: A decomposition analysis. Environmental Science and Pollution Research, 25, 6814-6825.

Li, X., Ozturk, I., Raza Syed, Q., Hafeez, M., Sohail, S. (2022), Does green environmental policy promote renewable energy consumption in BRICST? Fresh insights from panel quantile regression. Economic Research-Ekonomska Istraživanja, 35(1), 5807-5823.

Li, Y., Xu, D., Wang, J., Zhang, Y., Yu, X. (2020), Industrial path analysis for CO_2 transfers induced by final consumption: A comparison of the United States and China. Journal of Cleaner Production, 251, 119604.

Ludovici, G.M., de Souza, S.O., Chierici, A., Cascone, M.G., d'Errico, F., Malizia, A. (2020), Adaptation to ionizing radiation of higher plants: From environmental radioactivity to Chernobyl disaster. Journal of Environmental Radioactivity, 222, 106375.

Maji, I.K., Adamu, S. (2021), The impact of renewable energy consumption on sectoral environmental quality in Nigeria. Cleaner Environmental Systems, 2, 100009.

Mamipour, S., Beheshtipour, H., Feshari, M., Amiri, H. (2019), Factors influencing carbon dioxide emissions in Iran's provinces with emphasis on spatial linkages. Environmental Science and Pollution Research, 26, 18365-18378.

Maneejuk, P., Yamaka, W. (2022), Revisiting the environmental Kuznets curve hypothesis in OECD during 1970-2016: Panel smooth transition regression. Energy Reports, 8, 41-47.

McJeon, H., Mignone, B.K., O'Rourke, P., Horowitz, R., Kheshgi, H.S., Clarke, L., Edmonds, J. (2021), Fossil energy deployment through midcentury consistent with 2°C climate stabilization. Energy and Climate Change, 2, 100034.

Nathaniel, S., Anyanwu, O., Shah, M. (2020), Renewable energy, urbanization, and ecological footprint in the Middle East and North Africa region. Environmental Science and Pollution Research, 27, 14601-14613.

Nejat, P., Jomehzadeh, F., Taheri, M.M., Gohari, M., Majid, M.Z.A. (2015), A global review of energy consumption, CO_2 emissions and policy in the residential sector (with an overview of the top ten CO_2 emitting countries). Renewable and Sustainable Energy Reviews, 43, 843-862.

Nguyen, C.P., Schinckus, C., Dinh Su, T. (2020), Economic integration

and CO_2 emissions: Evidence from emerging economies. Climate and Development, 12(4), 369-384.
Our World in Data. (2023), Carbon Intensity of Electricity. Available from: https://ourworldindata.org [Last accessed on 2023 Mar 17].
Pedroni, P. (2004), Panel cointegration: Asymptotic and finite sample properties of pooled time series tests with an application to the PPP hypothesis. Econometric Theory, 20(3), 597-625.
Pesaran, M.H., Shin, Y. (1996), Cointegration and speed of convergence to equilibrium. Journal of Econometrics, 71(1-2), 117-143.
Pesaran, M.H., Shin, Y., Smith, R.J. (2001), Bounds testing approaches to the analysis of level relationships. Journal of Applied Econometrics, 16(3), 289-326.
Ponce, P., Khan, S.A.R. (2021), A causal link between renewable energy, energy efficiency, property rights, and CO_2 emissions in developed countries: A road map for environmental sustainability. Environmental Science and Pollution Research, 28, 37804-37817.
Prohl, S., Schneider, F.G. (2006), Sustainability of Public Debt and Budget Deficit: Panel Cointegration Analysis for the European Union Member Countries. Working Paper No. 0610.
Qi, Y., Wu, T. (2013), The politics of climate change in China. Wiley Interdisciplinary Reviews: Climate Change, 4(4), 301-313.
Rahman, M.M., Saidi, K., Mbarek, M.B. (2020), Economic growth in South Asia: The role of CO_2 emissions, population density and trade openness. Heliyon, 6(5), e03903.
Rahman, Z.U., Ahmad, M. (2019), Modeling the relationship between gross capital formation and CO_2 (a) symmetrically in the case of Pakistan: An empirical analysis through NARDL approach. Environmental Science and Pollution Research, 26, 8111-8124.
Rahman, Z.U., Cai, H., Ahmad, M. (2019), A new look at the remittances-FDI-energy-environment nexus in the case of selected Asian nations. The Singapore Economic Review, 68, 157-175.
Şahin, U. (2022), Forecasting share of renewables in primary energy consumption and CO_2 emissions of China and the United States under Covid-19 pandemic using a novel fractional nonlinear grey model. Expert Systems with Applications, 209, 118429.
Salahuddin, M., Alam, K., Ozturk, I., Sohag, K. (2018), The effects of electricity consumption, economic growth, financial development and foreign direct investment on CO_2 emissions in Kuwait. Renewable and Sustainable Energy Reviews, 81, 2002-2010.
Shaari, M.S., Abdul Karim, Z., Zainol Abidin, N. (2020), The effects of energy consumption and national output on CO_2 emissions: New evidence from OIC countries using a panel ARDL analysis. Sustainability, 12(8), 3312.
Shahbaz, M., Khan, S., Ali, A., Bhattacharya, M. (2017), The impact of globalization on CO_2 emissions in China. The Singapore Economic Review, 62(4), 929-957.
Shin, Y., Yu, B., Greenwood-Nimmo, M. (2014), Modelling asymmetric cointegration and dynamic multipliers in a nonlinear ARDL framework. In: Festschrift in Honor of Peter Schmidt: Econometric Methods and Applications. New York: Springer. p281-314.
Shui, B., Harriss, R.C. (2006), The role of CO_2 embodiment in US-China trade. Energy Policy, 34(18), 4063-4068.
Solaymani, S. (2019), CO_2 emissions patterns in 7 top carbon emitter economies: The case of transport sector. Energy, 168, 989-1001.
Su, Y., Jiang, Q., Khattak, S.I., Ahmad, M., Li, H. (2021), Do higher education research and development expenditures affect environmental sustainability? New evidence from Chinese provinces. Environmental Science and Pollution Research, 28, 66656-66676.
Ullah, S., Nadeem, M., Ali, K., Abbas, Q. (2022), Fossil fuel, industrial growth and inward FDI impact on CO_2 emissions in Vietnam: Testing the EKC hypothesis. Management of Environmental Quality: An International Journal, 33(2), 222-240.
Usman, O., Alola, A.A., Sarkodie, S.A. (2020), Assessment of the role of renewable energy consumption and trade policy on environmental degradation using innovation accounting: Evidence from the US. Renewable Energy, 150, 266-277.
Wang, Y., You, Y., Teng, Y. (2022), Optimized variables for environmental dynamics: China's renewable energy policy. Frontiers in Environmental Science, 10, 862714.
Wei, W., He, L., Li, X., Cui, Q., Chen, H. (2022), The effectiveness and trade-offs of renewable energy policies in achieving the dual decarbonization goals in China: A dynamic computable general equilibrium analysis. International Journal of Environmental Research and Public Health, 19(11), 6386.
World Bank Data. (2023). Available from: https://data.worldbank.org [Last accessed on 2023 Mar 17].
Wu, R., Wang, J., Wang, S., Feng, K. (2021), The drivers of declining CO_2 emissions trends in developed nations using an extended STIRPAT model: A historical and prospective analysis. Renewable and Sustainable Energy Reviews, 149, 111328.
Wu, Z., Huang, X., Chen, R., Mao, X., Qi, X. (2022), The United States and China on the paths and policies to carbon neutrality. Journal of Environmental Management, 320, 115785.
Xia, C., Wang, Z. (2020), The effect of fossil fuel and hydropower on carbon dioxide emissions: EKC validation with structural breaks. Journal of Environmental Engineering and Landscape Management, 28(1), 36-47.
Xinmin, W., Iqbal, K., Wang, Y. (2022), Energy use greenization, carbon dioxide emissions, and economic growth: An empirical analysis based in China. Frontiers in Environmental Science, 10, 871001.
Xu, D., Li, Y., Zhao, M., Wang, X., Zhang, Y., Chen, B., Yang, Z. (2022), Spatial characteristics analysis of sectoral carbon transfer path in international trade: A comparison of the United States and China. Applied Energy, 323, 119566.
You, C., Khattak, S.I., Ahmad, M. (2022), Do international collaborations in environmental-related technology development in the U.S. pay off in combating carbon dioxide emissions? Role of domestic environmental innovation, renewable energy consumption, and trade openness. Environmental Science and Pollution Research, 29, 19693-19713.
Zhan, L., Bo, Y., Lin, T., Fan, Z. (2021), Development and outlook of advanced nuclear energy technology. Energy Strategy Reviews, 34, 100630.
Zhang, L., Shen, Q., Wang, M., Sun, N., Wei, W., Lei, Y., Wang, Y. (2019), Driving factors and predictions of CO_2 emission in China's coal chemical industry. Journal of Cleaner Production, 210, 1131-1140.
Zhang, S., Ma, M., Li, K., Ma, Z., Feng, W., Cai, W. (2022), Historical carbon abatement in the commercial building operation: China versus the US. Energy Economics, 105, 105712.
Zhang, Y., Ren, J., Pu, Y., Wang, P. (2020), Solar energy potential assessment: A framework to integrate geographic, technological, and economic indices for a potential analysis. Renewable Energy, 149, 577-586.
Zhao, P., Lu, Z., Fang, J., Paramati, S. R., Jiang, K. (2020), Determinants of renewable and non-renewable energy demand in China. Structural Change and Economic Dynamics, 54, 202-209.
Zhao, W., Zhong, R., Sohail, S., Majeed, M.T., Ullah, S. (2021), Geopolitical risks, energy consumption, and CO_2 emissions in BRICS: An asymmetric analysis. Environmental Science and Pollution Research, 28, 39668-39679.
Zheng, J., Sheng, P. (2017), The impact of foreign direct investment (FDI) on the environment: Market perspectives and evidence from China. Economies, 5(1), 8-15.
Zhou, G., Liu, L., Luo, S. (2022), Sustainable development, ESG performance and company market value: Mediating effect of financial performance. Business Strategy and the Environment, 31(7), 3371-3387.