RESEARCH ARTICLE

Environmental concerns of financial inclusion and economic policy uncertainty in the era of globalization: evidence from low & high globalized OECD economies

Sami Ullah[1] · **Kishwar Ali**[2] · **Salman Ali Shah**[3] · **Muhammad Ehsan**[4]

Abstract

Environmental consequences of financial aspects, policy uncertainties and rapid globalization is the topic of intense debate in present years. However, this study contribute to existing literature in an innovative way. We classified the 33 OECD economies in two group's lower globalized economies (LGE) and highly globalized economies (HGE), based on their level of globalization. Considering the cross-sectional dependency and slope heterogeneity in the data this study employed the Augmented Mean Group method to estimate the influence of financial inclusion, economic policy uncertainty and globalization on the environment quality of both groups for the period 1996–2019. The results revealed a negative significant impact of financial inclusion, while a positive significant impact of economic policy uncertainty on CO_2 emissions in both groups, LGE and HGE. However the globalization estimated to have positive impact on CO_2 emission in LGE's, in HGE's it is significantly impeding the CO_2 emission. The interaction of globalization with financial inclusion and economic policy uncertainty respectively found negative and positive to effect the CO_2 in both LGE's and HGE's. The study suggests that, LGE's are need to prepare for economic globalization, move toward adopting energy-efficient technology and promote trade in less-polluting products in order to sustain their environment quality. The outcomes of this study are robust by employing different model specifications.

Keywords Financial inclusion · Economic policy uncertainty · Globalization · CO_2 emissions · OECD

Responsible Editor: Ilhan Ozturk

✉ Sami Ullah
samiullah@stu.zuel.edu.cn; sami.khan4050@yahoo.com

Kishwar Ali
kishwarali@stu.zuel.edu.cn; kishwar.mcb@yahoo.com

Salman Ali Shah
salmanali.eco@gmail.com

Muhammad Ehsan
mehsan107@gmail.com

1   Research Center for Labor Economics and Human Resources, Shandong University, Weihai, China

2   School of Management, Jiangsu University, Zhenjiang, China

3   School of Business, Guangxi University, Nanning, China

4   Faculty of Management Sciences, National University of Modern Languages, Islamabad, Pakistan

Introduction

In December 2015, the signatories of the United Nations Framework Convention on Climate Change (UNFCCC) endorsed the Paris Agreement to address consequences of climate change in the respective countries (United Nations 2015). According to the United Nations Framework Convention on Climate Change (UNFCCC), carbon emissions (CO2) are responsible for 75% of greenhouse gas emissions, and CO2 emissions are a major contributor to global warming and environmental degradation. Similarly, the UNFCCC convention has been actively striving (since 1994) to reduce the impact of greenhouse gases (GHGs) on ecosystem hostile regions. Furthermore, the UNFCCC's contracting parties have agreed to keep the increase in average global temperature well below 2 °C over pre-industrial level, and to follow the attempts to maintain it below 1.5 °C. The Paris Agreement's aspirational goal requires governments to think bigger and go further in their efforts to mitigate the negative effects of greenhouse

gases in order to achieve and maintain economic sustainability. Besides sustaining and addressing climate change challenges, the importance of reducing GHG emissions, particularly CO2, may be seen in the realization that preserving economic growth also needs the protection of environmental qualities at the same time. According to the United Nations' 2030 Sustainable Development Goals (SDG) framework, it is unlikely to achieve socioeconomic development without also assuring environmental protection (Li et al. 2021).

In recent years, the world economy has experienced fast transformation, raising concerns about changing climate, financial problems, and economic policy impasses. The role of environmental stability has risen to new heights, and many governments have committed to making investments in order to achieve these objectives (Adams et al. 2020). Environmental damages and climate change caused by Greenhouse Gases (GHG) are presently the most pressing worldwide challenges. Under this perspective, governments in many nations have resorted to renewable energy that minimize GHG emissions, and also have supported plans that develop renewable energy sources in order to avert environmental deterioration (Destek and Sarkodie 2019). Rising temperatures, grown storm strength, changed rainfall patterns, and increased sea levels are the consequences of environmental deterioration which are caused by carbon dioxide (CO2) and GHG (Dar and Asif 2017). The issue of CO2 and GHG emissions is particularly pressing in advanced economies, wherein massive increases in emissions are a result of rapid economic expansion, and high energy consumption.

Boosting economic growth while minimizing environmental damages is not a new argument, however the impact of financial inclusion and economic policy uncertainty in managing environmental sustainability in this time of rising globalization is a comparatively topical debate of concern. In order to achieve financial inclusion, world economies are boosting their productive capacity and globalizing rapidly in term of trade and investment. Rapid economic growth, on the other hand, demands higher energy, resulting in increased emissions as well as posing a severe threat to the individuals and environment (Ozatac et al. 2017). Globalization has transposed national boundaries, absorbed global economies, cultures and technology, and continues to produce composite mutual linkages. It encourages economic tactics that enhance energy usage and therefore harm the environment by bringing financial development, direct investment, and trade openness (Shahbaz et al. 2018). Globalization, on the other hand, provides sophisticated, energy-efficient technology that reduce CO2 emissions while simultaneously boosting the economy. Advanced technology allows for more efficient energy usage, which decreases energy usage and improves quality of the environment by lowering CO2 emissions (Saud et al. 2018).

Economic policy uncertainty has also increased as a result of global concerns. Certainly, anything that generates unpredictability will have an impact on the economy (Guidolin and La Ferrara 2010). The global pandemic (COVID-19) is a most recent case, which has caused a great deal of economic policy uncertainty throughout the world (Bakas and Triantafyllou 2020; Altig et al. 2020). Economic policy uncertainty (EPU) influences the climate in which firms operate, which has in significantly influence economic unit's decision making. Because CO2 emissions are related to production choices of a firm, which have an impact on environment quality (Jiang et al. 2019).

Financial inclusion, according to the World Bank, is described as individuals and businesses having access to a wide range of financial goods and services that fulfill their financial needs in a responsible, accessible, inexpensive, and long-term manner. Payments, transactions, savings, borrowing, insurance, and remittance flows are examples of such services and products. As a conclusion, increased access to such financial services is seen to surge economic growth while simultaneously reducing income disparity by offering opportunities to all; hence, a high degree of financial inclusiveness inside a nation may be regarded an indication of its economic stability (Sahay et al. 2015). As a result, the importance of financial inclusion in achieving better economic growth cannot be overstated. At the same time, because financial inclusion is so important in supporting economic growth, it is likely to have an impact on environmental quality (Lesani et al. 2020). For example, increased financial inclusion is likely to lead to higher gross fixed capital formation, which in turn will raise energy needs resources, causing environmental quality to deteriorate as a result of energy usage emission to the atmosphere. Numerous research have looked at the environmental consequences of financial development throughout the world, but the influence of financial inclusion in environment quality is recently debated topic. A very limited studies have examined the consequences on environment quality, see for instance (Le and Sarkodie 2020; Renzhi and Baek 2020; Zaidi et al. 2021).

Against this context, this research analyzed the influence of financial inclusion and economic policy uncertainty on environment quality with a role of globalization in 33 OECD economies for the period of 1996 to 2019. The major focus of OECD economies is green growth, however taking into consideration the socio-economic elements of environmental consequences (OECD 2005). The OECD economies are significantly reducing the CO2 emissions (see, Fig. 1) because of using energy-efficient technology since 2005.

Furthermore, the OECD panel is composed of countries that are financially developed, have steady economic policies, and are largely globalized, with higher rates of economic growth and CO2 emissions. In 2013, the OECD economies provided 72% of global GDP, and 69% of

Fig. 1 Total CO2 emissions in OECD countries. Source: Author's calculation based on IEA data
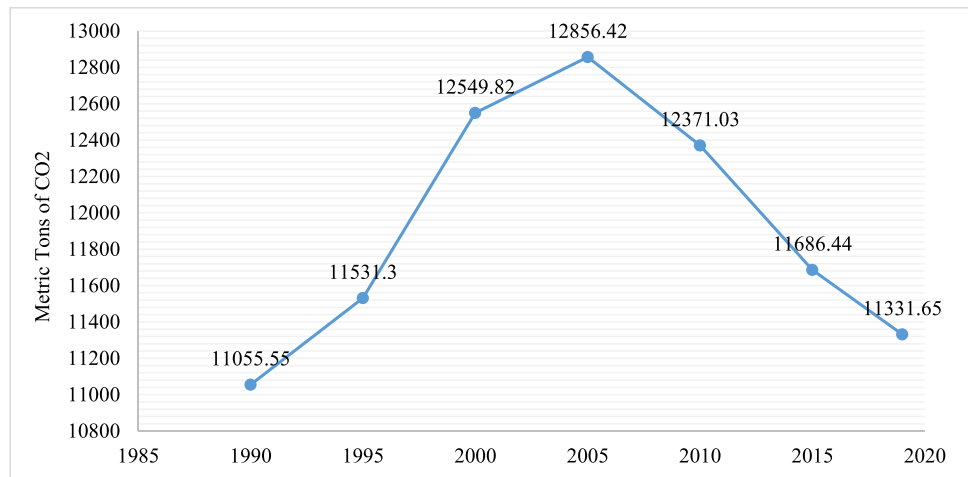
worldwide trade, as well as 36% of CO2 emissions and 40% of global energy usage. The OECD economies are relevant for our research analysis because this panel is major contributor to global revenue, financial developed, highly globalized, larger energy supplier, and highly industrialized in the world (Dogan and Seker 2016).

This study contributes to existing literature in several ways, but three of them are particularly noteworthy; (i) first for financial context, just few other studies have looked at the effects of financial inclusion upon environmental quality, and we were unable to locate any research on the confluence of financial inclusion and environment quality in OECD countries, instead the focus of most previous studies was financial development. As a result, our research is a crucial step in closing this gap. (ii) Secondly for the economic policy uncertainty, previous studies mostly relayed on the data of Economic Policy Uncertainty (EPU) index to measure policy uncertainty, which is limited to few countries and for a smaller time period that might cause inefficient results. In contrast, we used recently published Word Uncertainty Index (WUI) to measure economic policy uncertainty which is available for 143 countries for more than last 30 years. The larger dataset provides more efficient and reliable results. (iii) Thirdly for the globalization context, the inclusion of globalization emphasizes the use of a country classification system, with lower globalized economies (LGE) and highly globalized economies (HGE). As a result, the estimation was carried out separately for the two different groups of LGE and HGE, in order to better understand the environmental effects from globalization. As per our knowledge, this is very first study which classified the sample countries on their level of globalization. The study used the modern econometric techniques such as cross-sectional dependency test, second-generation panel unit-root and cointegration tests, augmented mean group

test and panel causality test to assure the consistent and reliable results.

The rest of the paper is organized as, section 2 is about Empirical Literature; section 3 describe the Methodology and Data used in this study; section 4 revealed the Empirical Results; and Conclusion and Policy Implications of this research are presented in section 5.

Empirical literature

A wide number of empirical studies have used various econometric approaches to empirically assess environmental quality at aggregate and disaggregate level, but we limit the empirical evidences to some of the latest research on the issue. We divided the empirical literature into three subsections to make it easier to understand: (2.1) Economic policy uncertainty and environmental quality; (2.2) financial inclusion and environmental quality; (2.3) globalization and environmental quality.

Economic policy uncertainty and environment quality

There is a paucity of empirical research as how economic uncertainty impacts environment quality explicitly or implicitly. For example, Jiang et al. (2020) explained that economic policy uncertainty (EPU) linked with an increase in state regulations, monetary, and fiscal policies influence the environment quality wherein individuals and organizations operate. Stronger EPU impacts macroeconomic variables, innovations, financial development, capital investment at the business level, firm profits and working capital, tourist industry, and economic growth according to empirical research (Adams et al. 2020; Ashraf and Shen 2019; Sagi et al. 2021). Al-Thaqeb and Algharabali (2019) explained that in recent globalized

world, the importance of uncertainties in policies associated with economic decision is consider a significant factor. Sagi et al. (2021) argued that EPU has an influence on Carbon dioxide emissions thru the direct policies of the government that may enhance or impede environmental damages. While Das et al. (2019) explained EPU as a factor of stock market, Xu et al. (2020) analyzed business innovation, and Levenko (2020) addresses uncertainty as determinant of savings. Climatic fluctuations are essential in economic analysis and policy advice, according to the recent climate scientific research (Golub et al. 2017; Workman et al. 2020). According to Golub (2020), uncertainty about climate policies reduces the prospect that an economy will convergence to a greater stable state. Both under-estimation and over-estimation of economic policy uncertainty insinuations for environmental policy-making according to Guo et al. (2019). Adedoyin et al. (2021) evaluate two policies in order to show a pathway for Japan to meet this ambitious energy and environmental goal. The study's findings demonstrate that emissions of carbon dioxide have a long-term association with GDP growth, renewables, and the economic complexity index, whereas air travel has a short-term impact. This is not unexpected that economic policy uncertainty is anticipated to have a substantial effect on firm's investment strategies, financial policies, and consumer purchasing power. Economic policy uncertainty also has a nonlinear effect on inflation expectations, and economic growth, according to Istiak and Alam (2019). These outcomes advised that investigating the role of EPU in environment quality is worth estimating. Relatively high EPU, as anticipated, has an impact on the energy usage, CO_2 emissions, and economic growth, all of which have consequences for environment sustainability and competitiveness (Kannadhasan and Das 2020).

Many other recent studies investigated the presence of EKC hypothesis by taking different sample in to account. For example, Murshed et al. (2021) assessed at how environmental policies and other major macroeconomic factors influence ecological footprints in four South Asian nations. The findings demonstrated that environmental regulations have an essential role in lowering ecological footprints in South Asia, both direct and indirect. Furthermore, the elasticity findings support the environment EKC curve and pollution haven theories. Non-renewable and renewable energy usage, on the other hand, are reported to enhance and lower ecological footprints, correspondingly. Rauf et al. (2018) examined into the Environmental Kuznets Curve (EKC) theory of Belt and Road Initiative (BRI) countries and found significant evidence of EKC in almost all region. Rehman et al. (2021) investigated the impact of CO_2 emission from different sources on Pakistan's economic advancement. Carbon dioxide emissions from Pakistan's transportation industry have an impact on the country's economic success, according to the findings. Positive increases to such carbon dioxide emissions have been shown to slow economic growth in the long run, whereas negative

shocks have been shown to promote growth in the short and long term. In addition Murshed et al. (2021) stated that ICT commerce significantly boosts renewable energy consumption, raises clean energy shares, decreases energy intensity, and decreases CO_2 emission employing data from South Asian nations. According to Adedoyin et al. (2021), increased tourism, real GDP per capita, and energy usage in the European Union region results in increased carbon emissions. Similarly, Salahuddin et al. (2016) found higher economic growth and internet usage in OECD countries are augmenting CO_2 emission, which is leading to environmental degradation.

Financial inclusion and environment quality

Firms and individuals in financial inclusion have access to valuable and economical financial services which fulfill their requirements, such as transactions, savings, payments, insurance and credit, which are offered in a sustainable manner (World Bank). Even though the effects of financial inclusion on growth in the economy have been extensively recognized (Huang et al. 2021; Kim et al. 2018), but the link among financial inclusion, and the environmental sustainability has received less attention. Among the few research which have looked at the financial inclusion-CO_2 pollution relationship, Le and Sarkodie (2020) investigated whether financial inclusion has an impact on carbon emissions in Asian. Their study have taken financial inclusion, along with several other controlled factors and found out that financial inclusion and other factor such as country income level, urbanization, industrial growth, energy usage, and FDI inflow, increased Carbon dioxide emissions also in Asian countries. Renzhi and Baek (2020) studied whether financial inclusion is beneficial in reducing CO_2 emissions in a group of 103 economies. A GMM models was regressed using a yearly panel data spanning 2004 until 2014. As per their findings financial inclusion was shown to be a CO_2 emission reducing tool in the nations of concern. Furthermore, the authors claimed that fostering financial inclusiveness can aid in mitigating the negative environmental effects of economic expansion and restoring environment welfare. In a latest studies on the advanced countries over the timeframe 2004–2017, Zaidi et al. (2021) used the dynamic commonly correlated effect (DCCE) estimator to investigate the dynamic impacts of financial inclusion on Carbon emission. They stated that increased levels of financial inclusiveness lowered CO_2 emissions in the long and short term.

Several previous research have recorded unclear evidence of financial development effects on CO_2 emissions standards throughout the globe, despite the fact that few extant studies have examined the CO_2 emission implications of financial inclusion. Financial development, according to Zhao and Yang (2020), encourages CO_2 emission reduction throughout China provinces. Likewise, Odhiambo (2020) argued particular about Sub-Saharan African (SSA) countries that

financial growth supports CO2 emission reduction policies. Wang et al. (2020), on the other hand, found that financial development increases Carbon dioxide emissions in the G7 economies. In a contrast of the environmental consequences of financial development in developed and emerging nations, Shoaib et al. (2020) asserted that, while financial development increases CO2 emissions regardless of a country's development status, the negative environmental effects of financial development are relatively greater in advanced nations than developing ones. However, According to Shakib et al. (2021) shown to be ineffective in explaining variations in CO2 emissions among the 42 BRI countries. Li et al. (2021) used a provincial dataset of China to indicate that investments in green initiatives lower short- and long-term carbon dioxide emissions. Extraction of natural resource, financial sector expansion, and energy investments, on the other hand, enhance carbon output in the short and long term.

Globalization and environment quality

Globalization is a broad concept and it have some serious consequences for environmental sustainability, hence, previous researchers have devoted their significant attention to identify the environment quality-globalization nexus. For example, based on EKC hypothesis Haseeb et al. (2018) investigated the connections between globalization, energy usage, GDP, urbanization, and CO2 emissions in BRICS nations. The study findings revealed a negative and substantial link amongst globalization and CO2 emissions for China, South Africa and Brazil, as well as a positive correlation for Russia and India. Salahuddin et al. (2019) used panel regression to analyze the relationship between globalization and CO2 emissions and found that globalization had an insignificant effect on CO2 emissions. In Argentina, Yuping et al. (2021) discovered long-term relationships between CO2 emission, renewable and non-renewable energy use, globalization, and economic growth. Renewable energy consumption and globalization were found to reduce emissions, but non-renewable energy consumption was found to increase emissions, both in the short and long term, according to the elasticity estimations. Globalization and eco-innovation lower ecological footprints, whereas urbanization drives environmental deterioration by increasing ecological footprints in G-7 nations, according to Ahmad et al. (2021).

Likewise, Zaidi et al. (2019) studied at the relationship among globalization and Carbon emission for the Asia-Pacific Economic Cooperation countries covering the period 1990 to 2016. They found that globalization decreases CO2 emissions. The study results also reported that globalization Granger cause CO2 emissions. The findings of this research also backed with the EKC hypothesis. In another study Liu et al. (2020) employed the KOF globalization index to predict the determinants of carbon emissions for the period 1970–2015 in G7

nations. The findings showed that, after raising CO2 emissions initially, globalization leads directly to CO2 emissions abatement, beyond a threshold level of globalization. Saint Akadiri et al. (2020) used the Autoregressive Distributed Lags ARDL model to demonstrate that globalization reduces both short - term and long CO2 emissions in China from 1970 to 2014.

Likewise, Alola and Joshua (2020) used a dataset from 1970 to 2014 to study the globalized emissions linkage for 217 lower, lower middle, upper middle, and high-income nations. The authors used the Pooled Mean Group-Autoregressive Distributed Lag (PMG-ARDL) approach to discover that globalization lowers CO2 emissions in the short term but increases in the long term. Mehmood (2021) also found that increasing level of globalization causing surge in CO2 emission in case of Singapore.

Ahmed and Le (2021) examined the influence of the globalization on CO2 emissions in six countries in South-east Asia and discovered that higher levels of trade globalization lead to reduce CO2 emissions. Shahbaz et al. (2021) examined the globalization-CO2 emissions linkage for India. The Autoregressive Distributed Lags (ARDL) technique was used to analyze annual data for the period 1970 to 2012. The empirical results indicated that the existence of long-run cointegration connection between these variables. Furthermore, increased levels of social, economic, and political globalization increases CO2 emissions in India.

Several studies in the previous empirical literature have examined the influence of financial inclusion, economic policy uncertainty and globalization on environment quality (CO2 emission), but there is still room to endure this argument. Most of the empirical studies have considered the financial development which is a narrower measure to effect the CO2 particularly in case of OECD countries. Similarly, none of the empirical study have conducted by taking globalization differences across the sample countries, which is key factor to impact the environment quality. Also, a very few empirical studies are available over the impact of economic policy uncertainty on CO2 emission, and more specifically for OECD economies. Hence, our study is a significant contribution to empirical literature by filling all these gaps.

Data and methodology

Data

This research investigated impact of financial inclusion, economic policy uncertainty and globalization on the environment quality of 33 OECD economies for the period of 1996 to 2019. Moreover, the sample countries are classified in 2 groups; the lower globalized economies (LGE), and highly globalized economies (HGE). According to the 2020 globalization ranking, the mean value (78.572) for the

all sample countries is calculated. After that the countries globalization ranking fall below the 78.572 are classified as LGE and the countries ranked above the 78.572 are classified as HGE. This gives us 15 LGE's and 18 HEG's. The list of both LGE and HGE is provided in Appendix Table 11. The selection of countries is purely based on the data availability of all the considered variables in this study.

We used CO2 emission (per capita metric tons) as a proxy indicator for environmental quality. For the financial inclusion we followed the study of Chuc et al. (2021) and calculated a composite index for financial inclusion (FNII). FNII is created from four indicators: the number of commercial bank branches per 100 thousands persons, the number of ATMs per 100 thousands persons, the number of depositors from commercial bank per thousand persons, and the total borrowers from the commercial banks per thousand person. After that FNII is calculated by employing Principle Component Analysis (PCA) technique, which is broadly used in previous studies (Chuc et al. 2021; Le et al. 2019). This technique is a modest and efficient process to reduce the large data into small set which still contains the much information as present in original data. Appendix Table 10 provides the outcomes of Principle Component Analysis. World uncertainty index is used to measure the economic policy uncertainty in the sample countries for the given time period. The KOF globalization index is used to proxy the globalization level. The GDP growth, energy usage (Kg of oil equivalent per capita) and FDI inflow (% of GDP) are used as control variables for CO2 emissions. The definitions and sources of all the variables used in this research are presented in Appendix Table 9.

Model description

The study applied the following dynamic panel data model to estimate the influence of financial inclusion, economic policy uncertainty and globalization on environmental quality along with control variables. The standard model of the study can be indicated as:

$$
\begin{aligned}
CO2\_Emis = &\ \alpha_o + \beta_1 FNII_{it} + \beta_2 POLU_{it} \\
&+ \beta_3 GOL_{it} + \beta_4 GDP_{it} + \beta_5 GDP^2_{it} \\
&+ \beta_6 ENGU_{it} + \beta_7 FDI_{it} + \varepsilon_{it}
\end{aligned} \tag{1}
$$

In Eq. (1) $CO2\_Emis$ denotes the carbon dioxide emissions, i shows countries, t shows a time of the study conducted, and α and β's are the coefficient to be estimated, and ε is the residual term. The term $FNII$ is financial inclusion, $POLU$ is economic policy uncertainty, GOL is the level of globalization. Agreeing from the previous literature (Bakhsh et al. 2021; Murshed 2020; Murshed et al. 2021; Rehman et al. 2021; Ullah et al. 2021), we used three most important

control variables of CO2 emission: GDP is Gross domestic products growth rate, $ENGU$ is energy usage and FDI is the inflow of FDI.

Following Eqs. 2 and 3 are estimated to investigate the joint effect of globalization with financial inclusion and economic policy uncertainty on CO2 emissions, where $GLOB$ is represents the globalization level in a country and $\delta_j Z_{it}$ symbolize the control variables.

$$
\begin{aligned}
CO2\_Emis_{i,t} = &\ \alpha_o + \beta_1 FNII_{it} + \beta_2 POLU_{it} \\
&+ \beta_3 GLOB_{it} + \beta_4 FNII_{it} * GLOB_{it} \\
&+ \sum_{j=1}^{k} \delta_j Z_{jit} + \lambda_t + \varepsilon_{i,t}
\end{aligned} \tag{2}
$$

$$
\begin{aligned}
CO2\_Emis_{i,t} = &\ \alpha_o + \beta_1 FNII_{it} + \beta_2 POLU_{it} \\
&+ \beta_3 GLOB_{it} + \beta_4 POLU_{it} * GLOB_{it} \\
&+ \sum_{j=1}^{k} \delta_j Z_{jit} + \lambda_t + \varepsilon_{i,t}
\end{aligned} \tag{3}
$$

Estimation methodology

Cross-sectional dependence and slope homogeneity test

The economic, regional, and cultural ties between the countries used in the sample might contribute to cross-sectional dependency (CD), which is a critical aspect in panel data models. These OECD economies are expected to be cross-sectionally reliant due to their economic interdependence. As a result, this is critical to check for the likelihood of CD, whereas overlooking CD concerns would result in estimations of stationarity and cointegrating characteristics erroneous and inconsistent (Adedoyin et al. 2020; Luo et al. 2021). As a result, the Pesaran (2004) CD test is used in our study, because of its ability to manage data with smaller cross-sectional units and limited time periods. Aside from CD, it is quite important to look for slope heterogeneity concerns, as slope coefficients are likely to differ among cross-sections. It is argued that ignoring slope heterogeneity issues leads to inflated elasticity estimations. Even though selected OECD economies are related in many ways, there are some significant disparities between them in the context of the current study. For example, these countries differ in terms of per capita CO2 emissions, energy usage, globalization, national incomes, and other macroeconomic factors. As a result, Pesaran and Yamagata (2008)'s slope homogeneity test has been applied in this study.

Panel unit root test

This is crucial to ensure for stationarity, as non-stationary series might produce misleading results. The CD problems in the data are not taken into consideration by

first-generation approaches like the Im et al. (2003) panel unit root test. Pesaran (2007) presented the cross-sectionally augmented (CIPS) second-generation panel unit root estimates to solve for the drawbacks of the first-generation approach. In the existence of CD problems in the dataset, this technique is thought to provide reliable and consistent stationarity characteristics (Ali et al. 2021; Ullah et al. 2021).

Cointegration test

The first-generation panel cointegration estimators, like the first-generation panel unit root techniques, fail to account for the CD problems. In order to determine the cointegrating characteristics between the parameters in the existence of CD, the Westerlund (2007) second-generation panel cointegration estimate was presented. The cross-sectional dependency is resolved in this technique by using a bootstrapped method to evaluate the standard errors of four statistical test: Gt, Ga, Pt, and Pa. Gt and Ga are group-mean statistics that are estimated where the null hypothesis of non-cointegration is tested against the alternate hypothesis of cointegration between the variables in at least one cross-section. In comparison, under a strict alternative hypothesis of cointegration among the series in all cross-sections, the two panel-mean statistics Pt and Pa are expected.

Long-run estimation test

The assumption of slope homogeneity across cross-sections is a significant constraint of commonly used panel data estimation methods such as the pooled ordinary least squares (POLS), fixed effects (FE), random effects (RE), dynamic ordinary least squares (DOLS), fully-modified ordinary least squares (FMOLS), and generalized method of moments (GMM). However, taking country-specific heterogeneous characteristics into account, the probability of the regressors being homogeneous for all nations within the sample

is exaggerated. As a result, these techniques are ineffective because the cross-sections in our sample have slope heterogeneity problems. To attain the long-run coefficients while controlling the CD and heterogeneity problems in the sample, Eberhardt and Teal (2010) Augmented Mean Group (AMG) method has been used. Besides dealing with CD and the slope heterogeneity problems simultaneously, the AMG method also consider the endogeneity problems arising from a strong association between the explanatory variables, regardless of whether the series are cointegrated or stationary (Luo et al. 2021; Murshed et al. 2021). The long-run coefficients for the OECD panel are also estimated by employing Pesaran (2006) common correlated effects mean group (CCEMG) model to ensure robustness.

Causality analysis

The implementation of the traditionally employed Granger (1969) panel causality estimate approach is invalid considering the slope heterogeneity limitations in the model. It is because, this approach predicts statistics where null hypothesis of the non-causality among two variables and the alternate hypothesis of causation between these variables over all individual cross-sections. However, in the case of slope heterogeneity concerns, this assumption is unlikely to persist. As a result, the causality technique proposed by Dumitrescu and Hurlin (2012) is employed in this study which accounts for the slope heterogeneity issues by estimating statistics under the alternate hypothesis of causality presence among two variables in at least one cross-section.

Empirical results

Pre-regression statistics

The study taken into analysis to investigate the influence of financial inclusion, economic policy uncertainty and

Table 1 Summary statistics and correlation matrix

	CO2	FNII	POLU	GLOB	ENGU	FDI	GDP
Mean	8.678	5.114	5.319	78.572	8.570	51.587	2.898
Std. dev	14.896	1.113	2.032	14.871	0.589	61.987	1.413
Min	0.219	−1.309	0.000	20.278	6.060	18.927	−2.143
Max	86.984	13.941	10.00	92.112	9.006	421.25	4.609
CO2	1.000						
FNII	−0.198**	1.000					
POLU	0.853**	−0.102*	1.000				
GLOB	0.310**	0.025	0.205**	1.000			
ENGU	0.672**	0.495**	0.586**	0.321**			
FDI	0.312**	0.330*	0.198*	0.480**	0.953**	1.000	
GDP	0.089*	−0.211**	0.013	0.118*	0.979**	0.998**	1.000

globalization on the environment quality for the panel of 33 OCED economies for the period of 1996 to 2019. Table 1 reveals the summary statistics and correlation matrix of all the variables taken in this study. The summary statistics of all variables shows the large variation between minimum and maximum values of all variables. Similarly, correlation matrix shows the negative relation of financial inclusion, while positive correlation of economic policy uncertainty and globalization indicators with CO2 emission dimensions.

Before checking the unit root and cointegration presence among the variables, it is necessary to check the cross-sectional dependence among the sample countries. As level of liberalization and globalization have increased over the period of time, the whole world become a closer to each other in term of economic and social aspects. As a results measures taken in one country may effect on the other country as well. We employed Pesaran (2004) test to identify the cross-sectional dependency (CD) among the selected OECD countries. The results presented in Table 2 confirmed the CD among the sample countries, indicating that any change in level of globalization, financial inclusion, and economic policy uncertainty in one OECD country could also influence the other OECD countries. Table 3 shows the results of Pesaran and Yamagata (2008) slope homogeneity test for all three regression models of the study, which confirm that there is slope heterogeneity problem in the model.

The confirmation of CD and slope heterogeneity in the data indicates to apply second-generation unit root and cointegration to confirm the stationarity of the variables and long-run relationship. The results presented in Table 4 confirms that all the variable taken into analysis are stationary at first-difference I (1), according to both CIPS and CADF tests. Hence, considering the problems of CD and

Table 2 CD test results

Variable	BP	LM	CD
CO2	2383.44***	73.345***	26.358***
	(0.000)	(0.000)	(0.000)
FNII	2435.47***	93.682***	22.3854***
	(0.000)	(0.000)	(0.000)
POLU	2695.55***	57.343***	28.2544***
	(0.000)	(0.000)	(0.000)
GLOB	5173.31***	52.344***	42.3145***
	(0.000)	(0.000)	(0.000)
ENGU	4471.22***	42.345***	34.235***
	(0.000)	(0.000)	(0.000)
FDI	3243.42***	42.812***	26.453***
	(0.000)	(0.000)	(0.000)
GDP	5173.21***	181.421***	32.132***
	(0.000)	(0.000)	(0.000)

*** indicates significance at 1%, values in () are p-values

Table 3 Slope homogeneity test results

	Model-1	Model-2	Model-3
$\tilde{\Delta}$	16.475***	17.384***	15.874***
$\tilde{\Delta}_{adjusted.}$	18.384***	19.374***	17.342***

Test statistics values are reported, *** indicates significance at 1%

heterogeneity in the model we used Westerlund Cointegration method and results presented in Table 5 confirms the existence of long-run relationship among the variables in all three model at 1% significance level.

Regression results

Considering the problems of cross-sectional dependency and slope heterogeneity in the data, we applied Augmented Mean Group (AMG) technique to estimate the long-run coefficients in all three models of the study individually for LGE and HGE, and the results are presented in Table 6. The reason to estimate the models individually for both groups is that countries in both group are not similar in term of globalization. So the diversity in globalization might have different consequences for environment quality as suggested by (Leal and Marques 2019).

The first panel of Table 6 indicating the results of highly globalized economies (HGE), indicating the negative significant impact of financial inclusion (FNII) and globalization (GLOB) on CO2 emission. These results of financial inclusion impact on CO2 emission are similar to the several previous studies see for example, (Le and Sarkodie 2020; Zaidi et al. 2021). Similarly the similar impact of globalization on CO2 emission can be also seen in the empirical studies of (Alola and Joshua 2020; Liu et al. 2020; Shahbaz et al. 2021). The study found a positive significant impact of economic policy uncertainty (POLU) on carbon emission in HGE's, similar to the studies of (Ashraf and Shen

Table 4 Panel unit-root test results

	CIPS		CADF	
	At Level	1st Difference	At Level	1st Difference
CO2	−1.213	−3.132***	−1.263	−3.683***
FNII	−2.101	−3.562***	−2.039	−3.238***
POLU	−2.111	−4.631***	−1.413	−3.693***
GLOB	−1.416	−4.511***	−2.026	−4.257***
ENGU	−1.813	−3.485***	−1.485	−4.483***
FDI	−1.637	−3.589***	−1.394	−3.475***
GDP	−1.283	−4.583***	−1.595	−4.583***
GDP^2	−1.223	−4.449***	−1.362	−4.472***

Akaike information criterion (AIC) is used to determine optimal lags, *** indicates significance at 1%

Table 5 Westerlund cointegration test

Statistic	Model-1 Value	Model-2 Value	Model-3 Value
Gt	−11.798*** (0.000)	−12.647***(0.000)	−12.578***(0.000)
Ga	−21.114***(0.000)	−18.467***(0.000)	−17.474***(0.000)
Pt	−18.059***(0.000)	−22.473***(0.000)	−22.848***(0.000)
Pa	−21.121***(0.000)	−17.547***(0.000)	−18.466***(0.000)

AIC is used to determine optimal lags, values in () are *p*-values, *** indicates significance at 1%

Table 6 Long-run coefficients results

Variables	Model 1	Model 2	Model 3
Panel 1. Highly Globalized OECD Economies (HGE)			
FNII	−0.632*** (0.2462)	−0.387** (0.1722)	−0.415*** (0.1938)
POLU	0.532** (0.2483)	0.465** (0.1837)	0.543* (0.2783)
GLOB	−0.987* (0.5022)	−0.434** (0.2112)	−0.564* (0.2843)
ENGU	0.375** (0.1812)	0.316* (0.1593)	0.252** (0.1211)
FDI	0.543*** (0.1833)	0.367** (0.1782)	0.497*** (0.1647)
GDP	0.256** (0.1193)	0.386* (0.1953)	0.198** (0.094)
GDP^2	−0.324** (0.1591)	−0.228*** (0.0361)	0.322 (0.2938)
FNII*GLOB		−0.386** (0.1911)	
POLU*GLOB			0.274** (0.1299)
Constant	−4.344*** (0.2321)	−4.270** (2.129)	−3.123*** (0.5644)
RMSE	0.0031	0.0037	0.0022
Wald-test	41.374***	46.237***	44.546***
EKC hypothesis	Validated	Validated	Invalidated
Panel 2. Lower Globalized OECD Economies (LGE)			
FNII	−0.230* (0.1172)	−0.344** (0.1617)	−0.365*** (0.1122)
POLU	0.365** (0.1813)	0.408** (0.1998)	0.466** (0.2299)
GLOB	0.648* (0.3261)	0.234** (0.1162)	0.264* (0.1348)
ENGU	0.476** (0.2372)	0.368** (0.1823)	0.186*** (0.0312)
FDI	0.326* (0.1640)	0.743*** (0.2734)	0.286** (0.1384)
GDP	0.378*** (0.1163)	0.283** (0.1391)	0.089** (0.0391)
GDP^2	−0.276*** (0.0921)	−0.382 (0.3192)	−0.128 (0.0991)
FNII*GLOB		−0.320** (0.1583)	
POLU*GLOB			−0.230* (0.1171)
Constant	−2.835*** (0.3848)	−2.380** (1.187)	−5.868*** (1.3843)
RMSE			
Wald-test	38.438***	41.212***	41.577***
EKC hypothesis	Validated	Invalidated	Invalidated

Values in () are standard errors, FNII = Financial inclusion index, POLU = Economic policy uncertainty, GLOB = globalization level, ENGU = Energy usage. * shows 10% significance, ** shows 5% significance, *** 1% significance. AMG estimation method applied. Dependent variable = CO2 emission

Source: Author's estimation

2019; Sagi et al. 2021). Thus, it is argued that financial inclusion and globalization improves while economic policy uncertainty damages the environment quality in HGE. Additionally, to examine the joint impact of globalization with financial inclusion and economic policy uncertainty, model 2 and model 3 are respectively estimated. The joint impact of GLOB with FNII found negative to influence the CO2 emission, whereas POLU still found to augment CO2 emission beside interaction of globalization. All of the three control variable found to have positive and significant impact on carbon emission, meaning that and increase in GDP, FDI inflow and energy usage results in increased level of CO2 emission, hence harming the environment quality in HGE. Moreover the negative and significant values of GDP^2 in model 1 and model 2 confirm the validation of Environment Kuznets Curve (EKC) in HGE.

The estimated results for Lower globalized economies (LGE) are presented in the second panel of Table 6. In second panel, the study indicated a negative and significant impact of FNII on CO2 emission in all three models for LGE, indicating that an increase in FNII likely to reduce the carbon emission and hence improve the environment quality, also seen by Renzhi and Baek (2020). Secondly, POLU is estimated to have positive impact on carbon emission, indicating that any enhancement in form of economic policy uncertainty in the country will retort the environment quality, similar to the findings of Golub (2020). Globalization also found to have a positive and significant impact on CO2 emission in case of LGE, as shown in the study of Ahmed and Le (2021). Finally, the joint impact of GLOB with FNII and POLU on CO2 emission are respectively given in model 2 and model 3 for LGE. FNII still have negative, and POLU have positive impact on CO2 emission after

interaction with GLOB, as indicated in both models. Moreover, all the control variables including GDP, FDI inflow and energy usage have positive and significant impact on CO2 emission, hence, impeding environment quality in LGE. The EKC hypothesis is validated only in model 1 for LGE. Moreover, the lower values of Root Mean Square Error (RMSE) indicate the accuracy of the estimated values in all three models. Similarly, higher values of the Wald-test also indicate that all the explanatory variables are sufficiently explaining the dependent variable and the all the models are good fitted.

The interesting facts we found in this analysis are that, the magnitude of the influence of our core variables such as FNII, POLU and GLOB on CO2 emission is higher in HGE as compared to LGE. Secondly, the magnitude of the influence of FNII and POLU on CO2 emission decreased after including the interaction term GLOB in both groups.

Table 7 Robustness results

Variables	Model 1	Model 2	Model 3
Panel 1. Highly Globalized OECD Economies (HGE)			
FNII	−0.785*** (0.2128)	−0.474** (0.2341)	−0.398* (0.1999)
POLU	0.389*** (0.0916)	0.320** (0.1573)	0.232** (0.1112)
GLOB	−0.259** (0.1251)	−0.228* (0.1151)	−0.202*** (0.0312)
ENGU	0.292*** (0.0238)	0.218** (0.1071)	0.111*** (0.0023)
FDI	0.982*** (0.0314)	0.624** (0.307)	0.462** (0.2291)
GDP	0.565** (0.2631)	0.346** (0.1691)	0.282** (0.1382)
GDP^2	−0.244*** (0.0382)	−0.178** (0.0863)	−0.196*** (0.0112)
FNII*GLOB		−0.254*** (0.0122)	
POLU*GLOB			0.332** (0.1611)
Constant	−2.234*** (0.4733)	−3.454*** (0.3483)	−4.433*** (1.3253)
RMSE	0.0131	0.0029	0.0031
Wald-test	51.432***	59.389***	55.476***
EKC hypothesis	Validated	Validated	Validated
Panel 2. Lower Globalized OECD Economies (LGE)			
FNII	−0.678*** (0.0233)	−0.335** (0.1643)	−0.256* (0.1241)
POLU	0.123*** (0.0038)	0.259** (0.1271)	0.143*** (0.0211)
GLOB	0.232* (0.1171)	0.276** (0.1352)	0.342* (0.1721)
ENGU	0.242*** (0.0236)	0.224** (0.1091)	0.228*** (0.0212)
FDI	0.299** (0.1491))	0.442** (0.2173)	0.415** (0.2061)
GDP	0.432** (0.2132)	0.388* (0.1951)	0.382** (0.1872)
GDP^2	−0.377*** (0.0437)	−0.268 (0.2312)	−0.284 (0.2411)
FNII*GLOB		−0.366*** (0.0117)	
POLU*GLOB			0.228*** (0.0226)
Constant	−3.867*** (1.0283)	−4.350*** (1.3481)	−2.354*** (0.3848)
RMSE			
Wald-test	47.347***	43.488***	49.384***
EKC hypothesis	Validated	Invalidated	Invalidated

Values in () are standard errors, FNII = Financial inclusion index, POLU = Economic policy uncertainty, GLOB = globalization level, ENGU = Energy usage. * shows 10% significance, ** shows 5% significance, *** 1% significance. CCEMG estimation method applied. Dependent variable = CO2 emission

Source: Author's estimation

Table 7 indicates the long-run coefficients estimated by using common correlated effects mean group (CCEMG) method for both panels, HGE and LGE. The overall significance level of the explanatory variables and signs in Table 7 are almost similar to those given in Table 6, confirms the robustness and consistency of the empirical findings across different econometric methods.

Finally, the regression outcomes are followed by the causality analysis. The results of Dumitrescu and Hurlin (2012) causality analysis given in Table 8 confirm the bidirectional causality among FNII and CO2, POLU and CO2, GLOB and CO2, and GDP and CO2. However, unidirectional causality is estimated from ENGU to CO2 and from FDI to CO2.

Discussion

The negative impact of financial inclusion on CO2 emissions in both groups LGE and HGE indicates the financial sector in the OECD countries is reached to the maturity level. It is efficiently distributing the resources to environment-friendly activities. Furthermore, the higher levels of financial inclusion is a significant source for attracting the foreign investment in these countries. The foreign investment always comes with latest technology, new production methods, and high level of research and development, which increases the energy efficiency and reduce the carbon emissions, hence improve the environment quality, the similar effect of financial inclusion on carbon emission is found in the study of Qin et al. (2021) for Emerging-7 (E7) countries.

Table 8 Panel causality results

Null-hypothesis	Z-bar statistics.	Probability.	Decision
FNII→CO2	4.4839	0.0000	Bidirectional Causality
CO2→FNII	2.4155	0.0171	
POLU→CO2	6.3833	0.0000	Bidirectional Causality
CO2→POLU	5.4781	0.0000	
GLOB→CO2	5.7564	0.0000	Bidirectional Causality
CO2→GLOB	4.4192	0.0000	
ENGU→CO2	3.4828	0.0000	Unidirectional Causality
CO2→ENGU	0.5383	0.5513	
FDI→CO2	4.5647	0.0000	Unidirectional Causality
CO2→FDI	0.4382	0.6473	
GDP→CO2	6.4748	0.0000	Bidirectional Causality
CO2→GDP	2.7355	0.0081	

→ Indicates "does not Granger cause", AIC is used to determine optimal lags

Economic policies of a country are strongly linked with business decisions, production methods, investment strategies and individual spending's. Thus, any uncertainty in policies effecting the individual or business decisions' directly affect the environment quality. Our outcomes regarding the role of economic policy uncertainty in CO2 emissions in both groups, LGE and HGE, are also parallel to the Adams et al. (2020) who find the same outcomes for resource rich countries. The uncertain policies hinder the firm's decision, restrict the adoption of cross border flow of capital, latest technology, and innovative eco-friendly production methods, which ultimately induce the carbon emissions and damages the environment quality.

The positive impact of economic and social globalization found in LGE's indicating that these countries are not fully ascertaining the advantages of globalization in term of adopting latest technology, research and development, and modern production methods which emerges due to globalization. Lower level of economic and social globalization pushed these countries to use obsolete technology and fossil fuels that give rise to CO2 emissions and damages the environment quality, this positive impact of globalization on CO2 emissions in LGE is similar to the findings of Alola and Joshua (2020). In contrast, the increasing globalization in HGE's are restricting the CO2 emissions. This is due the fact that these countries are taking maximum benefits from foreign direct investment in eco-friendly production methods, which are less likely to emit CO2 because of using modern technology. However, in both groups LGE and HGE, financial inclusion-globalization interaction has beneficial for the environment quality, whereas economic policy uncertainty-globalization interaction harming the environment as it increases the CO2 emissions. This negative influence of globalization on CO2 emissions is in line with the study of Ahmed and Le (2021), who finds the same results for South-East Asian countries.

Conclusion and policy suggestions

This study is taken into analysis keeping in mind a very comprehensive concerns of environmental quality; financial inclusion and economic policy uncertainty with role of globalization in 33 OECD economies using recent data from 1996 to 2019. Observing previous literature on the topic we found out that for financial sector most of the studies have taken financial development to influence environment quality. Instead, we have taken a broader aspect of financial sector, which is financial inclusion to impact environment quality that was missing in empirical literature, more specifically for OECD economies. Thus this study filled this gap first. Secondly, we consider the recently published data

on economic policy uncertainty and employed WUI index and analyzed its impact on environment quality. However, in prior studies EPU index is frequently used as an economic policy uncertainty measure, which is available for limited number of countries and for few year that might blur the actual influences of economic policy uncertainty. Similar, we separated the sample countries in two groups according to their level of globalization, lower globalized economies (LGE) and highly globalized economies (HGE) and respectively estimated the influence of financial inclusion, economic policy uncertainty and globalization on environment quality in both groups.

The estimated results indicates that financial inclusion has a beneficial impact on environment quality in both, LGE and HGE, as it found to have negative impact on CO2 emission. Conversely, economic policy uncertainty estimated to have a positive impact on CO2 emission, means damaging the environment quality in both groups. However, globalization in LGE estimated to have positive impact on CO2 emissions, whereas negative in HGE. Hence globalization improving the environment quality in HGE, while detreating in LGE. The moderating impact of globalization with financial inclusion and economic policy uncertainty is respectively found negative and positive to effect CO2 emission in both LGE's and HGE's.

The clear implications of this study on the basis of empirical findings are; first, the OECD countries should intensify their financial inclusion level as it helps to reduce the CO2 emissions. It is vital to promote green industrial sector, and green-technology through financial inclusion, which have lower carbon emission intensity. More essentially, the governments in OECD economies must formulate the policies which are compatible with environment sustainability, ensuring the complementarity among financial inclusion and environmental prosperity. Second, the economic policy uncertainty enhanced CO2 emissions in the OECD economies. This is not surprising, as economic policy uncertainty discourages investment in effective technology and innovation which is capable to reduce CO2 emissions. It is thus rational for OECD countries to indorse their economic policies that stimulates innovations, and encourage investment in the energy-efficient technology to reduce the CO2 emission. Thirdly, globalization could increase the environmental quality by decreasing CO2 emission as observed in HGE group. However, LGE are not enjoying the beneficial prospective of globalization in term of environmental consequences. The LGE's should focus on bringing-in investment in new technology and in renewable energy sources instead of fossil fuels dependent technology. Overall OECD economies should improve their environment policies via globalization to reduce CO2

emissions. For the environment sustainability through globalization, governments should enhance the trade and investment in energy-efficient products, and encourages the trade and investment in eco-friendly products by giving them different incentives and tax exemptions.

However, the findings of this study cannot be generalized for any other group of countries of regions. This study is limited to data of just OECD economies and there is room for further research on the topic by taking the data of some other country or region. The relevance of other aspects of globalization such as economic, social and political globalization can be also examined in term of their influence on environment quality.

Appendix

Table 9
Table 10
Table 11
Figure 2

Table 9 Variables description

| Variables	Description	Source
CO2	CO2 emission Per capita metric tons	OECD database/ World Bank
Financial Inclusion (FNII)	FNNI is financial inclusion composite index calculated through PCA method. The FNNI includes 4 primary variables; the number of commercial bank branches per 100 thousands persons, the number of ATM's per 100 thousands persons, the number of depositors from commercial bank per thousand persons, and the total borrowers from the commercial banks per thousand person.	IMF
Economic Policy Uncertainty (POLU)	World Uncertainty Index (WUI) is used to proxy economic policy uncertainty.	WUI Index
Globalization (GLOB)	Economic aspect of KOF globalization index, De facto prospective.	KOF Index
GDP	Per Capita GDP growth rate	World Bank
FDI	Foreign direct investment inflow (GDP %)	World Bank
Energy Usage (ENGU)	Kg of oil equivalent per capita	World Bank

Table 10 PCA results

	Eigen Value	Proportion Explained	Primary Variables	Eigen Vector	Correlation Coefficients
FNII	1.14681	0.8913	(i) the number of commercial bank branches per 100 thousands persons	0.6853	0.7348
			(ii) the number of ATM's per 100 thousands persons,		0.6931
			(iii) the number of depositors from commercial bank per thousand persons		0.6674
			(iV) the total borrowers from the commercial banks per thousand person		0.7669

Table 11 Sample countries (33 OECD Economies)

Highly Globalized Economies (HGE)		Lower Globalized Economies (LGE)	
Austria	Iceland	Australia	Slovak Republic
Belgium	Netherland	Chile	New Zealand
Canada	Norway	Greece	Slovenia
Czech Republic	Poland	Italy	Turkey
Denmark	Sweden	Japan	USA
France	Spain	South Korea	
Finland	Switzerland	Latvia	
Germany	United Kingdom (UK)	Luxembourg	
Hungary		Mexico	
Ireland		Portugal	

Fig. 2 CO_2 emissions (USD/Kg of CO_2) from energy usage in OECD countries. Source: OECD Environment Library
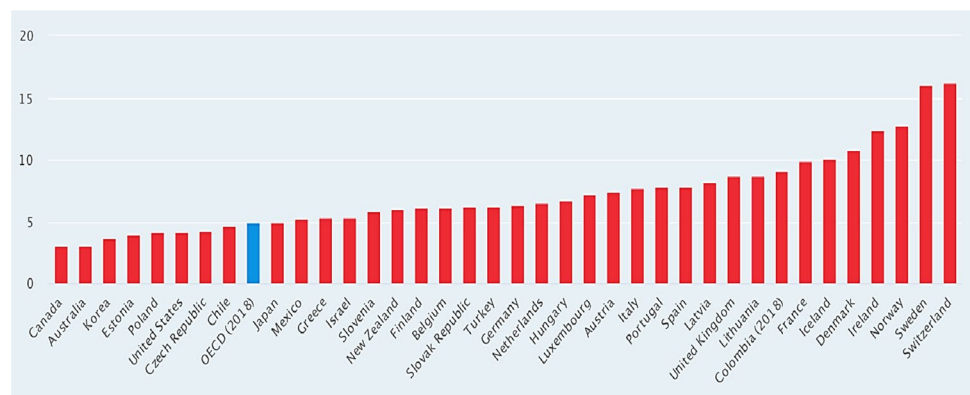
Authors contributions Responsibilities are as follows;

　Sami Ullah: conceptualization; supervision; writing—original draft preparation and editing.

　Kishwar Ali: conceptualization; formal analysis; validation; methodology;

　Salman Ali Shah: conceptualization; methodology; data curation; validation;

　Muhammad Ehsan: conceptualization; methodology; results interpretation; validation; writing—review and editing.

Data availability The datasets used and analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethical approval Study did not use any data which need approval.

Consent to participate section All authors have participated in the process, read and agreed to the published version of the manuscript.

Consent to publish All authors have read and agreed to the published version of the manuscript.

Competing interests/disclosure statement The authors reported no potential conflict of interest with respect to the research, authorship, and/or publication of this article.

References

Adams S, Boateng E, Acheampong AO (2020) Transport energy consumption and environmental quality: does urbanization matter? Sci Total Environ 744:140617

Adedoyin F, Ozturk I, Abubakar I, Kumeka T, Folarin O, Bekun FV (2020) Structural breaks in CO2 emissions: are they caused by climate change protests or other factors? J Environ Manag 266:110628

Adedoyin FF, Ozturk I, Bekun FV, Agboola PO, Agboola MO (2021) Renewable and non-renewable energy policy simulations for abating emissions in a complex economy: evidence from the novel dynamic ARDL. Renew Energy 177:1408–1420

Agreement P (2015) United Nations. United Nations Treaty Collect, 1-27

Ahmad M, Jiang P, Murshed M, Shehzad K, Akram R, Cui L, Khan Z (2021) Modelling the dynamic linkages between eco-innovation, urbanization, economic growth and ecological footprints for G7 countries: does financial globalization matter? Sustain Cities Soc 70:102881

Ahmed Z, Le HP (2021) Linking information communication technology, trade globalization index, and CO 2 emissions: evidence from advanced panel techniques. Environ Sci Pollut Res 28(7):8770–8781

Ali K, Bakhsh S, Ullah S, Ullah A, Ullah S (2021) Industrial growth and CO 2 emissions in Vietnam: the key role of financial development and fossil fuel consumption. Environ Sci Pollut Res 28(6):7515–7527

Alola AA, Joshua U (2020) Carbon emission effect of energy transition and globalization: inference from the low-, lower middle-, upper middle-, and high-income economies. Environ Sci Pollut Res 27(30):38276–38286

Al-Thaqeb SA, Algharabali BG (2019) Economic policy uncertainty: a literature review. J Econ Asymmetries 20:e00133

Altig D, Baker S, Barrero JM, Bloom N, Bunn P, Chen S et al (2020) Economic uncertainty before and during the COVID-19 pandemic. J Public Econ 191:104274

Ashraf BN, Shen Y (2019) Economic policy uncertainty and banks' loan pricing. J Financ Stab 44:100695

Bakas D, Triantafyllou A (2020) Commodity price volatility and the economic uncertainty of pandemics. Econ Lett 193:109283

Bakhsh S, Yin H, Shabir M (2021) Foreign investment and CO2 emissions: do technological innovation and institutional quality matter? Evidence from system GMM approach. Environ Sci Pollut Res 28(15):19424–19438

Chuc AT, Li W, Phi NTM, Le QT, Yoshino N, Taghizadeh-Hesary F (2021) The necessity of financial inclusion for enhancing the economic impacts of remittances. Borsa Istanbul Review

Dar JA, Asif M (2017) Is financial development good for carbon mitigation in India? A regime shift-based cointegration analysis. Carbon Manag 8(5–6):435–443

Das D, Kannadhasan M, Bhattacharyya M (2019) Do the emerging stock markets react to international economic policy uncertainty, geopolitical risk and financial stress alike? North Am J Econ Finance 48:1–19

Destek MA, Sarkodie SA (2019) Investigation of environmental Kuznets curve for ecological footprint: the role of energy and financial development. Sci Total Environ 650:2483–2489

Dogan E, Seker F (2016) The influence of real output, renewable and non-renewable energy, trade and financial development on carbon emissions in the top renewable energy countries. Renew Sust Energ Rev 60:1074–1085

Dumitrescu E-I, Hurlin C (2012) Testing for Granger non-causality in heterogeneous panels. Econ Model 29:1450–1460. https://doi.org/10.1016/j.econmod.2012.02.014

Eberhardt M, Teal F (2010) *Productivity analysis in global manufacturing production. Economics series working papers 515*. Available from. University of Oxford, Department of Economics https://www.economics.ox.ac.uk/materials/paper s/4729/paper515.pdf

Golub A (2020) Technological transition and carbon constraints under uncertainty *ancillary benefits of climate policy*. Springer, pp 69–87

Golub A, Lubowski R, Piris-Cabezas P (2017) Balancing risks from climate policy uncertainties: the role of options and reduced emissions from deforestation and forest degradation. Ecol Econ 138:90–98

Granger CWJ (1969) Investigating causal relations by econometric models and cross-spectral methods. Econometrica 37:424–438

Guidolin M, La Ferrara E (2010) The economic effects of violent conflict: evidence from asset market reactions. J Peace Res 47(6):671–684

Guo J, Du L, Wei C (2019) Equity-efficiency trade-off in China's energy capping policy. Energy Policy 126:57–65

Haseeb A, Xia E, Baloch MA, Abbas K (2018) Financial development, globalization, and CO 2 emission in the presence of EKC: evidence from BRICS countries. Environ Sci Pollut Res 25(31):31283–31296

Huang X, Ding A, Gao J, Zheng B, Zhou D, Qi X et al (2021) Enhanced secondary pollution offset reduction of primary emissions during COVID-19 lockdown in China. Natl Sci Rev 8(2):nwaa137

Im KS, Pesaran MH, Shin Y (2003) Testing for unit roots in heterogeneous panels. J Econ 115:53–74

Istiak K, Alam MR (2019) Oil prices, policy uncertainty and asymmetries in inflation expectations. J Econ Stud

Jiang K, You D, Merrill R, Li Z (2019) Implementation of a multi-agent environmental regulation strategy under Chinese fiscal decentralization: an evolutionary game theoretical approach. J Clean Prod 214:902–915

Jiang Y, Tian G, Wu Y, Mo B (2020) Impacts of geopolitical risks and economic policy uncertainty on Chinese tourism-listed company stock. Int J Finance Econ

Kannadhasan M, Das D (2020) Do Asian emerging stock markets react to international economic policy uncertainty and geopolitical risk alike? A quantile regression approach. Financ Res Lett 34:101276

Kim DW, Yu JS, Hassan MK (2018) Financial inclusion and economic growth in OIC countries. Res Int Bus Financ 43:1–14

Le HP, Sarkodie SA (2020) Dynamic linkage between renewable and conventional energy use, environmental quality and economic growth: evidence from emerging market and developing economies. Energy Rep 6:965–973

Le T-H, Chuc AT, Taghizadeh-Hesary F (2019) Financial inclusion and its impact on financial efficiency and sustainability: empirical evidence from Asia. Borsa Istanbul Rev 19(4):310–322

Leal PH, Marques AC (2019) Are de jure and de facto globalization undermining the environment? Evidence from high and low globalized EU countries. J Environ Manag 250:109460

Lesani SB, Mashhadi A, Habibnejad SA, Habibi Mojandeh M (2020) The mechanisms of protection of environment at economic activities in Iran. Public Law Stud Q 50(3):899–920

Levenko N (2020) Perceived uncertainty as a key driver of household saving. Int Rev Econ Financ 65:126–145

Li ZZ, Li RYM, Malik MY, Murshed M, Khan Z, Umar M (2021) Determinants of carbon emission in China: how good is green investment? Sustain Prod Consum 27:392–401

Liu M, Ren X, Cheng C, Wang Z (2020) The role of globalization in CO2 emissions: a semi-parametric panel data analysis for G7. Sci Total Environ 718:137379

Luo R, Ullah S, Ali K (2021) Pathway towards sustainability in selected Asian countries: influence of green investment, technology innovations, and economic growth on CO2 emission. Sustainability 13(22):12873

Mehmood U (2021) Globalization-driven CO 2 emissions in Singapore: an application of ARDL approach. Environ Sci Pollut Res 28(9):11317–11322

Murshed M (2020) An empirical analysis of the non-linear impacts of ICT-trade openness on renewable energy transition, energy efficiency, clean cooking fuel access and environmental sustainability in South Asia. Environ Sci Pollut Res 27(29):36254–36281

Murshed M, Rahman MA, Alam MS, Ahmad P, Dagar V (2021) The nexus between environmental regulations, economic growth, and environmental sustainability: linking environmental patents to ecological footprint reduction in South Asia. Environ Sci Pollut Res:1–22

Odhiambo NM (2020) Financial development, income inequality and carbon emissions in Sub-Saharan African countries: a panel data analysis. Energy Explor Exploitation 38(5):1914–1931

Organisation for Economic Co-operation and Development Staff (2005) OECD Factbook 2005: Economic, Environmental and Social Statistics. OECD

Ozatac N, Gokmenoglu KK, Taspinar N (2017) Testing the EKC hypothesis by considering trade openness, urbanization, and financial development: the case of Turkey. Environ Sci Pollut Res 24(20):16690–16701

Pesaran MH (2004) General diagnostic tests for cross-sectional dependence in panels. Univ. Cambridge. Cambridge Work. Pap. Econ. 0435

Pesaran MH (2006) Estimation and inference in large heterogeneous panels with a multifactor error structure. Econometrica 74(4):967–1012

Pesaran MH (2007) A simple panel unit root test in the presence of cross-section dependence. J Appl Econ 22:265–312. https://doi.org/10.1002/jae.951

Pesaran M, Yamagata T (2008) Testing slope homogeneity in large panels. J Econ 142:50–93. https://doi.org/10.1016/j.jeconom.2007.05.010

Qin L, Raheem S, Murshed M, Miao X, Khan Z, Kirikkaleli D (2021) Does financial inclusion limit carbon dioxide emissions? Analyzing the role of globalization and renewable electricity output. Sustain Dev

Rauf A, Liu X, Amin W, Ozturk I, Rehman OU, Hafeez M (2018) Testing EKC hypothesis with energy and sustainable development challenges: a fresh evidence from belt and road initiative economies. Environ Sci Pollut Res 25(32):32066–32080

Rehman A, Ma H, Ozturk I, Murshed M, Dagar V (2021) The dynamic impacts of CO2 emissions from different sources on Pakistan's economic progress: a roadmap to sustainable development. Environ Dev Sustain 23(12):17857–17880

Renzhi N, Baek YJ (2020) Can financial inclusion be an effective mitigation measure? Evidence from panel data analysis of the environmental Kuznets curve. Financ Res Lett 37:101725

Sagi N, Zaguri M, Hawlena D (2021) Soil CO2 influx in drylands: a conceptual framework and empirical examination. Soil Biol Biochem 108209

Sahay MR, Cihak M, N'Diaye MP, Barajas MA, Mitra MS, Kyobe MA et al (2015) Financial inclusion: can it meet multiple macroeconomic goals? International Monetary Fund

Saint Akadiri S, Alola AA, Bekun FV, Etokakpan MU (2020) Does electricity consumption and globalization increase pollutant emissions? Implications for environmental sustainability target for China. Environ Sci Pollut Res 27(20):25450–25460

Salahuddin M, Alam K, Ozturk I (2016) The effects of internet usage and economic growth on CO2 emissions in OECD countries: a panel investigation. Renew Sust Energ Rev 62:1226–1235

Salahuddin M, Ali MI, Vink N, Gow J (2019) The effects of urbanization and globalization on CO 2 emissions: evidence from the sub-Saharan Africa (SSA) countries. Environ Sci Pollut Res 26(3):2699–2709

Saud S, Baloch MA, Lodhi RN (2018) The nexus between energy consumption and financial development: estimating the role of globalization in Next-11 countries. Environ Sci Pollut Res 25(19):18651–18661

Shahbaz M, Sharma R, Sinha A, Jiao Z (2021) Analyzing nonlinear impact of economic growth drivers on CO2 emissions: Designing an SDG framework for India. Energy Policy 148:111965

Shahbaz M, Zakaria M, Shahzad SJH, Mahalik MK (2018) The energy consumption and economic growth nexus in top ten energy-consuming countries: fresh evidence from using the quantile-on-quantile approach. Energy Econ 71:282–301

Shakib M, Yumei H, Rauf A, Alam M, Murshed M, Mahmood H (2021) Revisiting the energy-economy-environment relationships for attaining environmental sustainability: evidence from belt and road initiative countries. Environ Sci Pollut Res:1–18

Shoaib HM, Rafique MZ, Nadeem AM, Huang S (2020) Impact of financial development on CO 2 emissions: a comparative analysis of developing countries (D 8) and developed countries (G 8). Environ Sci Pollut Res 27(11):12461–12475

Ullah S, Nadeem M, Ali K, Abbas Q (2021) Fossil fuel, industrial growth and inward FDI impact on CO2 emissions in Vietnam: testing the EKC hypothesis. Manag Environ Qual Int J. https://doi.org/10.1108/MEQ-03-2021-0051

Wang L, Vo XV, Shahbaz M, Ak A (2020) Globalization and carbon emissions: is there any role of agriculture value-added, financial development, and natural resource rent in the aftermath of COP21? J Environ Manag 268:110712

Westerlund J (2007) Testing for error correction in panel data. Oxf Bull Econ Stat 69:709–748. https://doi.org/10.1111/j.1468-0084.2007.00477.x

Workman AD, Welling DB, Carter BS, Curry WT, Holbrook EH, Gray ST, . . . Bleier BS (2020) Endonasal instrumentation and aerosolization risk in the era of COVID-19: simulation, literature review, and proposed mitigation strategies. Paper presented at the International forum of allergy & rhinology

Xu K, Loh L, Chen Q (2020) Sustainable innovation governance: an analysis of regional innovation with a super efficiency slack-based measure model. Sustainability 12(7):3008

Yuping L, Ramzan M, Xincheng L, Murshed M, Awosusi AA, Bah SI, Adebayo TS (2021) Determinants of carbon emissions in Argentina: the roles of renewable energy consumption and globalization. Energy Rep 7:4747–4760

Zaidi SAH, Wei Z, Gedikli A, Zafar MW, Hou F, Iftikhar Y (2019) The impact of globalization, natural resources abundance, and human capital on financial development: evidence from thirty-one OECD countries. Res Policy 64:101476

Zaidi SAH, Hussain M, Zaman QU (2021) Dynamic linkages between financial inclusion and carbon emissions: evidence from selected OECD countries. Resour Environ Sustain 4:100022

Zhao B, Yang W (2020) Does financial development influence CO2 emissions? A Chinese province-level study. Energy 200:117523

Publisher's note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.