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Assessment of the influence of Institutions and Globalization on environmental pollution for Open and Closed economies

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Abstract

As the environmental sustainability effectiveness of various political systems is taken into consideration, it is doubtful as to whether the presumption of the overall efficiency of democracy can be sustained in global governance architecture. The effectiveness of autocracies and democracies (i.e., governance indicators are compared in the present study) with reference to strengths and weaknesses in environmental objectives. This analysis explores the effect of autocracy, democracy, as well as the trend of globalization on CO_2 emissions for open and closed economies from 1990 to 2020. Crucial indicators such as economic growth, renewable energy and non-renewable energy are controlled for while examining the roles of economic expansion on the disaggregated energy consumption portfolios for both open and closed economies. The empirical analysis revealed some insightful results. First, for the open economies, with the expectation of non-renewable energy which show a positive significant impact on emissions, all variables show a negative effect on emissions. Furthermore, the closed economies result indicate that, apart from renewable energy which has a negative relationship with emissions, all the variables including the interaction terms have a positive relation with emissions. However, an inverted U-shaped environmental Kuznets curve (EKC) hypothesis was validated for both economies.

Keywords: Open economies, closed economies, democracy, autocracy, Environmental Kuznets Curve, globalization index, environmental sustainability.

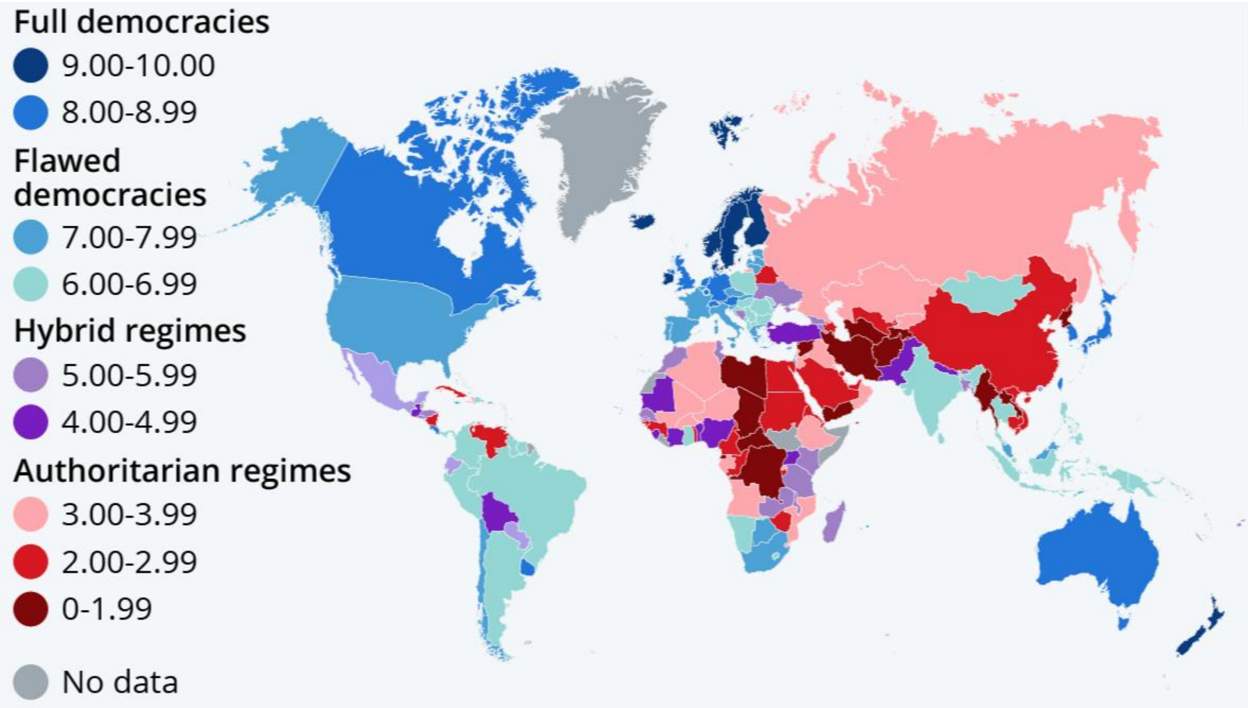
1. Introduction

Threats faced by the global environment continue to increase as innovation, economic growth and energy-led activities continue to surge (Ahmad et al., 2022). Particularly, the looming crisis of global warming, attributed to environmental degradation from excessive carbon emissions threatens the sustainability of life in future (Sadiq et al., 2022). In response to this problem, international organizations, governments, and civil society, have increased environmental consciousness through different media, and collaborative efforts through characteristically-democratic features to drive efforts at mitigating negative environmental consequences (Kue et al., 2022). Notable among these is the United Nation's Sustainable Development Goals (SDGs) in 2015, which recommends countries to achieve 17 developmental objectives by 2030. The goal is to attain parity and reconfigure the current developmental path of nations across the globe. SDG 16 and 13 demands equitable governance and attention to climate and the global environment, respectively.

Economic expansion and energy-led activities dominate the focus of industrial engagements (Shabhaz et al., 2018). Because fossil fuels dominate the energy mix of many countries, increased industrialization aggravates the climate situation through surging carbon emissions (Miao et al., 2022; Adebayo, 2022). To this end, meeting the SDG-13 goal makes it imperative to meet SDG 16, which focuses on governance that upholds democracy, accountability, and open development. This nexus establishes the basis for this research. As shown in Figure 1, global governance structures suggest that only 8.4% of the world's population exist in full democracy, while 41% live in flawed democracy, 15% in hybrid regimes and 35.6% live in authoritarian regimes (Statista Democracy Index, 2021). Open and democratic governance has been on the trial in the past, and the past few years during and after the global pandemic, humanity is still dealing with the biggest setback to individual freedom in years. In 2020, about 70% (116 out of 167) of countries recorded a decline in their total democracy score compared with 2019. Only 22.6% (38) countries saw an increase in their performance. Asian economies such as Taiwan, South Korea and Japan gained full democracy status whereas two Western European countries (France and Portugal) downgraded into flawed democracies. The United States remains a flawed democratic state. Currently the top 10 most democratic countries in the world include Norway, Iceland, Sweden, New Zealand, Canada, Finland, Ireland, Australia, and Switzerland.

In addition to their status as the most democratic countries, these countries exist at the forefront of open economic engagements as well as the war against climate change and clean energy transitioning. Canada for instance, generates well over 50 percent of its electrical energy demand from alternative sources. Norway harvests about 97% of its energy requirement from renewable energy sources, mainly hydro. Norway's drive toward a more symbiotic relationship with the environment through cleaner energy generation is among the best in Europe. Norway currently has a higher adoption rate of electric vehicles (EV) compared with other EU states, currently at 40% annually since 2017. Sweden also has ambitious goals of energy and climate adaptation. It sets a 50% more efficient energy use by 2030, 100% renewable energy production by 2040 and zero emissions of GHG by 2045. Its investment in wind energy production shows it has installed 3631 wind turbines of 7506 MW and estimated to generate an annual production of 19.8 TWh. Considering planned investments for renewable energy production, Sweden is set to achieve its 2030 target in 2022, eight years earlier (Swedish Energy Agency, 2022). Similar developments are observed in Iceland, Finland, New Zealand, and Switzerland. From all indications, these countries are among the few in the world at the brink of accomplishing the common net-zero target by 2050 and renewable energy targets of 2030.

Figure 1. Democracy Index rates by country/territory 2021 (Statista, 2021)



Over the years, studies have sought to understand environmental deterioration from causes such as globalization (Dingru et al. 2021; Jahanger et al. 2022), economic growth (Adedapo et al. 2021; Shahbaz et al. 2018), natural resource utilization (Erdoğan et al. 2020; Hussain et al., 2021) and clean energies (Acheampong et al. 2019; Yuping et al., 2021) from developed and developing economy contexts. However, nascent consideration exists from a governance orientation (i.e. democracy and authoritarian) relative to carbon neutrality. Governance has always been associated with societal development. Likewise, indicators of governance are broadly subjective and often challenging to measure (Adebayo, 2022). Thus, consequences of the type of governance structure of a country may impact its position on environmental quality in the form of policies and regulations enforced.

Examinations on the nexus between environmental quality and governance structure vis-à-vis economic orientation are scant (Kamal et al., 2021). The few extant works on this link have often studied the influence of corruption and institutional excellence components (Su et al., 2021; Kamal et al., 2021; Adebayo, 2022). In theory, different governance structures can have different effects on environmental issues like climate change and carbon neutrality (Su et al., 2021; Adebayo, 2022). For example, in Su et al. (2021), evidence from Brazil (flawed democracy) showed a positive link between political stability and reduced atmospheric carbon pollution. Thus, the political system in Brazil facilitates the mitigation of carbon emissions. Consequently, Vu and Huang (2020) revealed that political risks associate with rising CO_2 emissions in Vietnam (authoritarian regime). Thus, in line with these studies that find links between political risks and achieving carbon neutrality, this present study performs a comparative assessment of the role of governance structure (i.e. democratic and authoritarian) for establishing carbon neutrality. In addition, it considers the additional role played by the interactions between the governance structures and other known determinants of carbon neutrality like globalization, economic development, renewable energy and fossil fuel utilization.

To address the study's overarching goal, this research aims to investigate the correlation between democratic and authoritarian governance structures and carbon neutrality, particularly in full democracy and full authoritarian contexts. The examination is driven by the recognition that full democracies prioritize objectives such as enhanced income standards, economic growth, and fairness, which can contribute to environmental quality through practices like clean production and environmental mindfulness (Jagani & Hong, 2022; Barbosa et al., 2022). Modernization theorists argue that democracies actively support environmental sustainability by engaging in rational economic activities and efficient resource utilization to mitigate adverse environmental effects (Jahanger et al., 2022). Moreover, the dynamic interactions between democracy and authoritarian structures play a crucial role in addressing social issues like environmental safety (Povitkina, 2015).

In democratic jurisdictions, the ease of collecting data on human, institutional, and socio-economic activities facilitate environmental impact assessments, providing a foundation to pressure democratic governments to take a lead role in combating adverse environmental consequences, unlike in authoritarian contexts (Jahanger et al., 2021; Kamal et al., 2021). The study is guided by the following specific objectives: To assess the effect of different governance types, particularly democracy and authoritarian structures, on carbon neutrality objectives, ii. To examine the extent to which governance types, such as democracy and authoritarian structures, significantly influence social objectives, with a focus on carbon emissions, and iii. To examine the effect of pertinent economic indicators as globalization, economic expansion, in addition to governance types on CO_2 emissions.

However, evidence contrary to these assertions exist in some contexts. Lv (2017) for example, showed that democracy in some countries shrinks positive environmental outcomes due to bureaucratic procedures. Similarly, Satrovic, Ahmad, and Muslija, (2021) reveal that democratic accountability increased anthropogenic consequences. Povitkina, (2015) also proved that those economies with low bureaucratic capacity performed well on environmental quality. An indication that authoritarian governance can also facilitate quality environments. These conclusions do not just suggest the lack of clarity on the link between governance structure and carbon neutrality, they also reveal that economic entities whose actions impact the environment, behave in ways influenced by how they are governed (Smith & Stirling, 2018). Thus, if either governance is likely to drive pro-environmental development or otherwise, then understanding the interactions between governance structures (i.e. democracy and authoritarian) can prove immensely helpful to pressurize other kinds of governance systems like flawed and hybrid democracies to develop policy and structures to effectively pursue the sustainable development agenda (Jahanger et al., 2022).

This study contributes by addressing the inadequacies in current energy and economic strategies, particularly in meeting global sustainability targets like SDG 13. Recognizing the impact of governance structures and economic orientations on sustainable development, the research emphasizes the need for structure-specific strategy reforms to achieve global carbon neutrality targets. The primary contribution lies in the development of a tailored framework for achieving SDGs in both democratic and authoritarian states. The framework, derived from an examination of the top ten full democracies and authoritarian countries globally, serves as a valuable basis for creating models applicable to countries with similar governance structures, including flawed democracies and hybrid systems. Focused on addressing energy-related challenges, the framework aims not only to drive SDG 13 accomplishment but also extends its scope to encompass certain goals in SDG 16. This policy-level insight fills a gap in existing broad policy strategies, making this study a convergent point for comprehensive and targeted contributions.

2. Literature Review and Hypotheses

2.1 Theoretical framework

As the awareness of climate change and poor environmental consequences increase, many governments have taken action to protect the environment. Many countries, particularly those with full democracy status are at various phases of implementing policies to ensure environmental sustainability (Khan, 2023). Thus, the growth in regulated economic expansion is believed to reduce carbon emission rates. As affirmed by Khan and Imran (2023), as well as Ofori et al. (2023) this study adopts clean/renewable energy (CE) utilization into its framework. Further, because many countries (both democratic and authoritarian) rely on fossil fuels (non-renewable energy NCE), it is assumed that nonrenewable energy utlization will impact environmental quality as these energy sources are notorious sources of greenhouse gas. The decreased reliance on nonrenewable energy sources would improve energy efficiency, which can drive the replacement of fossil energy sources (Khan & Imran, 2023). To attain this objective, more clean energy is to be generated to reduce the nonrenewable energy sources. While increasing renewable energy generation, there is the higher likelihood of improving environmental quality. Thus, it is hypothesized that renewable energy utilization negatively impacts CO_2 emissions.

The study also examines globalization (economic globalization (EG), political globalization (PG), as well as social globalization (SG) as a determinant of environmental quality. Research on globalization and environmental quality show a litany of mixed results (Awosusi et al., 2023). For instance, globalization provides much financing for green innovation and practices that drive environmental quality. Contrary, Adebayo and Acheampong (2022) argue that globalization drives trade liberalization, which may cause resource exploitation and urbanization which both have negative consequences on environmental excellence. Hence, the impact of globalization on environmental excellence is unidirectional. It is theorized that governance structure impacts social well-being. Thus, democratic (DC), and authoritarian (AC) governance may be pro-environment or against. Saleem (2023) reveals political structure increased CO_2 emissions, whereas Su et al. (2021) suggested that political stability mitigates poor environment quality in Brazil. Based on these opposing views, it is proposed that democratic governance improves environmental quality while authoritarian governance negatively impacts environmental quality.

2.2 Democratic and authoritarian governance and the environment

Unlike authoritarian governance, literature on democracy and the environment widely exists. For example, among the Gulf Cooperation Council (GCC) regions, Satrovic et al. (2021) examined the link between democracy, electricity consumption, urbanization, and CO_2 generation from 1992 to 2019 using an FMOLS technique. While urbanization in this assessment enhanced environmental performance, electricity consumption and democracy negatively impacted the environment. A similar study among European states, revealed that democracy increased environmental degradation. Pohjolainen et al. (2021), using an AMG estimation technique showed democracy increased environmental degradation. Among 41 one-belt-one-road (OBOR) countries, You et al. (2020) also showed that democracy has a negative effect on CO_2 emissions which worsens environmental quality. These findings including those of other scholars like Khan (2023), reveal that governance indicators affect environmental quality, in the context of the UK, post Brexit decision. However, other studies have also established findings opposed to these, to suggest democracy can have both types of effects on the environment. For instance, in Akalin and Erdogan (2021), an assessment of the link between democracy, unclean energy utilization and income among OECD states showed democracy, unclean energy (non-renewable energy) and income all decrease environmental depletion likewise renewable energy consumption. Selseng et al. (2022) also in a similar assessment determines that, democracy shows no significant effect on environmental quality. Thus, these findings present the need for further investigation into this relationship. The role of governance structure, like democracy on the environment is inconclusive. Accountability fostered by democracy may drive positive outcomes for the environment (Satrovic et al., 2021), although shown ineffective in some instances. While much focus has been on democracy and its effect on environmental excellence, little consideration has been given to the full effect of autocracy in the face of democracies. Ofori et al., (2023) revealed that governance structures improved environmental quality. Similarly, Adams and Nsiah (2019) on evidence from 28 sub-Saharan African states showed democracy associates positively with CO_2 emissions while autocracy and non-renewable energy have an insignificant effect on CO_2 emission in the presence of democracy. In essence, very few studies have ventured into the effects of authoritarian governance on the environment, this is evident in the literature. As such this study contributes to this paucity of studies in the literature, not by just evaluating this role of authoritarian structure on environmental quality, it also conducts a comparative analysis of the effects of authoritarian (autocratic) governance and democratic governance on the environment. Therefore, based on the afore discussed, this study proposes that;

H1: Democratic and authoritarian governance structures affect environmental quality.

2.3 Globalization and CO_2 Nexus

Globalization is assessed to impact many facets including social, economic, and political dimensions of humans. Globalization connects economies via trade, politics, and social exchanges. Globalization worsens CO_2 emissions through social movements, acquisition of obsolete technology, international trade, and foreign direct investments (Koengkan et al., 2020).

This assertion in literature is determined as the pollution-haven hypothesis. However, globalization can also facilitate the transfer of green technology and innovations which would also lessen emissions to cut down environmental pollution. Thus, referred to as the pollution-hallow hypothesis. Extant works reveal varying effects of globalization on CO_2 emissions. While Yuping et al. (2021) suggest globalization contributes to reduced CO_2 emissions in Argentina, in that 0.75% reduction in CO_2 is the result of a 1% increase in globalization, Asongu, (2018) showed that, among sub-Saharan African states, a rise in economic globalization increased CO_2 emissions. While comparing developed and developing countries, Khan et al. (2021) showed that economic globalization decreased emissions in developing countries and rather worsened ecological protection in developed countries. Jahanger et al. (2022) also studied economic globalization and CO_2 emissions in 73 developing economies. Using the ARDL-PMG, the study revealed that increased economic globalization caused significant growth in CO_2 emissions. From a financial globalization perspective among G7 member states, Ahmad et al. (2021) establishe that financial globalization increases protection for the environment. These studies suggest a fairly, inconclusive role of globalization, especially economic globalization on environmental quality. This gap underpins this current study's examination of the effect of social and political globalization in addition to economic globalization, which suggests an apparent lack of consensus on its effect on CO_2. Thus, in light of this discussion, this study posits that,

H2: Globalization improves environmental quality via carbon emissions.

2.4 Economic expansion and CO_2 Nexus

Studies into the relationship between real income and environmental quality have been on the rise for a considerable time now. This has mainly been considered through the EKC framework perspective. Numerous studies have since confirmed the EKC hypothesis, in that as an economy expands economically, it possesses the ability to govern the growth of its environmental footprints, which at initial stages of economic development is unfeasible. Many studies as such have established that income increases environmental deterioration. Awususi et al. (2022) examined the real income and environmental quality nexus using the MMQR and causality techniques, established that income expansion increased environmental degradation. While performing a similar assessment with evidence from Turkey from 1980-2018, Adebayo et al. (2022) also showed that economic growth increased environmental degradation. Ahmad et al. (2023) similarly established a positive association between income expansion and CO_2 emissions. This study considered newly industrialized countries (NICs) using the MMQR technique. Among BRICS nations Dingru et al. (2021) used the FMOLS, FE-OLS as well as DOLS to determine a positive link between real GDP growth and pollutant emissions. Other studies including Ahmad and Du, (2017), Kirrikkaleli et al. (2021) and Gyamfi et al. (2020) establish similar positive associations between real income growth and environmental degradation. Despite this trend, studies like Khan and Imran (2023) also reveal a significant negative correlation between per capita income and CO2 emissions in both the short and long run. In spite of the varying views, assessments of this relationship from a governance structure perspective remains nascent in the literature. This current study, in line with this gap, considers the effect of real income on environmental quality from the perspective of democratic and authoritarian countries. As assessment category that is largely missing in the literature.

H3: Economic expansion improves environmental quality via CO_2 emissions.

2.5 Clean energy and the CO_2 Nexus

Experts generally conclude that renewable energy expansion improves the CO_2 emission situation, in that cleaner energy consumption lessens the carbon emissions released into the atmosphere. As such, several studies have established a positive relationship between clean energy sources and environmental quality. For instance, He et al. (2021) showed that environmental quality increases as clean energy utilization increased. Awosusi et al. (2021), showed that clean energy curbs emissions with a gradual shift, DOLS, FMOLS and ARDL techniques. Similarly, Caglar (2021) in examining the antecedents of carbon emissions in Japan and revealed that a fall in clean energy generation increased carbon emissions. Oladipupo et al. (2021) further presents evidence from Portugal with similar conclusions that the growth in clean energy utilization mitigates environmental depletion. Evidence from the 28 European Union member countries also indicates that significant shrinks in carbon emissions is attributed to significant expansions in cleaner energy production and utilization (Leitao & Lorente, 2020). However, the influence of political risk on the utilization of renewable energy remains a developing phenomenon. Awosusi, et al. (2023), recently investigated this nexus over the period 1984 to 2019, using the dynamic autoregressive distributed lag approach. Economic globalization exhibits a positive influence on renewable energy in the long term, with a neutral effect in the short term. Conversely, political risk and environmental degradation are found to have adverse relationships with renewable energy over both time horizons. Additionally, a causal link from political risk to renewable energy and from renewable energy to economic globalization was revealed. A feedback causal interaction is identified between renewable energy and environmental degradation, as well as between economic growth and renewable energy. Therefore, this study relies on this review to hypothesize that,

H4: Clean energy utilization affect the environment via carbon emissions.

2.6 Research Gap

The existing literature highlights several crucial research gaps in the field of environmental studies. Firstly, a notable gap involves the absence of studies exploring the relationship between real income and environmental quality concerning governance structures, particularly in democratic and authoritarian countries. While numerous studies confirm the positive link between income expansion and environmental deterioration, the nuanced examination of this relationship based on governance structures remains under explored.

Secondly, the extensive literature on the impact of democracy on the environment has left a significant gap regarding the full effects of autocracy on environmental quality. The limited studies on authoritarian governance and the environment show conflicting results, emphasizing the need for comprehensive investigations into the environmental impacts of different governance structures.

Moreover, in the realm of globalization and CO_2 emissions, there is a gap in the literature concerning the social and political dimensions of globalization. While economic globalization's impact has been explored, the role of social and political globalization remains relatively understudied, necessitating further investigation into their distinct impacts on CO2 emissions.

Furthermore, the relationship between economic expansion and environmental quality, primarily examined through the Environmental Kuznets Curve (EKC) framework, lacks consideration of governance structures. The majority of studies focus on the economic aspect, neglecting the potential mediating role of governance structures such as democratic and authoritarian systems. This gap underscores the need to explore how governance structures might influence the relationship between real income growth and environmental quality.

Lastly, despite numerous studies affirming the positive relationship between clean energy utilization and environmental quality, a gap exists in the absence of a thorough examination of potential nuances or influencing factors. Limited exploration into specific conditions, contexts, or variables affecting the effectiveness of clean energy in curbing carbon emissions suggests the need for more nuanced investigations.

In summary, these identified research gaps underscore the importance of conducting studies that consider governance structures, explore social and political dimensions of globalization, and delve into nuanced factors influencing the relationship between economic activities and environmental outcomes.

3. Data and Methodology

3.1 Data and Model Construction

The purpose of this investigation is to determine the extent to which democracy, autocracy, and the globalization process have an impact on the EKC theoretical framework over the course of the years 1990 to 2020 for a panel data of open and closed economies. This investigation is predicated on the accessibility of data (please see the sample nations listed in appendix Table 1). This analysis also controls the environmental impact of economic growth, clean energy, and non-renewable energy. This helps mitigate the possibility of unobserved heterogeneity that could arise throughout the evaluation. Based on research that has already been done and published (Jahanger et al., 2022; Satrovic et al., 2021; Pohjolainen et al., 2021; Liu et al., 2020; Li, 2009 , *inter alia*), which is summarized in the different parts of the literature study (see Section 2), we can say that the following is the linear function of the econometric approach:

$$CO2_{it} = \beta_0 + \beta_1 K_{it} + \beta_2 \mathrm{EG}_{it} + \beta_3 \mathrm{PG}_{it} + \beta_4 \mathrm{SG}_{it} + \beta_5 \mathrm{W}_{it} + \varepsilon_{it} \qquad (1)$$

Where, CO_2 denotes carbon emission per capita, K denotes governance index (Democracy and Autocracy), EG for economic globalization, PG for political globalization, SG for social globalization and W for the control coefficients (growth, renewable energy and non-renewable energy). In addition, we log all the coefficients, with the exception of democracy and autocracy, to achieve scale equivalent and lessen the likelihood of heteroscedasticity problems. In addition, we evaluated the possible influence of governance index (democracy and autocracy), globalization indexes (economical, political and social), as well as the other control coefficients which are expressed in Model I below as eq. 2 by incorporating the square of growth to help validate the presence of EKC:

MODEL I: $LCO2_{it} = \beta_0 + \beta_1 K_{it} + \beta_2 \mathrm{LEG}_{it} + \beta_3 \mathrm{LPG}_{it} + \beta_4 \mathrm{LSG}_{it} + \beta_5 \mathrm{LY}_{it} + \beta_6 \mathrm{LY2}_{it} + \beta_7 \mathrm{LCE}_{it} + \beta_8 \mathrm{LNCE}_{it} + \varepsilon_{it}$ (2)

Whereby subscripts i and t denote countries and time, respectively, ε_{it} as error term, β_0 is the constant term while$\beta_{1-}\beta_8$ also denotes variables to be evaluated. Economic growth is obtained from WDI(2021), CO_2 emission, renewable and non-renewable energy are from British Petroleum (BP, 2021), democracy and autocracy is obtained from Polity (2021) and economic, political and social globalizations are from KOF globalization index (KGI, 2021). Moreover, Table 1 reports the variables description summary along the data source.

Table 1. Description of Variables

Name of Indicator	Abbreviation	Proxy/Scale of Measurement	Source
Carbon Dioxide Emissions Per Capita	CO_2	Measured in metric tonnes	BP
Democracy	DC	Scale value (0-10)	Polity
Autocracy	AC	Scale value (0-10)	Polity
Economic Growth	Y	GDP per capita (constant 2015 US$)	WDI
Square of Economic Growth	Y^2	Square of GDP per capita (constant 2015 US$)	WDI
Renewable energy	CE	Renewables Consumption (Exajoules)	BP
Non-renewable energy	NCE	Non-renewables Consumption (Exajoules)	BP
Economic Globalization	EG	KOF Globalization Index	KGI
Political Globalization	PG	KOF Globalization Index	KGI
Social Globalization	SG	KOF Globalization Index	KGI
Interaction term	EG*DC	Economic globalization*Democracy	
Interaction term	PG*DC	Political globalization *Democracy	
Interaction term	SG*DC	Social globalization*Democracy	
Interaction term	EG*AC	Economic globalization*Autocracy	
Interaction term	PG*AC	Political globalization *Autocracy	
Interaction term	SG*AC	Social globalization*Autocracy	

Source: Authors compilation

Furthermore, to examine the interactive effect involving governance index (democracy and autocracy), and globalization index (economical, political and social) on CO_2 emissions, we expand. Model 1 with interaction terms of governance index and globalization index as (K*EG) in Model II, K*PG in Model III and K*SG for Model IV which can be expressed in eqs. 3, 4 and 5 as:

MODEL II: $LCO2_{it} = \beta_0 + \beta_1 K_{it} + \beta_2 \text{LEG}_{it} + \beta_3 \text{LPG}_{it} + \beta_4 \text{LSG}_{it} + \beta_5 \text{LY}_{it} + \beta_6 \text{LY2}_{it} + \beta_7 \text{LCE}_{it} + \beta_8 \text{LNCE}_{it} + \beta_9 \text{LEG} * \text{K}_{it} + \varepsilon_{it}$ (3)

MODEL III: $LCO2_{it} = \beta_0 + \beta_1 K_{it} + \beta_2 \text{LEG}_{it} + \beta_3 \text{LPG}_{it} + \beta_4 \text{LSG}_{it} + \beta_5 \text{LY}_{it} + \beta_6 \text{LY2}_{it} + \beta_7 \text{LCE}_{it} + \beta_8 \text{LNCE}_{it} + \beta_9 \text{LPG} * \text{K}_{it} + \varepsilon_{it}$ (4)

MODEL IV: $LCO2_{it} = \beta_0 + \beta_1 K_{it} + \beta_2 \text{LEG}_{it} + \beta_3 \text{LPG}_{it} + \beta_4 \text{LSG}_{it} + \beta_5 \text{LY}_{it} + \beta_6 \text{LY2}_{it} + \beta_7 \text{LCE}_{it} + \beta_8 \text{LNCE}_{it} + \beta_9 \text{LSG} * \text{K}_{it} + \varepsilon_{it}$ (5)

Note, the K in all the equations denotes the governance index, thus, democracy and autocracy coefficients.

3.2. Methodical framework.

Pre-estimation Tests

3.2.1. Cross-sectional Dependence and Slope Homogeneity Tests

Given the increased globalization and fewer trade restrictions, cross-sectional dependency (CD) in panel regression is expected to be present in the contemporary period (Zaman, 2023 a & b, Gyamfi 2022). Thus, looking out for the presence of CD and eliminating its associated problems will improve the robustness and accuracy of estimates. Hence, the Breusch and Pagan (1980) LM, Pesaran (2015) and scaled LM, Pesaran (2007) CD are used to check for the presence of CD in this panel data.

The test statistics for the four tests are as follows.

$$\mathrm{LM} = \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} T_{ij}\hat{p}_{ij}^{2} \rightarrow \chi^2 \frac{N(N-1)}{2} \tag{6}$$

$$\mathrm{LM_s} = \sqrt{\frac{1}{N(N-1)}} \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} (T_{ij}\hat{p}_{ij}^{2} - 1) \rightarrow N(0,1) \tag{7}$$

$$\mathrm{CD_p} = \sqrt{\frac{2}{N(N-1)}} \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} T_{ij}\, \hat{p}_{ij} \rightarrow N(0,1) \tag{8}$$

$$\mathrm{LM_{BC}} = \sqrt{\frac{1}{N(N-1)}} \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} (T_{ij}\hat{p}_{ij}^{2} - 1) - \frac{N}{2(T-1)} \rightarrow N(0,1) \tag{9}$$

Similarly, erroneously assuming a homogeneous slope variable where heterogeneity exists might show in deceptive outcomes. Consequently, we test for heterogeneity in the data series using the Pesaran and Yamagata (2008) version of Swamy's (1970) slope heterogeneity test (SH).

$$\tilde{\Delta}_{SH} = (N)^{\frac{1}{2}}(2k)^{-\frac{1}{2}}\left(\frac{1}{N}\tilde{S} - k\right) \tag{10}$$

$$\tilde{\Delta}_{ASH} = (N)^{\frac{1}{2}}\left(\frac{2k(T-k-1}{T+1}\right)^{-\frac{1}{2}}\left(\frac{1}{N}\tilde{S} - 2k\right) \tag{11}$$

Whereas delta tilde as well as adjusted delta tilde are revealed by $\tilde{\Delta}_{SH}$and $\tilde{\Delta}_{ASH}$.

3.1.2 Panel unit root tests

We then evaluate the unit root properties of the coefficients using second-generation panel unit root tests that are robust to CD and slope heterogeneity. This analysis depend on the Pesaran (2007) cross-sectional augmented IPS techniques, which is the CIPS technique. The CADF technique is shown as;

$$CADF_i = t_i(N,T) = \frac{\left(y_{i,-1}^T \bar{M} y_{i,-1}\right)^{-1}\left(y_{i,-1}^T \bar{M} \Delta y_i\right)}{\sqrt{\sigma_i^2}\left(y_{i,-1}^T \bar{M} y_{i,-1}\right)^{-1}} \qquad (12)$$

The value of CIPS is derived by averaging the CADF test statistics in the following manner.

$$\widehat{\mathrm{CIPS}} = \frac{1}{\mathrm{N}} \sum_{\mathrm{i=1}}^{\mathrm{n}} \mathrm{CADF_i} \qquad (13)$$

The cross-section augmented Dickey-Fuller test derived from Equation (12) is denoted by the term CADF in Equation (13).

3.1.3 Panel Cointegration Test

This study utilized the Westerlund (2007) cointegration technique to evaluate the long-run interconnectedness regarding CO_2 emission and the independent coefficients. Different from the first-generation cointegration tests, this text considers CD and slope heterogeneity. The technique is shown as:

$$\alpha i(L)\Delta y_{it} = y2_{it} + \beta_i(y_{it} - 1 - \acute{\alpha}_i \mathrm{x_{it}}) + \lambda_\mathrm{i}(\mathrm{L})\mathrm{v_{it}} + \eta_\mathrm{i} \qquad [14]$$

Where $\delta_{1i} = \beta_i(1)\hat{\vartheta}_{21} - \beta_i\lambda_{1i} + \beta_i\hat{\vartheta}2_iandy2_i = -\beta_i\lambda 2_i$

Westerlund cointegration techniques are as follows:

$$G_t = \frac{1}{N}\sum_{i-1}^{N}\frac{\acute{\alpha}_i}{SE(\acute{\alpha}_i)} \qquad [15]$$

$$G_\alpha = \frac{1}{N}\sum_{i-1}^{N}\frac{\mathrm{T}\acute{\alpha}_i}{\acute{\alpha}_i(1)} \qquad [16]$$

$$P_T = \frac{\acute{\alpha}}{SE(\acute{\alpha})} \qquad [17]$$

$$P_\alpha = \mathrm{T}\acute{\alpha} \qquad [18]$$

The group means statistics, comprising G_a and G_t, are shown in Equations 15 and 16. Panel statistics, comprising P_a and P_t, are represented by equations 17 and 18.

3.2 Long Period Association

As the CS-ARDL method (Chudik, Mohaddes, Pesaran, and Raissi, 2016; Chudik and Pesaran, 2015) is the most powerful and accurate in terms of sample diagnostic accuracy, it is used to analyze and provide the long-term strategy based on the MG method. When expressing heterogeneous time effects, the CS-ARDL technique deals with cross-sectional dependence effectively. The CS-ARDL also has the following advantages: (i) it provides the most reliable, productive, and precise results attainable in panel data evaluation. (ii) It addresses CS-ARDL issues successfully, characterizes heterogeneous time series, and eliminates the need for pre-testing the relationship between the explanatory variables. (iii) It deals with problems of slope uniformity and spillover impacts among variables. (iv) It excerpts both the long as well as short-haul impact (Chudik et al., 2016; Chudik, Mohaddes, Pesaran, & Raissi, 2017; Chudik & Pesaran, 2015; M. Pesaran & Smith, 1995). The equation below depicts the CSARDL method

$$y_{it}=\sum_{l=1}^{py} \varphi_{it}\, y_{i,t}+\sum_{l=0}^{pz} \beta'_{il} Z_{i,t-l}+\sum_{l=0}^{pt} \Psi'_{il}\, Z_{t-l}+e_{it} \quad \ldots\ldots\ldots\ldots\ldots (19)$$

where $\bar{X}_t= (\bar{Y}_{t-1},\bar{Z}_{t-1})l$= average cross-reliance's are proved by $\bar{Y}_t$,Z_t. Moreover, $\bar{X}_{t-1}$ represent averages of both independent as well as dependent coefficients. The variables of the average group as well as long period are exemplified as follows in (Eq. 2) requirement, $p_y = 2$ and $p_x = 1$, and ARDL (1,0) requirement, $p_y = 1$ and $p_x = 0$. The CS-ARDL evaluations of the separate mean equal coefficient are then assumed by

$$\hat{\theta}_{CS\text{-}ARDL,i}=\frac{\sum_{l=0}^{px} \widehat{\beta}_{il}}{1-\sum_{l=1}^{py} \widehat{\varphi}_{il}} \quad \ldots\ldots\ldots\ldots (20)$$

$$\hat{\theta}_{mean\ group(MG)}= \frac{1}{N}\sum_{i=1}^{N} \hat{\theta}_i$$

Moreover, the Augmented Mean Group (AMG) technique was used as a robustness check for the analysis.

4. Results and Discussion

4.1 Descriptive Statistics

This section provides a general overview of the dataset explored in this analysis. In Table 2, separate descriptive statistics are presented for closed and open economies. A cursory view of the statistics reveals that the average values of all the variables are marginally higher for open economies compared with closed economies. Specifically, it is observed that the mean log for CO_2 of is slightly higher for open economies than closed economies with high variations between them as shown by their standard errors. Whereas the mean GDP for closed economies is 10.32 with a variation of 0.56, that of closed economy is 10.55 with a variation of 0.37. Closed economies have an average clean and non-renewable energy intake of -2.96 and 0.95 respectively, while that of open economies has theirs at -2.52 and 1.01 respectively. The globalization indicators all follow a similar trend showing that open economies have marginally higher values compared with closed economies. The skewness reveals that GDP, renewable energy consumption, and all globalization indicators (economic, social, and political) are all skewed to the left for both closed and open economies. On the other hand, non-renewable energy is skewed to the right for both set of countries. However, while CO_2 is skewed to the left for closed economies, that of open economies is skewed to the right. Also, autocracy and democracy are skewed to the right for closed and open economies, respectively. Based on the Jarque-Bera test, we rejected the null assumption of normal distribution.

Table 3 presents the results of the correlation analysis for both sets of countries. The results show that all coefficients are positively correlated with CO_2 in both countries except autocracy for closed economies and political globalization for open economies. While all variables except renewable and non-renewable energy consumption are negatively correlated with autocracy for closed economy, the opposite is observed for democracy with the exception of economic and social globalization showing a negative correlation. The result further shows that positive correlation is observed for the remaining variables under closed economy while a mix of positive and negative correlation is observed for the remaining variables under open economies. The result further reveals that almost all the absolute values of correlation coefficients are below 0.8, indicating a less likelihood of multicollinearity.

Table 2. Descriptive Statistical outcome

CLOSED ECONOMIES								
	LCO_2	AC	LY	LCE	LNCE	LEG	LPG	LSG
Mean	2.074296	2.872857	10.31889	-2.962150	0.948346	4.236439	4.491667	4.341378
Median	2.333696	2.831691	10.57922	-2.735000	0.561484	4.256734	4.502473	4.408121
Maximum	2.968520	3.918789	10.90111	-0.667249	2.634631	4.487838	4.591173	4.499752
Minimum	0.190019	2.088064	8.943945	-5.320040	0.078683	3.533910	4.278609	3.876067
Std. Dev.	0.808131	0.589453	0.555176	1.183483	0.819114	0.224199	0.076078	0.156116
Skewness	-1.009742	0.312346	-1.032472	-0.274458	1.014313	-1.362815	-0.894151	-1.353950
Kurtosis	2.887417	1.679886	2.815523	2.287104	2.664173	4.235968	3.512647	4.030669
Jarque-Bera	23.86410	12.44216	25.07181	4.722254	24.66393	52.24728	20.18819	48.97081
P-Value	0.000007	0.001987	0.000004	0.094314	0.000004	0.000000	0.000041	0.000000
Sum	290.4014	402.2000	1444.645	-414.7010	132.7684	593.1015	628.8334	607.7930
Sum Sq. Dev	90.77741	48.29619	42.84264	194.6878	93.26174	6.986853	0.804507	3.387741
OPEN ECONOMIES								
	LCO_2	DC	LY	LCE	LNCE	LEG	LPG	LSG
Mean	2.048956	45.62013	10.55639	-2.505570	1.085430	4.308068	4.521124	4.383704
Median	2.078076	10.95927	10.57943	-2.343837	0.718253	4.332616	4.553561	4.407100
Maximum	3.015337	329.0649	11.53881	1.742194	4.557225	4.509308	4.604270	4.517357
Minimum	1.064413	3.783103	9.383728	-9.216855	-0.777730	3.837840	4.237001	3.841157
Std. Dev.	0.367283	67.46681	0.372776	1.829835	1.293745	0.136337	0.091421	0.105412

Skewness	0.124664	2.801234	-0.340982	-0.492736	0.829577	-1.110904	-1.433090	-2.036344
Kurtosis	2.994467	11.12638	3.637894	3.583266	3.134409	4.032904	3.756718	9.271544
Jarque-Bera	2	1700.890	15.22336	22.89408	48.37451	104.8080	153.4171	976.2535
P-Value	0.581055	0.000000	0.000495	0.000011	0.000000	0.000000	0.000000	0.000000
Sum	858.5127	19114.83	4423.127	-1049.834	454.7952	1805.081	1894.351	1836.772
Sum Sq. Dev	56.38675	1902640.	58.08625	1399.587	699.6389	7.769711	3.493561	4.644711

Table 3. Correlation outcome

CLOSED ECONOMIES								
	LCO_2	AC	LY	LCE	LNCE	LEG	LPG	LSG
LCO_2	1							
AC	-0.360215*	1						
LY	0.894537*	-0.410879*	1					
LCE	0.426089*	0.135768**	0.635336*	1				
LNCE	0.674414*	0.412264*	0.572637*	0.555937*	1			
LEG	0.707111*	-0.824976*	0.738340*	0.274693*	0.087134***	1		
LPG	0.590128*	-0.697311*	0.744413*	0.452329*	0.122821*	0.916137*	1	
LSG	0.878865*	-0.422693*	0.979245*	0.688908*	0.549320*	0.775657*	0.788856*	1
OPEN ECONOMIES								
LCO_2	1							
DC	0.412384*	1						
LY	0.360623*	0.103412**	1					

LCE	0.214303*	0.578215*	0.305155*	1				
LNCE	0.325931*	0.876790*	0.076666	0.623299*	1			
LEG	0.096638**	-0.445553*	0.494772*	-0.011465	-0.427530*	1		
LPG	-0.237583*	0.114609**	-0.022224	0.424802*	0.319192*	0.172917*	1	
LSG	0.254022*	-0.121114**	0.777781*	0.291798*	-0.157577*	0.673968*	-0.004932	1

NOTE: *<0.01, **<0.05, ***<0.10

4.2. Cross-sectional dependency (CD) and Slope Homogeneity (SH) tests

The results from the cross-sectional dependency and the homogeneity test are shown in Table 4. Based on the outcomes presented, the study fails to accept the null hypothesis at a 1% level of significance for all the variables for both closed and open economies. This implies that all variables are cross-sectionally dependent. Following the evidence of CD between all the variables, we proceed to unit root tests.

Table 4. Cross-sectional dependency (CD) and Slope Homogeneity (SH) Examinations

Model	Pesaran CD Test	p-value	Pesaran LM Test	p-value	Breuch-Pagan LM	p-value
			CLOSED ECONOMIES			
LCO_2	11.22486*	(0.000)	46.92719*	(0.000)	332.1230*	(0.000)
AC	20.12743*	(0.000)	58.21627*	(0.000)	405.2845*	(0.000)
LY	19.01321*	(0.000)	51.57232*	(0.000)	362.2268*	(0.000)
LCE	19.23879*	(0.000)	52.87364*	(0.000)	370.6604*	(0.000)
LNCE	10.39828*	(0.000)	32.23762*	(0.000)	236.9236*	(0.000)
LEG	6.072632*	(0.000)	8.883635*	(0.008)	85.57253*	(0.000)
LPG	17.72087*	(0.000)	44.65484*	(0.000)	317.3964*	(0.000)
LSG	19.94355*	(0.000)	57.06738*	(0.000)	397.8389*	(0.000)
Slope Homogeneity (SH)						
	COEFFICIENT	p-value				
SH ($\tilde{\Delta}$ test)	4.0060*	(0.002)				
SH($\tilde{\Delta}$ adj test)	3.8872*	(0.009)				
			OPEN ECONOMIES			
LCO_2	38.41630*	(0.000)	121.3906*	(0.000)	2718.768*	(0.000)
DC	18.89240	(0.000)	139.1008*	(0.000)	3081.719*	(0.000)
LY	46.50533*	(0.000)	115.1445*	(0.000)	2590.759*	(0.000)
LCE	60.16521*	(0.000)	166.1416*	(0.000)	3635.891*	(0.000)
LNCE	19.70853*	(0.000)	98.69720*	(0.000)	2253.691*	(0.000)
LEG	21.42374*	(0.000)	52.53574*	(0.008)	1307.662*	(0.000)
LPG	54.14693*	(0.000)	134.8392*	(0.000)	2994.381*	(0.000)
LSG	61.33611*	(0.000)	172.6292*	(0.000)	3768.847*	(0.000)
Slope Homogeneity (SH)						
	COEFFICIENT	p-value				
SH ($\tilde{\Delta}$ test)	5.1960*	(0.005)				
SH($\tilde{\Delta}$ adj test)	4.7070*	(0.000)				

NOTE: *<0.01

4.3. Panel unit root and cointegration tests

To assess the unit roots, we apply second generation unit root tests that are robust to the CD and slope heterogeneity test (see Table 5). When non-stationary variables are estimated, they produce spurious estimates. As such it is imperative for all variables to be stationary to produce robust outcomes. After finding evidence of stationarity among the variables, we can then proceed to conduct a cointegration test. The result shows that although the variables are statistically significant at level, they are also statistically significant at 1% level of significance at first difference. This means that all the variables are stationary at first difference. With this evidence, we proceed to perform the cointegration test (see Table 6). The result of Westerlund cointegration test suggest a rejection of the null hypothesis of no cointegration in favour of the alternate hypothesis of cointegration among the study variables for both open and closed economies.

Table 5. Panel CADF and CIPS unit root test

VARIABLES	CIPS		CADF	
	I(1)		I(1)	
	C	C&T	C	C&T
LCO_2	-4.0591*	-5.2310*	-4.2041*	-5.8891*
AC	-4.3241*	-4.5431*	-5.1013*	-5.3567*
DC	-5.4103*	-5.4682*	-4.9018*	-6.9292*
LY	-4.3443*	-4.4234*	-4.3290*	-5.2397*
LCE	-4.8830*	-4.8419*	-4.2087*	-5.6211*
LNCE	-5.1875*	-5.2234*	-6.3784*	-7.4180*
LEG	-5.4972*	-6.6700*	-7.0354*	-8.1321*
LPG	-4.7121**	-5.8524*	-5.9782*	-5.4986*
LSG	-9.2600*	-8.2040*	-7.6994*	-7.7692*

NOTE: *<0.01, **<0.05, ***<0.10

Table 6. Westerlund Cointegration Techniques

	Westerlund technique			
	Open Economies		**Closed Economies**	
Statistics	Value	p-value	Value	p-value
Gτ	-3.0531*	(0.000)	-3.7675*	(0.000)
Gα	-4.9407*	(0.008)	-3.1467*	(0.001)
Pτ	-3.6201*	(0.005)	-3.2635**	(0.038)
Pα	-5.0424*	(0.005)	-4.4370*	(0.015)

NOTE: *<0.01, **<0.05, ***<0.10

4.4. Long and short run by CS-ARDL technique.

The current study is aimed at investigating the long and short run interaction between governance and globalization indicators and how the globalization indicators impact the EKC theoretical framework from the period 1990 to 2020 for a panel data of open and closed economies. The study also compares the similarities and or differences in environmental impact in the two sets of countries. To this end, we adopt a multiple regression model as specified in models (1) to (4) with governance and globalization indicators forming the core of these models while controlling for growth, renewable energy, and non-renewable energy for each economy.

4.4.1. Result description for Open Economies

Table 7 displays result from the CS-ARDL technique for open economies. A cursory inspection of the result indicates that democracy is highly significant with a negative coefficient for all the four models in both the long run and short run. This implies that a percentage increase in democracy indicators will decrease environmental pollution for open economies both in the long and short run. The result also reveals that growth has a significantly positive impact on environmental pollution in the long run but has no statistical influence in the short run. This means that holding all factors constant, a 1% increase in growth will yield an increase in environmental pollution between 0.237 and 0.144%. The square of growth on the other hand exerts a negative influence on environmental pollution in the long run under all the models, however, a positive influence is recorded for only models 1 and 2 in the short run. Further, while renewable energy negatively influences environmental pollution under all the models in the long run, and has no effect in the short run, non-renewable energy positively impacts environmental pollution both in the long and short run. This suggests that a 1% increase in the consumption of non-renewable energy will result in a corresponding percentage increase in pollution in both the short and long term. The coefficient of non-renewable energy is positive and statistically significant for all the models. This suggest that increasing renewable energy by 1% will lead to an increase in pollution between 0.5% and 1.10% in open economies in the long run and between 0.20% and 0.49% in the short run.

On the issue of globalization indicators, whereas all the variables are significant in the long run, most of them are not significant in the short term. Specifically, all the globalization indicators (economic, social, and political) negatively influence environmental pollution in the long run, however, no effect is found in the short run. Interestingly, the interactive terms also contribute to decreasing environmental pollution both in the long and short run. Thus, while environmental pollution decreases by 0.0028% and 3.66% in the long and short run respectively with a percentage increase in the interaction between economic globalization and democracy, 0.22% and 9.66% reduction in both periods respectively are realised when political globalization and democracy are interacted. On the other hand, the interaction between social globalization and democracy will decrease pollution by 0.05% in the long run.

Table 7. CS-ARDL technique for Open Economies

Variables	MODEL I	MODEL II	MODEL III	MODEL IV
LONG-RUN				
DC	-0.0034*	-0.0016*	-0.0021**	-0.0021*
LY	0.2473*	0.1443*	0.0634*	0.1206**
LY^2	-0.0212*	-0.0567**	-0.1940*	-0.1150*
LCE	-0.0442*	-0.1190*	-0.0223*	-0.1574*
LNCE	1.0976*	0.7326*	1.0572**	0.5898*
LEG	-0.5269*	-0.0912***	-0.2273*	-0.0105**
LPG	-0.0191**	-2.1205*	-0.5729**	-1.9452*
LSG	-0.4398*	-0.8836*	-0.4854*	-0.9496*
LEG*DC	--	-0.0028**	--	--
LPG*DC	--	--	-0.2202*	--
LSG*DC	--	--	--	-0.0459***
F-STAT	0.1143*	0.2340*	0.2450**	0.2345**
SHORT-RUN				
ECM	-0.4354*	-0.4853*	-0.6549*	-0.4325*
D(AC)	-0.1728	3.1082	-4.5977	-3.4622
D(LY)	0.07468	0.0894	-0.0351	0.1037
D(LY^2)	0.3131**	0.2812***	-0.3571	0.2863
D(LCE)	0.0107	0.0425	0.0278	0.0416
D(LNCE)	0.3821	0.4609**	0.1974**	0.4903*
D(LEG)	-0.1914	-2.2389	0.1282	-0.0863
D(LPG)	-0.3235	0.0147	-72.563	-0.0840
D(LSG)	-0.0053	-0.0960	-0.0578	-2.9819
D(LEG*DC)	--	-3.6557***	--	--
D(LPG*DC)	--		-9.6580**	--
D(LSG*DC)	--		--	7.4376

NOTE: *<0.01, **<0.05, ***<0.10, D for short-run coefficients, optimal lags for CS-ARDL by using AIC.

4.4.2. Result description for closed economies

Table 8 displays the result from the CS-ARDL technique for closed economies. The result reveal that autocracy has a statistically significant and positive impact on environmental pollution under all the models in the long run but insignificant in the short run for all four models. Thus, a 1% increase in autocracy will result in between 0.68% and 2.03% increase in environmental pollution in the long term. The result further reveal a positive effect of growth on environmental pollution in the long run, however, the growth squared exerts a negative influence on environmental pollution in the same period. This implies that a percentage change in growth will account for between 0.11% and 0.21% increase in pollution, however, when growth doubles, a percentage change will decrease pollution by between 0.0009% to 0.0048%.

Also, whereas renewable energy exerts a negative impact on environmental pollution in the long run under all the models except in model 4, non-renewable induces a positive influence under all four models in the long run and under model 3 in the short run. Specifically, whereas a percentage increase in renewable energy will generate between 0.02% and 0.10% decrease in environmental pollution in the long run, a percentage increase in non-renewable energy will result in between 1.07% to 1.24% increase in pollution in the long run and 0.52% in the short run.

Focusing on the globalization indicators, the direct effect shows that all the globalization indicators (i.e. economic, political, and social globalization) contribute positively to environmental pollution in the long run. In other words, whereas a percentage increase in economic globalization aggravates environmental pollution between 0.09% and 0.75%, a similar percentage increase in political globalisation will account for between 0.15% and 0.90% in the long run. On the other hand, a 1% increase in social globalization will induce pollution between 0.20% and 8.75%. In the short run however, economic and political globalization are only statistically significant under models 2 and 1, respectively. Thus, whereas economic globalization mitigates pollution in model 2, political globalization aggravates pollution in model 1. The interaction terms further reveal that, environmental pollution increases with a percentage increase in all the interactive terms. Specifically, while the interaction between economic globalization and autocracy will yield a 0.16% increase in pollution, which of the interaction between political globalization and autocracy will produce a 2.54% growth in pollution. Likewise, the interaction between social globalization and autocracy will generate a 0.16% growth in environmental pollution in the long term.

Table 8. CS-ARDL technique for Closed Economies

Variables	MODEL I	MODEL II	MODEL III	MODEL IV
	LONG-RUN			
AC	1.3232*	0.6791***	1.8848*	2.0266**
LY	0.1287**	0.1520*	0.2199*	0.1092**
LY^2	-0.0012**	-0.0034**	-0.0009*	-0.0048*
LCE	-0.0197**	-0.0215*	-0.0967*	0.0177**
LNCE	1.2162*	1.2416*	1.0698*	1.2359*
LEG	0.2390*	0.7503**	0.0930**	0.1963**
LPG	0.1537**	0.1802**	0.9047**	0.4669**
LSG	0.3064**	0.2018**	8.7527*	0.3255*
LEG*AC	--	0.1645*	--	--
LPG*AC	--	--	2.5393*	--
LSG*AC	--	--	--	0.1665*
F-STAT	0.2443*	0.3041*	0.3482**	0.3640**
SHORT-RUN				
ECM	-0.7247*	-0.7288*	-0.4648**	-0.7430*
D(AC)	-1.4134	-9.3523	29.1538	16.3897
D(LY)	0.1191	0.1260	0.0566	0.1091
D(LY^2)	0.0234	0.9307	-2.0005	0.3956
D(LCE)	0.0266	0.0247	0.0593	0.0275
D(LNCE)	0.1702	0.1330	0.5233**	0.1755
D(LEG)	-0.2574	-4.2329**	-0.0366	-0.1595
D(LPG)	0.5666**	0.6989	0.7037	-61.53547
D(LSG)	0.1341	0.1458	12.6146	0.2096
D(LEG*AC)	--	1.8057	--	--
D(LPG*AC)	--	--	-8.432714	--
D(LSG*AC)	--	--	--	25.2269

NOTE: *<0.01, **<0.05, ***<0.10, D for short-run coefficients, optimal lags for CS-ARDL by using AIC.

4.4.3. Result discussion

In this section, we present an insight into the study's outcomes. Evidently, the study shows that environmental pollution is largely influenced by governance systems. Interestingly, whereas democratic countries are able to mitigate pollution, autocratic countries rather aggravate their pollution levels. This outcome is critical to environmental policy formulation in that it gives a better understanding of how countries can safeguard their environment and improve its quality if the rule of law with regards environmental laws and policies are allowed to work effectively. The negative effect of democracy on environmental pollution could be attributed to the freedom with which environmental issues are openly discussed without intimidations from political leaders or stakeholders under democratic regimes which then equips the relevant stakeholders with the required knowledge and information to freely address environmental challenges. The outcome on environmental pollution mitigation effect of democracy is in line with the studies of Hamid et al. (2022) for BRICS countries, Haseeb and Azam (2021) for lower- middle-, upper-middle- and high-income countries, Lu, Mahalik, Mahalik and Zhao (2022) for 35 OECD economies, Ahmed, Caglar, and Murshed(2022) for 46 Pakistan and Ahmed, Ahmad, Rjoub, Kalugina and Hussain (2021) for G7 countries. Also, Jahanger, Usman, and Balsalobre-Lorente (2021) found that autocracy reduces pollution while democracy increases emissions. On the contrary, the result disagrees with Selseng, Linnerud and Holden(2022) for 127 economies, Pohjolainen et al.(2021) for European Economies, Acheampong, Opoku and Dzator (2022) for 46 African nations and Akalin and Erdogan (2021), who argued that democracy encourages entrepreneurial freedom which then increases growth and thus, pollution.

The significance of the coefficients of economic growth and its squared form is an indication of the presence of the EKC hypothesis in the two economies. This implies that for both sets of countries, environmental pollution increases with increasing growth. However, beyond a given threshold of economic growth, pollution decreases. This finding is in tandem with the studies of (Anwar, Siddique, Eyup Dogan, & Sharif, 2021; Bhat, Sofi, & Sajith, 2021; Farooq, Ozturk, Tariq, & Akram, 2022; Hanif, Nawaz, Hussain, & Bhatti, 2022; Jahanger, 2022; Leitão, Balsalobre-Lorente, & Cantos-Cantos, 2021; Nathaniel, Alam, Murshed, Mahmood, & Ahmad, 2021; Omri & Saidi, 2022; Wang, Zhang, Li, & Li, 2022). The Environmental Kuznets Curve (EKC) hypothesizes that ecological damage initially surges with economic development, reaching a threshold, and then declines as a society becomes wealthier. This hypothesis suggests that in the initial phases of economic progress, industrialization and increased production contribute to higher pollution levels. However, as economies grow and countries become more environmentally conscious, there is a shift towards cleaner technologies, improved regulatory frameworks, and greater investment in sustainable practices. This leads to a decline in pollution levels as countries prioritize environmental protection and adopt cleaner production methods. The EKC implies that economic prosperity can eventually be decoupled from environmental degradation, offering a pathway towards sustainable development and reduced pollution.

Energy consumption as a critical component of economic growth affects environment quality in two major ways depending on the source or and type of energy. Indeed, the results of the study on energy consumption indicate that whereas renewable energy consumption mitigates environmental pollution in both sets of countries (Ali et al., 2023; Ofori et al., 2023; Radmehr et al., 2023), non-renewable energy consumption aggravates emission (Gyamfi et al., 2023). Other studies whose results are tangential with ours include (Alharthi, Dogan, & Taskin, 2021; Anwar, Siddique, et al., 2021; Anwar, Sinha, et al., 2021; R. Ulucak, Erdogan, & Bostanci, 2021; Z. S. Ulucak & Yucel, 2021; Yuping et al., 2021). Indeed, energy sources derived from fossil fuels produces significantly higher amounts of CO2 emissions and other pollutants that contributes to the destruction of the ozon layer, leading to global warming and hence a reduction in environmental quality. On the other hand, renewable energy sourced from sources such as solar, hydro, wind, and geothermal power produces little or no carbon emissions, which helps to improve environmental quality. By shifting towards renewable energy, societies can reduce their reliance on coal, oil, and natural gas, thereby mitigating air and water pollution associated with the extraction, transportation, and combustion of fossil fuels. The adoption of renewable energy technologies not only curtails greenhouse gas emissions but also promotes cleaner air and water, fostering a more sustainable and environmentally friendly energy system. As renewable energy becomes more widespread, it plays a crucial role in addressing the root causes of pollution and contributing to a cleaner, healthier planet.

With regards globalization, it is instructive to observe that whereas all the globalization indicators contribute to environmental pollution mitigation in open economies, that of the closed economies aggravate pollution. Our result for open economies supports the findings of other scholars such as Mehmood (2021) who found that economic and social globalization reduces environmental pollution in Singapore. Yang and Jahanger (2020) and Awosusi et al. (2022) also found globalization to decrease environmental pollution. Likewise, our findings on closed economies support the empirical evidence provided by Destek (2020), Padhan, Chandra, Kumar, Ahmed and Hammoudeh (2020), and Kamran, Teng, Imran and Owais (2019) who have all reported a positive influence of globalization indicators on environmental pollution. Further, the interaction effect outcomes suggest that whereas economic, political, and social globalization moderate democracy to retard environmental pollution in opened economies, the globalization indicators moderate autocracy to aggravate environmental pollution in closed economies.

Finally, we examine the robustness of the study’s outcome using the AMG model approach (see Table 9). The results for the long run estimates from the CS-ARDL technique for both the closed and open economies are confirmed by the outcomes of the AMG model. Indeed, the directions of effects under the CS-ARDL technique approach are consistent with that of the AMG estimator, confirming the reliability of the results.

Table-9: AMG outcome for Robustness check.

Variables	**Open Economies**	**Closed Economies**
DC	-0.0209*	--
AC	--	1.9204**
LY	0.2870*	0.1750**
LY^2	-0.0377*	-0.0015
LCE	-0.0154**	-0.0991*
LNCE	0.4794*	0.5795*
LEG	-2.1603**	1.3707***
LPG	-1.0210**	1.9926**
LSG	-0.2364*	0.4924***
LEG*DC	-0.3990*	--
LPG*DC	-0.1394**	--
LSG*DC	-0.1468*	--
LEG*AC	--	0.7722*
LPG*AC	--	2.1159*
LSG*AC	--	0.8707**
Wald test	1092.200*	1100.134*
R^2		0.6805

Note :*< 0.01, **<0.05, ***<0.10

5. Conclusion and policy recommendations

5.1 Conclusion

The present study analysed the influence of autocracy, democracy, and the trend of globalization on CO_2 emissions for open and closed economies. To achieve this purpose, the study used a panel dataset from 1990 to 2020. The study applied the panel IPS and CIPS unit root tests and the Westerlund cointegration technique to examine cross-section dependence in the data. Next, we employed the CS-ARDL technique to ascertain the short and long run effects and the AMG model to test for robustness. The outcomes of the study reveal that whereas democracy decreases pollution, autocracy promotes pollution. Evidence of the EKC were found in both closed and open economies. The study also reveals that the renewable energy improves environmental quality by reducing pollution in both set of countries. Also non-renewable energy consumption aggravates pollution in both economies. Further, whereas globalization indicators improve environmental quality in open economies, they aggravate pollution in closed economies. Similarly, the interactive terms improves environmental quality in open economies but retards environmental quality by increasing pollution in closed economies. Finally, test of robustness confirms the validity of the study outcomes since the direction of causality in the coefficients in the CS-ADRL model is similar to that of AMG model.

5.2 Policy Recommendations

These results are indicative of important policy directions for the authorities in both Open and Closed economies:

5.2.1 Short- and Medium-term policy recommendations for both Open and Close Economies.

An investigating and applying co-governance strategies to align climate and environmental policies should be encouraged, specifically in relation to nationally set contributions. This strategy has been effectively duplicated in several nations, such as China, Chile, Finland, Ghana, Mexico, Norway, and the United Kingdom[1]. Moreover, promoting the exchange of effective methods and resources among global and local organisations for the understudy countries must be encouraged[2]. This can facilitate the efficient execution of environmental policy. Furthermore, advocating for the widespread adoption of integrated assessments of climate and air quality strategies to facilitate strong and standardised policymaking[3]. This can facilitate comprehension of the repercussions of different policies and initiatives on the environment.

5.2.2 Long-term Policy Recommendation for Open Economies

A convincing linkage can be established connecting environmental justice and environmental administration by utilizing the democratic system of environmental dialogue as the foundation. The term "environmental justice linking mechanism" refers to the wide utilisation of

[1] Policies that tackle climate and air pollution at the same time can raise global climate ambition (unep.org)

[2] Policies and strategies | UNEP - UN Environment Programme. https://www.unep.org/about-un-environment/policies-and-strategies.

[3] For people and planet: the UNEP strategy for 2022–2025. https://www.unep.org/resources/people-and-planet-unep-strategy-2022-2025.

environmental legislative power, judicial authority, and administrative authorities to enforce environmental legislation, as well as the adoption of a variety of strategies to activate and integrate it completely. To be more specific, the environmental administrative authority of the government should be placed at the forefront through the government's macro decision-making and by depending on the deterrent effect that the authorities can have in order to avoid and limit environmental damage. At the same time, the governments should make it possible for environmental democracy to flourish in an open setting. By taking into account the viewpoints of the general public, the countries will be able to close any gaps in the decision-making process of the governments and create a strategy for the distribution of power and rights that is relatively comprehensive and is tailored to the specific national circumstances of the country in question with regard to environmental safeguards. Second, the regulations that govern the openness of commerce brought about by globalization must be rethought so as to provide room for the exchange of clean and renewable forms of energy.

In addition, trade operations that come with technologies that are not favourable to the environment should be subject to taxes, and the revenue generated from these levies should be utilized to fund environmental restoration efforts. In order to meet the environmental SDGs of open economies, it is possible to cut CO_2 emissions by switching to renewable energy from fossil fuels. Furthermore, the trend of globalization considerably contributes to the promotion of environmental deterioration. It is the responsibility of the government to establish tough laws and regulations that must be adhered to by domestic and international investors and businesses who wish to develop an environmentally friendly industrial system. In addition, we suggest that open economies develop efficient and appropriate policy guidance and collaboration in order to mitigate the negative effects that globalization has on the environment. In light of the fact that the process of globalization has negative effects on the environment, the authors recommend that governments and other regulatory agencies do not underestimate the part that globalization plays in the CO_2 emission dynamics of developing nations when formulating policies for the inclusive and long-term management of the environment. In addition, the authors suggest that governments in poor countries should view "globalization" as an important productive tool in climate change policy frameworks in order to enhance the priority of environmental quality in the long term.

5.2.3 Policy Recommendation for Closed economies

The closed economies have the potential to increase their commerce with the open economies through the importation of carbon-free technologies and green energy base utilization. This strategy has promising implications for environmental conservation, which might result in a healthier environment. Nevertheless, because sustainability is a worldwide concern, open economies and economies with a higher level of industrialization have a responsibility to assist closed economies in developing power generation capabilities, reorganizing energy-saving machines and equipment, and developing renewables machinery in order to lower levels of pollutants. It is extremely ideal for environmental regulatory agencies to play a significant function concerning a clean environment and enforce environmental instruments on dirty sectors and companies. The authorities should promote carbon-free technology and renewable energy sources by giving tax incentives that are more lenient toward these areas. Despite this, an effective climate policy should be able to strike a balance between competing interests, cooperative efforts, and emissions. In order to reduce carbon emissions, it is vital for governments to take bold actions to promote environmentally friendly trade, innovation, recognition of brilliant concepts, and boldness in an ecosystem. In light of this, it is suggested that the authorities of these countries should strongly urge institutions to lend their support to the division of research and development (R&D) in the process of developing environmentally friendly technology (i.e., solar biogas and biomass). The quality of the climate can be improved by putting into place policies that allow for the purchase of licensed carbon credits; inspiring initiatives such as tree plantation drives; the output of renewable energy; energy savings; and providing impactful ecological educational campaigns.

5.3 Limitation and future research

In spite of the fact that this study adds to the existing body of information, it does have a number of caveats as well as some suggestions for further investigation. First, the scope of this research might be broadened to include additional sociocultural variables in the context of the role of carbon emissions. The future study will also be able to ascertain the impact of each unit of measure of globalization on ecological expertise for countries in Sub-Saharan Africa associated with growing democracy. This will help policymakers come up with a more thorough plan to reach a number of sustainable development goals.

6. Declarations

Availability of data and materials

The data for this present study are sourced from WDI as outlined in the data section

Competing interests

I wish to disclose here that there are no potential conflicts of interest at any level of this study.

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Authors' contributions

All authors read and approved the final version to BSE journal

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Appendix

Table 1. List of Countries

Open Economies	Closed Economies
Norway	China
Sweden	Morocco
New Zealand	Algeria
Iceland	Vietnam
Finland	Russia
Japan	Turkey
Australia	Tunisia
Switzerland	Iran
Canada	Nicaragua