Natural Resource Rents, Globalisation and Environmental Degradation: New Insight from 5 Richest African Economies

Samson Aladejare (aladejare4reel2000@gmail.com)
Federal University Wukari
https://orcid.org/0000-0002-2464-026X

Research Article

Keywords: Natural resource rents, Globalisation, Environmental degradation, Urbanisation, Human capital development, African economies

Posted Date: April 12th, 2022

DOI: https://doi.org/10.21203/rs.3.rs-1379935/v2

License: This work is licensed under a Creative Commons Attribution 4.0 International License.
Read Full License
Natural Resource Rents, Globalisation and Environmental Degradation: New Insight from 5 Richest African Economies

Abstract
Environmental degradation has continued to be a major global challenge; hence, it is consistently drawing attention from policymakers and academics. Therefore, this study further contributes to the literature by investigating the contributions of natural resource rents and globalisation to environmental degradation in the 5 richest African economies from 1990 to 2019. Four techniques were applied: the fixed and random effect, feasible generalised least squares and the augmented mean group. The Hausman test was used to affirm the supremacy of the feasible generalised least squares outcomes and, consequently, its use to derive the study inferences. A Dumitrescu and Hurlin causality test was also employed to determine the direction of causality between the subject variables. Findings from the study showed that natural resource rents significantly contribute to environmental degradation. In contrast, globalisation reduces environmental degradation. Urbanisation, which served as a control measure, enhanced environmental sustainability. Robustness checks on the study models revealed the validity and reliability of the models' inferences. The Additional outcomes from the robustness checks revealed that while economic growth has no substantial effect on environmental degradation, human capital development significantly worsens the environment. The study highlights relevant policy actions that could substantially reduce environmental degradation.

Keywords: Natural resource rents; Globalisation; Environmental degradation; Urbanisation; Human capital development; African economies.

JEL Classification: H3, L72, N57, O13, Q3.

1. Introduction
Natural resource rents play an essential role in the development of a country, particularly for developing nations aspiring to upgrade to a developed one. Such developing nations rely heavily on exploiting their natural resources to grow their national income substantially (Gao and Tian, 2016; Hassan et al., 2019; and Xue et al., 2021). Evidence abounds of how natural resources have considerably aided the growth and development of countries in different parts of the world.

Natural resources are not harmful to the environment; instead, their extractive process can be detrimental to the environment. Since humans have realised the significance of natural resources to their economic growth, many have also gone wrong with the environment. Today's critical environmental issue is climate change, caused by global warming, emanating primarily from the detrimental effects of human extraction of natural resources for economic growth. For instance, human extraction of nonrenewable natural resources in minerals, crude oil, and natural gas is known to degrade the environment (Balsalobre-Lorente et al., 2018; Ahmadov and van der Borg, 2019). Notwithstanding, global warming and other long-term climate trends are anticipated to continue due to growing levels of heat-trapping greenhouse gases (GHG) in the atmosphere. It is on record that the average global temperature in 2021 alone was about 1.11°C; and global temperature data from 2015 to 2021 consistently exceeded 1°C, which is above the pre-industrial levels (WMO, 2022). Consequently, world economies have a growing worldwide campaign for environmental preservation and sustainability. Such concerted effort at saving the environment from further degradation led to the birth of various world environmental protection agreements such as the Earth Summit of 1992 in Rio de Janeiro, the
Kyoto Protocol of 1997 in Japan, the Durban Platform for Enhanced Action of 2011 in South Africa, the Cancun Agreement of 2010 in Mexico, and the more recent Paris Agreement of 2015 in France.

As of 2019, global carbon dioxide (CO$_2$) emissions per capita stood at 4.76 (Mtoe), global methane (CH$_2$) was 8,280,687 (kt of CO$_2$ equivalent), and global average ecological footprint per capita (EFP) was 2.75 (gha) (IEA, 2021a). Significant factors in the literature that impact global emissions have been identified to include exploration of natural resources, effects of globalisation, rising urbanisation, economic growth and human capital (Ulucak and Khan, 2020; Nathaniel et al., 2020a, b, c, d; Xue et al., 2021; Xiaoman et al., 2021; Hussain et al., 2021; and Khan et al. 2021).

The African continent is often considered less threat to global warming. However, the continent has seen its emission levels grow gradually over time. For instance, Africa’s CO$_2$ emissions rose from 764 (Mtoe) in the year 2000 to 1,365 (Mtoe) in 2019 (BP, 2021). Recent industrial drives, increase demand for natural resources, and development quest in the continent has seen its contributions to global emissions grow. Aside from Africa’s overwhelming agrarian wealth, its extractive sector is estimated to account for about 30% of the world’s minerals reserves (UNEP, 2022). Africa is home to 40% of the world’s gold deposits and about 90% of the world’s chromium and platinum (Aladejare, 2020; and UNEP, 2022). Similarly, Africa’s rich oil and natural gas reserves constitute about 12% and 8% of the world’s total reserves, respectively (UNEP, 2022). Interestingly, only five countries in the continent significantly account for its total emissions. Leading emitters in the continent include South Africa, Egypt, Algeria, Nigeria and Morroco (Table 1). These countries are the 5 richest African economies (5-RAEs) in the gross domestic product (GDP), income levels and foreign direct investment (FDI) inflows and outflows (Table 1). However, they also account for 77% of the entire continent’s CO$_2$ emissions as of 2019 (Table 1). The 5-RAEs are not just well endowed in minerals, oil and natural gas deposits, but are also top earners from this natural wealth, hence, their growth in natural resource explorations. It is a known fact that economic prosperity often triggers industrial growth, which heightens natural resource extraction (Aladejare, 2021). The extraction of natural resources diminishes the biocapacity of the ecosystem, which causes environmental degradation.

Table 1: The 5-RAEs' indicators as of 2019

|                | GDP         | GDP per capita (PPP) | FDI inflow | FDI outflow | Total CO$_2$ emission (Mtoe) |
|----------------|-------------|----------------------|------------|-------------|------------------------------|
| Entire Africa  | $2.6 trillion | $5,593.6*            | $45.4 billion | $5 billion | 1,365                        |
| Nigeria        | $448.12 billion | $6,054.8            | $2.4 billion | $285 million | 134                          |
| South Africa   | $387.94 billion | $13,753.8           | $3.1 billion | $3.1 billion | 462                          |
| Egypt          | $303.08 billion | $14,023.2           | $5.9 billion | $405 million | 222                          |
| Algeria        | $171.77 billion | $15,696.4           | $1.38 billion | $31.1 million | 161                          |
| Morocco        | $119.87 billion | $9,235.2            | $1.6 billion | $893 million | 68                           |
| **Total for richest 5** | $1.43 trillion | $11,752.7*          | $14.38 billion | $4,994 billion | 1,047**                      |

* indicate average GDP per capita

Source: Author’s computation from UNCTAD (2021), WDI (2022) and BP (2022).

Furthermore, the effects of globalisation which essentially entails associating with the rest of the world, have helped to open up the 5-RAEs to new investments and technology transfer. When countries widen their interactions with other nations, the benefits can arise in different dimensions, including knowledge sharing, technology transfer, economic interdependency, and alteration of people’s lifestyles (Onifade et al., 2021a). Consequently, globalisation in the 5-
RAEs has been developing significantly in the last few decades due to their quest for economic growth and development. Despite the world’s growth in globalisation and its positive benefits, there are some attendant adverse implications of globalisation-driven economic activities that could also result in global warming; hence, posing adverse results to the environment (Dunlap and Jorgenson, 2012). For instance, adopting unfriendly environmental, industrial procedures, and conventional energy usage contributes substantially to pollution levels through higher GHG emissions (IPCC, 2018). Therefore, understanding the significant role of natural resources exploitations and growing globalisation trends in environmental degradation in the 5-RAEs should be considered essential.

Another key contributor to pollutant emissions is urbanisation, closely linked with growing income levels. Remarkably, the 5-RAEs has been undergoing rapid urbanisation drives in the past two decades. Hence, this study evaluates whether this drive alongside natural resource rents and globalisation poses significant adverse effects for the continent’s environmental health.

Due to the adoption of different estimation approaches in extant studies, there are divergent outcomes of the effect of natural resource rents on the environment. It is important to note that these studies were concentrated on regional blocs where economic advancement was considered highly progressive (see Danish et al., 2019; Uluacak and Khan, 2020; Nathaniel et al., 2020d; Xue et al., 2021; Xiaoman et al., 2021; etc.). Furthermore, due to the variety in techniques and study samples in the literature, findings on the effects of globalisation on environmental degradation have continued to generate ambiguous outcomes. For instance, some studies have aligned with the pollutant-inducing consequence of globalisation (Acheampong et al., 2019; Shahbaz et al., 2019; Le and Ozturk, 2020; Nathaniel et al., 2020d; Onifade et al., 2021b; Tawiah et al., 2021, etc.). In contrast, some other studies have aligned with the pollutant-reducing outcome of globalisation (Zaidi et al., 2019; Awan et al., 2020; Mehmood et al., 2020; Erdogan et al., 2021; Onifade et al., 2021a, etc.). On the other hand, there are also studies that have found no correlation between globalisation and environmental degradation (Haseeb et al., 2018; Salahudin et al., 2019; Yameogo et al., 2021). Hence the motivation for this study, since it is obvious that there is an empirical failure to derive a consensus contribution of globalisation to environmental degradation.

As prior noted, the effect of natural resource rents and globalisation on the environment has not been done in isolation. Other factors such as urbanisation, economic growth and human capital have also been considered in the relationship. Onifade et al. (2021a) noted that examining the nexus between natural resources, globalisation, and environmental degradation should not be done in isolation if a realistic understanding of the association is to be derived. Consequently, this study controls the effect of natural resource rents and globalisation on environmental degradation by incorporating the impact of urbanisation. Furthermore, the impact of economic growth and human capital development were included to ascertain the robustness of the study’s inferences.

It is noteworthy that literature on the subject matter, even for Africa, is relatively scant, much less for the richest economies in the continent. The only related study in the literature is Erdogan et al. (2021) which introduced globalisation as a mitigating variable between natural resource abundance and dependence and environmental sustainability in Sub-Saharan African (SSA) countries. Notwithstanding, this study differs from Erdogan et al. (2021) in variable measurements and techniques. For instance, Erdogan et al. (2021) used only EFP to measure environmental degradation. In contrast, this study adopted CO₂, CH₄ and EFP for a robust
measure of environmental degradation. Furthermore, to measure globalisation, Erdogan et al. (2021) adopted the aggregated KOF index of globalisation. However, to efficiently examine the consequences of globalisation, single indicators can be biased. The intuition is that globalisation is a multifarious concept beyond trade openness and capital flows (Gygli et al., 2019). It incorporates interactions between people in various countries sharing ideas and information or governments of different nations collaborating to solve challenges of global reach. An indicator that is widely favoured in the literature to possess these qualities is the KOF globalisation index. The index assesses globalisation along the economic, social and political dimensions (Dreher et al., 2008). Hence, using its aggregation to proxy globalisation overwhelmingly in prior studies (Nathaniel et al., 2020d; Majeed et al., 2021; Onifade et al., 2021a; Xue et al., 2021; etc.). For a robust understanding of the impact of globalisation, this study combined the effects from the degree of openness with the KOF globalisation index. However, a recent revision of the KOF globalisation index, which permits flexibility in aggregating various dimensions and features of globalisation into broad measures of de facto and de jure, was adopted. Hence, the improvement on existing literature and the motivation for this study.

The study sample is drawn from the period between 1990 and 2019 from the 5-RAEs including Nigeria, Egypt, South Africa, Morocco and Algeria. It is essential to state that the inclusion of the three richest North African countries in the study of the subject matter improves the related SSA countries’ studies in which they are being excluded. Furthermore, the 5-RAEs often wear the tag of emerging economies due to the potential rapid development sustained by their abundant natural resources and globalisation drive. However, their energy dynamics coupled with globalisation and urbanisation challenges make them susceptible to environmental degradation.

There are some crucial findings from the study worth acknowledging. First, the study showed that a sustained upward trajectory in natural resource rents and human capital development is emission-inducing on the 5-RAEs. In contrast, globalisation and urbanisation demonstrates the potential to be emission-reducing on the 5-RAEs. The indication is that maintaining the natural resources exploitation techniques in these countries leaves their environment and the entire African environment prone to degradation since they constitute the key emitters. Second, the study also found that economic growth had no significant effect on environmental degradation.

The sequence of this study takes the following order. Section one is the introduction, Section two is the literature review, Section three is the study’s data and methodology, Section four contains results and analysis, and Section 5 concludes the study with policy directives.

2. Literature Review
2.1 Theoretical review
In assessing how natural resource rents and globalisation contributes to environmental degradation in the 5-RAEs, a brief theoretical exposition of the subject matter is imperative. Consequently, the theoretical linkage between the subject matter follows two particular interests.

2.1.1 Natural resources and environmental degradation: A theoretical outline
The theoretical linkage between natural resources and environmental degradation can be associated with the pioneering work of Schnaiberg in the field of environmental sociology known as the treadmill of production. The theory shows how economic desires by individuals for a prosperous life creates environmental degradation (Schnaiberg, 1970). The treadmill of
production is anchored on the premise that rapid economic growth and development often lead to an enormous quest for natural resources and novel technologies. Thus, as economic agents continue to pursue higher economic growth and development, more pressure on energy demand is exerted, which further induces new investments in more natural resources exploitation. Environmental degradation is worsened whenever this occurs (Majeed et al., 2021; Isiksal, 2021).

In determining the actual propelling force that sustains the treadmill, Curran (2017) further augmented the theory by concentrating on how those who direct the production process are the core agents operating the treadmill. Also, the state and workers are believed to lend their support for the inefficient treadmill’s continued reproduction through the positional economy of consumption (Curran, 2017). The positional economy of consumption is related to procedures in which the consumption of some economic agents can adversely impact the “use-value” of other agents’ consumption (Curran, 2017). Intuitively, there are some addictive factors that influence individuals’ insatiable demand for sophisticated goods, which in turn fuels their engagement in the treadmill of production for the purpose of gaining income and wealth levels required for upgrading to higher growth and development levels (Curran, 2017).

2.1.2 Globalisation and environmental degradation: A theoretical outline

Globalisation is vital to the 5-RAEs since the bulk of their exports and income is from natural resources. Various theories have offered possible support for the nexus between globalisation and environmental degradation. Their postulations have been validated in extant literature (Destek and Okumus, 2019; Terzi and Pata, 2019; Balsalobre-Lorente et al., 2019; Tawiah et al., 2021; etc.). The most prominent theoretical propositions are the pollution haven theory and the pollution halo hypothesis.

The pollution haven hypothesis is known to have gained momentum notably when Walter and Ugelow (1979) indicated that trade and foreign investment that grew on the influence of globalisation are providing platforms for diverting pollution-intensive production abroad. The critique about the detrimental effects of globalisation on the environment is often anchored on the pollution haven hypothesis (Terzi and Pata, 2019; Nathaniel et al., 2020d; Tawiah et al., 2021); and the argument on its validity is still available for further exploration.

Another growing theoretical school of thought on the globalisation-environmental degradation nexus is the pollution halo hypothesis, popularised by Birdsall and Wheeler (1993). In contrast to the pollution haven theory, the view of the pollution halo theory is that globalisation provides an avenue for the transfer of cross country technology between developed and developing countries. The reasoning is that developing countries are expected to reap the technological skills from the developed countries, which will profit them in terms of improved environmental quality and reduced degradation (Birdsall and Wheeler, 1993; Balsalobre-Lorente et al., 2019; Tawiah et al., 2021). Similar to the pollution haven theory, the validity of the pollution halo hypothesis still leaves room for further verification as there is mixed evidence in the empirical literature (Destek and Okumus, 2019; Balsalobre-Lorente et al., 2019; Ahmad et al., 2021). Consequently, the discourse on the role of globalisation in environmental degradation is still subject to further empirical probing.

2.2 Empirical review

2.2.1 The natural resources-environmental degradation nexus
Empirical studies abound on the effect of natural resources on the environment for different regional blocs in the world. Furthermore, the practical finds of these studies have varied due to their application of different econometric techniques and emission indicators.

For example, Balsalobre-Lorente et al. (2018) employed the panel least squares (PLS) approach and showed that natural resources diminish CO\textsubscript{2} emissions for 5 European Union (EU) economies. Ulucak and Khan (2020) applied the fully modified ordinary least squares (FMOLS) and the dynamic ordinary least squares (DOLS) methodologies. Inferences from the study indicated that natural resources reduce CO\textsubscript{2} emissions for BRICS economies. Majeed et al. (2021) used the cross-sectional autoregressive distributed lag (CS-ARDL) estimator to find that natural resources substantially improve CO\textsubscript{2} emissions for the Gulf cooperation council (GCC). Xiaoman et al. (2021) adopted the continuously updated, fully modified (CUP-FM) and continuously updated bias-corrected (CUP-BC) approaches. The study found that natural resource abundance positively impacts CO\textsubscript{2} emissions for the Middle East and North Africa (MENA) economies. Xue et al. (2021) applied the dynamic common correlated effects (DCCE) technique and derived the conclusion that natural resources reduce CO\textsubscript{2}, CH\textsubscript{4} and nitrous oxide (N\textsubscript{2}O) emissions for South Asian countries. Usman et al. (2022) employed the augmented mean group (AMG), and the common correlated effects mean group (CCEMG) methodologies. Findings from the study showed that natural resources reduce EFP for financially resource-rich countries.

In contrast, Sarkodie (2019) used the panel mean group (PMG) approach and found that natural resource rents increase CO\textsubscript{2} emissions for 16 EU economies. Analogously, Bekun et al. (2019) adopted the PMG approach and found that natural resources add to CO\textsubscript{2} emissions for 16 EU economies. Danish et al. (2019) adopted the AMG approach and submitted that natural resources aggravates CO\textsubscript{2} emissions for BRICS economies. Wang et al. (2020) adopted the CS-ARDL approach and concluded that natural resources increase CO\textsubscript{2} emissions for G-7 economies. Nathaniel et al. (2020d) employed the AMG and the CCEMG methods and derived the exacerbating effect of natural resources on CO\textsubscript{2} emissions for Latin American and Caribbean countries (LACCs). Similarly, Onifade et al. (2021a) used AMG, FMOLS and the DOLS techniques and concluded that natural resources enhance CO\textsubscript{2} emissions for E7 economies. Erdogan et al. (2021) applied the CUP-FM and CUP-BC techniques and concluded that natural resources dependence for SSA economies adversely impacts EFP.

2.2.2 The globalisation-environmental degradation nexus

Similar to the prior regional empirical studies, the contribution of globalisation to environmental degradation also vary due to the application of different econometric techniques and globalisation variable proxy.

Extant studies such as Twerefou et al. (2017) used the generalised method of moments (GMM) technique and submitted that trade openness and FDI increases CO\textsubscript{2} emissions for 36 SSA countries. Acheampong et al. (2019) applied panel fixed effect (FE), random effect (RE) and GMM techniques; and concluded that FDI and trade openness are CO\textsubscript{2} inducing for 46 SSA countries. Similarly, Kalayıcı and Hayalőğlu (2019) adopted a FE model. They found that the aggregated KOF index (a measure for globalisation) and trade openness enhance environmental degradation for the North American Free Trade Agreement (NAFTA) economies. Shahbaz et al. (2019) used the GMM technique and reported that globalisation exacerbates CO\textsubscript{2} emissions for G-7 countries. Liu et al. (2020) used the panel FE approach and submitted that the aggregated KOF globalisation index improves CO\textsubscript{2} emissions for G7 economies. By employing the CS-ARDL technique, Wang et al. (2020) also concluded that the effect of the aggregated
KOF globalisation index increases CO\textsubscript{2} emissions for G7 economies. Nathaniel et al. (2020d) used the AMG and the CCEMG techniques and concluded that the aggregated KOF globalisation index improves CO\textsubscript{2} emissions for LACCs. Analogously, in a study for 47 emerging markets and developing economies, Le and Ozturk (2020) used the CCEMG, AMG and the dynamic common correlated effects (DCCE) methods and concluded that the aggregated KOF globalisation index is CO\textsubscript{2} inducive for 47 emerging markets and developing economies. Onifade et al. (2021b) employed the DOLS and FMOLS technique and concluded that trade openness improves CO\textsubscript{2} emissions for Turkey and the Caspian region. Tawiah et al. (2021) employed the FE-OLS estimator and derived the conclusion that trade openness and FDI promotes CO\textsubscript{2} emissions for 123 developed and developing countries.

There are also studies that have affirmed the reducing effect of globalisation on environmental degradation. Such studies include Zaidi et al. (2019) employed the CUP-FM and CUP-BC and derived the conclusion that the aggregated KOF globalisation index reduces CO\textsubscript{2} emissions for Asia Pacific Economic Cooperation (APEC) countries. Awan et al. (2020) applied the FE and the feasible generalised least square (FGLS) techniques and concluded that the aggregated KOF globalisation index is CO\textsubscript{2} reducing for MENA countries. Also, Mehmood et al. (2020) used the ARDL technique and submitted that the aggregated KOF globalisation index reduces CO\textsubscript{2} emissions in South Asian countries. Erdogan et al. (2021) adopted the CUP-FM and CUP-BC approaches and documented that the aggregated KOF globalisation index improves environmental sustainability by reducing EFP for SSA countries. Onifade et al. (2021a) employed the AMG, FMOLS and DOLS methodologies and concluded that the aggregated KOF globalisation index reduces CO\textsubscript{2} emissions for E7 economies. Xue et al. (2021) applied the DCCE technique and reported that the aggregated KOF globalisation index reduces CO\textsubscript{2} and N\textsubscript{2}O emissions for South Asian countries. Furthermore, Usman et al. (2022) employed the AMG and the CCEMG approach and submitted that the aggregated KOF globalisation index enhances EFP for financially-resource rich countries.

The third group of literature are studies that have found no association between globalisation and environmental degradation. In this category are studies such as Salahuddin et al. (2019). The study adopted the mean group (MG), AMG and the CCEMG techniques and admitted that the aggregated KOF globalisation index has no effect on CO\textsubscript{2} emissions for 44 SSA countries. Furthermore, Yameogo et al. (2021) adopted the GMM approach and concluded that aggregated KOF globalisation index has no substantial effect on CO\textsubscript{2} and N\textsubscript{2}O emissions for 20 SSA countries. Likewise, Haseeb et al. (2018) applied the dynamic seemingly unrelated regression (DSUR) technique and demonstrated that the aggregated KOF globalisation index has no effect on CO\textsubscript{2} emissions for BRICS countries.

In all these studies, there are variables that have prominently been considered control or interacting variables, either in the natural resource-environmental degradation nexus or in the globalisation-environmental degradation relationship. Amongst these group of control variables, urbanisation, human capital development, and economic growth have been prominent and reported to have significant varying effects on environmental degradation (Haseeb et al. 2018; Salahuddin et al., 2019; Zaidi et al., 2019; Liu et al., 2020; Erdogan et al., 2021; Onifade et al., 2021a, etc.). In addition, there are studies that have specifically evaluated the role of urbanisation in environmental degradation (Ahmed et al. 2019; Khan et al., 2019; Wang et al., 2020; Ahmed et al. 2020, etc.). Thus, suggesting the more crucial role of urbanisation control in attaining environmental quality.

2.3. Literature gap
From the above literature review, it is evident that there is no study that has examined the impact of natural resource rents and globalisation on environmental degradation for the 5-RAEs as this study. Also, the use of CO₂, CH₄ and EFP as environmental degradation indicators in this study provides a robust measure. The review shows that most previous studies have overwhelmingly relied solely on CO₂ emissions or EFP, which can be misleading. Thus, this study constitutes an improvement to the literature. Similarly, this study used more robust measures to assess the effect of globalisation. In contrast to the aggregated KOF globalisation index overwhelmingly used in previous studies, the newly revised KOF globalisation index disaggregates globalisation into de facto, and de jure measures along political, economic, and social perspectives were adopted. The degree of openness was added as a third measure for globalisation. None of the reviewed studies had robustly combined these measures of globalisation, thus, an addition to the literature. It is also noteworthy that the reviewed studies measured natural resource rent by aggregation. In this study, the effect of natural resource rents on the environmental degradation indicators is disaggregated into mineral, oil and natural gas rent. Methodologically, this study combined the FE, RE, FGLS, and the AMG techniques, which is rare in any African related study. These substantial gaps in the literature constitute the contributions of this study to the natural resources-globalisation-environmental degradation nexus debate.

3. Methodology
3.1 Data sources and variable description
By employing data observation between 1990 and 2019, this study investigates the contribution of natural resource rents and globalisation to environmental degradation in the 5-RAEs. Three measures of natural resource rent were applied in this study; they are rents from mineral, oil and natural gas. The 5-RAEs are abundantly endowed in these natural resources, and their income contributes significantly to their economic growth and development. Similarly, three environmental degradation measures, CO₂, CH₄ and EFP, were applied as environmental degradation indicators. The justification for adopting CO₂ and CH₄ emissions as environmental degradation indicators is their substantial share in GHG emissions. CO₂ emissions constitute the most significant share in GHG emissions, followed by CH₄. CO₂ emissions primarily emanate from energy use, transportation, and industrial output (Li et al., 2020), while CH₄ is derived from oil, natural gas, and coal (Yusuf et al., 2020). EFP, on the other hand, is a modern measure of environmental quality. The measure uniquely considers the unit of different natural areas needed to aid an economy. These natural areas include cropland, forest products, carbon space, built-up land, fishing grounds, and grazing land. Further justification for the EFP indicator stems from mining activities inducing loss of biodiversity, pollution of surface water, groundwater, and soil erosion.

The impact of globalisation can be broad, extending to the extraction of natural resources because trade is linked with efficient technology transfer (Majeed et al., 2021). On the contrary, the quantum of trade and foreign investment in dirty technology can also result in globalisation being environmentally detrimental. Globalisation is crucial to the 5-RAEs because natural resources exports constitute the principal source of their income. As prior noted, this study adopted the recent de facto and de jure classification of globalisation by the KOF globalisation index. The de facto globalisation indicator assesses actual international flows and activities. In contrast, the de jure globalisation indicator measures policies and terms that, in essence, permit, facilitate and promote flows and activities (Gygli, 2019). Although both indicators viewed globalisation between economic, social and political dimensions, they differ in their dimensional structure; hence, their preference to the aggregated KOF globalisation indicator
used in extant studies. The degree of trade openness was used as a third indicator of globalisation to proxy the receptive nature of the economy.

Urbanisation was adopted as a control variable in line with related studies since the relationship between natural resource rents, globalisation, and environmental degradation cannot exist in isolation. Urbanisation can enhance energy, housing, and transport demands, triggering fossil fuel consumption and generating more CO\textsubscript{2} emissions. On the other hand, urbanisation has the potential to reduce pollution levels by encouraging resource efficiency through train and bus-based mass transportation (Ahmed et al., 2019).

Two robustness checks were conducted on the study’s inferences using economic growth and human capital development. Both variables have been established in the literature to contribute to emissions. For instance, as economic growth increases, the demand for natural resources also rises, but with intensified ecological pressures. Furthermore, human capital development policies and strategies can enhance or reduce environmental degradation in the 5-RAEs.

Captured in Table 2 is the complete description of the study variables, their corresponding measurements and sources.

| Variable                  | Measurement                                      | Sources                        | Symbol |
|---------------------------|--------------------------------------------------|--------------------------------|--------|
| Carbon dioxide emissions  | Metric tons per capita                           | WDI (2022)                     | CO\textsubscript{2} |
| Methane emissions         | Kiloton (kt) of CO\textsubscript{2} equivalent   | WDI (2022)                     | CH\textsubscript{4} |
| Ecological footprint      | Global hectares (gha) per capita                 | Global footprint network (2022) | EFP    |
| Mineral rents             | Mineral rents % of GDP                           | WDI (2022)                     | MY     |
| Natural gas rents         | Natural gas rents % of GDP                        | WDI (2022)                     | NY     |
| Oil rents                 | Oil rents % of GDP                               | WDI (2022)                     | OY     |
| De facto globalisation    | Weight in percentage                             | KOF globalisation index (2021) | GIDF   |
| De jure globalisation     | Weight in percentage                             | KOF globalisation index (2021) | GIDJ   |
| Degree of openness        | \( \frac{import + export}{GDP} \times 100 \)     | WDI (2022)                     | DOP    |
| Urbanisation              | Urban population growth (%)                       | WDI (2022)                     | UPG    |
| Economic growth           | GDP per capita growth (%)                         | WDI (2022)                     | YGP    |
| Human capital development | Human capital index                              | Penn World Table (2021)        | HC     |

Source: Author’s computation.

3.2 Model construction
3.2.1 Cross-sectional dependency test
One major challenge in panel data estimation is the presence of cross-sectional dependency (CSD). A growing number of recent studies have immensely articulated the substantial effect of CSD as an essential step towards deriving not just the appropriate model selection but also to guarantee the robustness of estimated parameters for a panel study analysis; drawn from samples with the likelihood of being cross-sectionally dependent (Gyamfi et al., 2021; Wang et al., 2020; and Shen et al., 2021). When the CSD characteristic of a panel data analysis is ignored, it leaves room for inconsistency and inefficiency in estimated coefficients. Hence, a
CSD test among variables is imperative to surmount this problem. Baltagi et al. (2012) had noted that CSD is not a problem when handling micro panels (i.e., a panel data with a period lesser than the number of cross-sectional units); but indeed is a problem when handling macro panels (i.e., a panel data with period more significant than the number of cross-sectional units). In this study, the sample data is for 5 countries and spanning for 30 time periods. Hence, a CSD test is imperative because of the macro structure of the panel dataset. To this end, this study applied four CSD tests which are Breusch and Pagan (1980) Lagrange multiplier (LM) test, Pesaran (2004) scaled LM test, Pesaran (2004) CSD test and Baltagi et al. (2012) bias-corrected scaled LM test. The test equation is as expressed below.

\[
CSD = \left[ \frac{WZ(Z - 1)}{2} \right]^{1/2} \tilde{y} \tag{Equ. 1}
\]

where \( \tilde{y} = \left[ \frac{2}{Z(Z-1)} \right] \sum_{i=1}^{Z-1} \sum_{j=i+1}^{Z} \tilde{y}_{ij}^2 \) and \( \tilde{y}_{ij}^2 \) denote the pair-wise cross-sectional correlation parameters. \( W \) represent time unit/sample periods, and \( Z \) represents panel cross-sectional size. Once the presence of CSD is confirmed, the appropriate econometric techniques that apply to CSD issues would be involved. Specifically, the Breusch-Pagan CSD equation is as specified:

\[
CSD = W \sum_{i=1}^{Z-1} \sum_{j=i+1}^{Z} \tilde{y}_{ij}^2 \tag{Equ. 2}
\]

and the Pesaran (2004) CSD test is presented as:

\[
CSD = \sqrt{\frac{2W}{Z(Z-1)}} \sum_{i=1}^{Z-1} \sum_{j=i+1}^{Z-1} y_{ij} \tag{Equ. 3}
\]

The output of both the Breusch-Pagan LM test and Pesaran CSD test would be of more interest since the study dataset is characterised by \( W > Z \).

3.2.2 Panel unit root tests

The stationarity of the variables is assessed after the outputs of the CSD tests. Conventional first-generation unit root approaches, such as Levin-Lin and Chu (LLC) and I'm, Pesaran, and Shin (IPS), are deficient in mitigating CSD issues. Thus, keeping in view the existence of CSD, this study used both first and second-generation cross-sectional unit root tests. For the first generation CSD unit root test, Madalla and Wu (1999) was applied, while Pesaran (2003) cross-sectional augmented Dickey-Fuller (CADF) and Pesaran (2007) cross-sectional IPS (CIPS) constitute the second generational unit root test. The equation form of CADF test statistic is as follows:

\[
\Delta G_{it} = \infty_{it} + \tau_{i}G_{i,t-1} + \delta_{i}\tilde{G}_{t-1} + \varphi_{i}\Delta\tilde{G}_{t} + \mu_{it} \tag{Equ. 4}
\]

where \( \infty_{it} \), \( G_{it} \) and \( \mu_{it} \) represents the intercept, study variables and error term, respectively, inserting the first lag expression yields the following equation:

\[
\Delta G_{it} = \infty_{it} + \tau_{i}G_{i,t-1} + \delta_{i}\tilde{G}_{t-1} + \sum_{j=0}^{p} \varphi_{ij}\Delta\tilde{G}_{t-j} + \sum_{j=1}^{p} \tau_{ij}\Delta G_{i,t-j} + \mu_{it} \tag{Equ. 5}
\]
where $\tilde{G}_{t-j}$ and $\Delta G_{i,t-j}$ denote the intercept, mean of lagged and first difference operator, respectively, across the specific cross-sections. To show the CIPS test statistics, the following equation is derived:

$$CIPS = \frac{1}{Z} \sum_{i=1}^{Z} \tau_{i}(Z, W)$$  \hspace{1cm} \text{Equ. 6}$$

where the coefficient $\tau_{i}(Z, W)$ indicates CADF test statistics which can further be expressed as:

$$CIPS = \frac{1}{Z} \sum_{i=1}^{Z} CADF_{i}$$  \hspace{1cm} \text{Equ. 7}$$

If the tests confirm that the study variables are stationary at I(1), then the need for cointegration testing arises before parameter estimation. The CADF and CIPS panel unit root tests generate reliable proof of both CSD and heterogeneity in a panel series.

3.2.3 Panel cointegration test

After the application of the panel unit root test that incorporates CSD, it is also vital to ascertain the presence of a long-run association between the variables. A cointegration test that incorporates CSD into its estimation process would have been appropriate, such as the Westerlund (2007) error-correction model-based cointegration test. However, the test restricts cointegration to a maximum of 6 variables in a model; hence, the constraint to its application in this study. To this end, three residual-based panel cointegration tests were employed, and they are Kao (1999), Pedroni (1999) and Westerlund (2005) test. While all three tests have a null of no cointegration, the Kao and Pedroni test have an alternative of all panels cointegrated. On the other hand, the Westerlund test, which is based on the variance ratio test statistics, has its default test built on the framework wherein the autoregressive coefficient is board explicit. The alternative hypothesis is divided between the choice of all panel or partial panel cointegration. To incorporate the CSD feature of the series, the tests were conducted without subtracting the cross-sectional means from the series as proposed by Levin et al. (2002).

3.3 Panel estimation technique

3.3.1 FE and RE model

Conventionally, panel data modelling is known to examine the time and group effect that aligns with specific effect and heterogeneity effect, and these effects are FE or RE (Park, 2011). A panel data model examines the specific effects, time effects, or both. In doing this, the FE and RE model is often deployed. The FE verifies if the constants differ across individuals or periods, as against the RE that examines variations in error variances. Merits of both effects are of the following:

1.) The RE model offers estimates for time-constant covariates.
2.) The FE model is applied for the purpose of deriving unbiased estimates.
3.) The FE provides a more reliable estimate for deriving the actual causal effect of an entity.
4.) Both effects aid in panel analysis comprising time-series and cross-sectional data.
It is also important to note that if \( W \) (the time units of the data) is large and \( Z \) (the number of cross-sectional units) is small, the variations in the parameter estimates of the FE and RE are likely to be minimal. Consequently, the estimation choice in such a situation is a function of computational convenience. Based on this reasoning, the FE may be preferable. However, when \( Z \) is large, and \( W \) is small, the estimates derived by both approaches may vary substantially.

The general RE estimation for the study is expressed as:

\[
Y_{it} = (\beta_0 + \mu_{0j}) + \sum_{j=1}^{k} \beta_j X_{j, it} + \varepsilon_{it} \quad \text{(Equ. 8)}
\]

where \( Y \) is the dependent variable, \( X \) the regressor variable, \( \beta_0 \) is the global intercept and \( \mu_{0j} \) represents the random intercept.

Similarly, the general FE estimation for the study is expressed as:

\[
Y_{it} = \theta_i + \omega_i + \sum_{j=1}^{k} \beta_j X_{j, it} + \varepsilon_{it} \quad \text{(Equ. 9)}
\]

Where \( \theta_i \) is the individual-specific fixed effect component and \( \omega_i \) is a time fixed effect.

### 3.3.2 FGLS model

For the purpose of dealing with autocorrelation, heteroscedasticity and CSD in panel data modelling, Beck and Katz (1995) and Reed and Ye (2011) recommended two techniques which are the FGLS and panel-corrected standard error (PCSE) techniques. The choice between both techniques is based on the rule of thumb: if the period is greater than or equal to cross-sectional units, the FGLS approach is efficient. On the other hand, if the reverse is the case, the PCSE technique should be applied. The result of both techniques is, by default, free from autocorrelation, heteroscedasticity, and CSD. Hence, since this study’s data aligns with the FGLS condition, the PCSE procedure was not estimated.

Generally, the FGLS estimator of \( \beta \) is stated as:

\[
\hat{\beta}_{\text{FGLS}} = (X^W\hat{\Omega}^{-1}X)^{-1}X^W\hat{\Omega}^{-1}y \quad \text{(Equ. 10)}
\]

where \( \hat{\Omega} \) denotes an innovation covariance estimate based on a model. Thus, the computed parameter covariance matrix follows the expression:

\[
\hat{\Sigma}_{\text{FGLS}} = \hat{\sigma}_{\text{FGLS}}^2 (X^W\hat{\Omega}^{-1}X)^{-1} \quad \text{(Equ. 11)}
\]

where

\[
\hat{\sigma}_{\text{FGLS}}^2 = y^W \left[ \hat{\Omega}^{-1} - \hat{\Omega}^{-1}X(X^W\hat{\Omega}^{-1}X)^{-1}X^W\hat{\Omega}^{-1} \right] y / (W - p) \quad \text{(Equ. 12)}
\]

For computing the FGLS parameters, the following conditions are required:

1.) OLS is first run on the data, and then residuals are estimated (\( \hat{\varepsilon}_i \)).
2.) $\hat{\Omega}$ is computed as a result of having a model for the innovations covariance.
3.) $\hat{\beta}_{FGLS}$ is computed in addition with its covariance matrix $\hat{\Sigma}_{FGLS}$.

Hence, if $\hat{\Omega}$ proved to be a consistent estimator of $\Omega$, and the predictors that constitute $X$ are truly independent, then the FGLS estimators are considered consistent and efficient. It should be noted that to achieve full efficiency, we may not require an efficient estimate of the coefficients in $\beta$; rather, only a consistent one is required, which the FGLS technique provides.

3.3.3 AMG model
For further comparison of the study parameters, the AMG, as suggested by Bond and Eberhardt (2013), was employed. The AMG also account for CSD and heterogeneity in panel data analysis (Dogan et al., 2020). The technique incorporates a common dynamic process in a regression approach involving two interrelated steps, as shown in Equations 13 and 14.

**Step 1 AMG process:**

$$\Delta y_{it} = \alpha_t + b_i \Delta x_{it} + \psi_t R_t + \sum_{w=2}^{W} \zeta_i \Delta Q_t + \epsilon_{it} \quad (Equ. 13)$$

**Step 2 AMG process:**

$$\hat{b}_{AMG} = Z^{-1} \sum_{i=1}^{Z} \hat{b}_i \quad (Equ. 14)$$

where $\zeta_i$ is the parameter of the time dummies, $b_i$ is the country-specific estimate of parameter, $R_t, x_{it}$ and $y_{it}$ denote the unobserved common factor, and $\hat{b}_{AMG}$ represents the AMG estimator.

3.3.4 Test for causality
The constraint of both the FGLS and the AMG techniques in providing causality information between the variables necessitated a causality test. Hence, the Dumitrescu and Hurlin (2012) (D-H) causality technique was adopted.

The D-H test is considered superior to the conventional vector error-correction model causality because of its ability to account for CSD and heterogeneity in panel data. The D-H causality test has two different statistics: the Zbar-statistics and Wbar-statistics. While the Zbar shows the standard normal distribution, the Wbar is the mean. Both statistics from the D-H test offer three causality options: no causality, unidirectional causality, and bidirectional causality among variables. The D-H causality process entails estimating Equation 15, which is expressed as:

$$Y_{it} = \xi_i + \sum_{i=1}^{P} \Gamma_i^{(p)} Y_{i,t-n} + \sum_{i=1}^{P} \lambda_i^{(p)} X_{i,t-n} + \mu_{it} \quad (Equ. 15)$$

where the intercept ($\xi_i$) and parameters ($\lambda_i = (\lambda_i^{(1)}, ..., \lambda_i^{(p)})$) remain static; and $\Gamma_i^{(p)}$ is the autoregressive coefficient, while $\lambda_i^{(p)}$ the regression parameter.
In order to prevent complicating the model selection process between FE, RE, FGLS and AMG, the conventional Hausman (1978) test was applied. The Hausman test statistic follows a chi-square distribution asymptotically to decide whether a model is efficient or consistent to another.

4. Results and Discussion

4.1 Descriptive statistic test results

Table 3 shows the aggregate descriptive statistic for the 5-RAEs within the study period. Their mean CO$_2$ emissions per capita is 2.87 (Mtoes) approximately, which is above the 0.7 (Mtoes) average for the African continent (IEA, 2021a). Similarly, the particular mean CO$_2$ emissions for the 5-RAEs is captured in Table 4. Algeria is revealed to have the lowest mean CO$_2$ emissions of 0.7 (Mtoes), while Morocco has the highest mean of 7.3 (Mtoes). However, the 5-RAEs’ average CH$_4$ emissions is 50,602 (kt of CO$_2$ equivalent), which is less than Africa’s average of 358,170 (kt of CO$_2$ equivalent) (WDI, 2022). Table 4 shows that Algeria has the highest mean CH$_4$ emissions of 109,223 (kt of CO$_2$ equivalent), while South Africa’s mean CH$_4$ emissions of 13,551 (kt of CO$_2$ equivalent) is the lowest. The mean EFP for the 5-RAEs is 11 (gha) approximately, as against Africa’s mean of 1.32 (gha) (GFP, 2022).

Output in Table 4 shows that South Africa has the highest EFP mean of 48.9 (gha), while Nigeria has the lowest mean of 1.1 (gha).

| Table 3: Aggregate descriptive statistic |
|----------------------------------------|
| Variable    | Mean   | Std. Dev. | Min   | Max   | Observations |
|-------------|--------|-----------|-------|-------|--------------|
| $CO_2$      | Overall | 2.872     | 2.404 | 0.481 | N = 150      |
|             | Between | 2.628     | 0.669 | 1.713 | n = 5        |
|             | Within  | 0.469     | 4.106 |       | T = 30       |
| $CH_4$      | Overall | 50602.37  | 32839.86 | 10260 | N = 150      |
|             | Between | 35321.98  | 13551.17 | 26709.21 | n = 5        |
|             | Within  | 8581.57   | 71214.21 |       | T = 30       |
| $EFP$       | Overall | 11.010    | 19.341 | 1.004 | N = 150      |
|             | Between | 21.205    | 1.146 |       | n = 5        |
|             | Within  | 3.459     | -2.231 |       | T = 30       |
| $MY$        | Overall | 0.549     | 0.965 | 0     | N = 150      |
|             | Between | 0.658     | 0.005 |       | n = 5        |
|             | Within  | 0.763     | -0.669 |       | T = 30       |
| $NY$        | Overall | 0.855     | 1.127 | 0.001 | N = 150      |
|             | Between | 1.073     | 0.003 |       | n = 5        |
|             | Within  | 0.587     | -0.742 |       | T = 30       |
| $OY$        | Overall | 7.982     | 8.366 | 0     | N = 150      |
|             | Between | 8.190     | 0.004 |       | n = 5        |
|             | Within  | 3.995     | -2.290 |       | T = 30       |
| $GIDF$      | Overall | 53.944    | 9.296 | 36.417 | N = 150      |
|             | Between | 6.228     | 46.938 | 71.777 | n = 5        |
|             | Within  | 7.428     | 32.882 | 66.122 | T = 30       |
| $GIDJ$      | Overall | 58.492    | 9.951 | 31.152 | N = 150      |
|             | Between | 5.180     | 53.299 | 72.770 | n = 5        |
|             | Within  | 8.798     | 30.791 | 65.963 | T = 30       |
| $DOP$       | Overall | 43.053    | 24.213 | 2.971 | N = 150      |
|             | Between | 24.841    | 3.318 |       | n = 5        |
|             | Within  | 9.450     | 23.492 |       | T = 30       |
| $UPG$       | Overall | 2.838     | 0.971 | 1.699 | N = 150      |
|             | Between | 0.995     | 1.951 |       | n = 5        |
|             | Within  | 0.382     | 2.273 |       | T = 30       |
Furthermore, the average MY, NY and OY for the 5-RAEs is 0.55%, 0.86% and 7.98%, respectively. Table 4 reveals that Egypt has the highest mean value of 0.14% for MY, and Nigeria, with 0.07%, is the lowest amongst the 5-RAEs. However, Nigeria is revealed to have the highest NY mean of 2.6%, while South Africa has the lowest with 0.003%. Likewise, Nigeria has the highest OY mean of 18.8%, and South Africa has the lowest with 0.004%. The aggregate GIDF mean for the 5-RAEs is 53.9%, while their GIDJ average is 58.5%. Further evidence in Table 4 shows that Morocco has the highest GIDF mean with 59.6%, and Nigeria with 46.9% is the lowest. Thus, Morocco and Nigeria have had more and less international access to trade flows, respectively. On the other hand, South Africa has the highest GIDJ mean of 66%, which indicates it has the best globalisation policies and terms. In comparison, Algeria, with the lowest GIDJ mean of 53.3%, suggest its globalisation policies and terms are the least attractive amongst the 5-RAEs. The aggregate mean value for DOP in the 5-RAEs is 2.84%, and UPG mean is 2.84%. Individual output in Table 4 indicates that South Africa has the highest DOP mean (66.7%), while Morocco (3.3%) has the lowest mean. Thus, South Africa and Morocco are the most and least receptive of the 5-RAEs, respectively. Table 4 reveals that Algeria has the highest UPG mean (4.5%), while Egypt has the lowest mean (2%); thereby suggesting that urbanisation growth is fastest and slowest in Algeria and Egypt, respectively.

### Table 4: Summary statistic of cross-sections

| Variable | Nigeria | Egypt | South Africa | Algeria | Morocco |
|----------|---------|-------|--------------|---------|---------|
| \(CO_2\) | Mean    | 2.921 | 2.021        | 1.416   | 0.669   |
|          | Std. Dev.| 0.485 | 0.418        | 0.339   | 0.081   | 0.774   |
| \(CH_4\) | Mean    | 40607.67 | 47507.33 | 13551.17 | 10923.2 |
|          | Std. Dev.| 10568.96 | 9717.57   | 2477.18   | 12448.24 | 42122.53 |
| \(EFP\)  | Mean    | 1.146 | 1.661        | 48.940  | 1.819   | 1.486   |
|          | Std. Dev.| 0.086 | 0.215        | 7.822   | 0.409   | 0.229   |
| \(MY\)   | Mean    | 0.065 | 0.142        | 1.221   | 0.005   | 1.312   |
|          | Std. Dev.| 0.069 | 0.190        | 1.574   | 0.007   | 0.687   |
| \(NY\)   | Mean    | 2.622 | 0.995        | 0.003   | 0.624   | 0.029   |
|          | Std. Dev.| 0.929 | 0.801        | 0.002   | 0.512   | 0.018   |
| \(OY\)   | Mean    | 18.756 | 8.015     | 0.004   | 13.072  | 0.064   |
|          | Std. Dev.| 6.323 | 3.384        | 0.002   | 5.529   | 0.058   |
| \(GIDF\) | Mean    | 46.938 | 57.955    | 57.830  | 47.396  | 59.599  |
|          | Std. Dev.| 4.842 | 4.609        | 8.638   | 3.985   | 12.178  |
| \(GIDJ\) | Mean    | 53.936 | 65.963    | 60.408  | 53.299  | 58.853  |
|          | Std. Dev.| 7.439 | 6.504        | 7.938   | 7.873   | 13.233  |
| \(DOP\)  | Mean    | 59.436 | 48.580    | 66.656  | 37.273  | 3.318   |
|          | Std. Dev.| 8.765 | 10.129       | 14.359  | 8.553   | 0.204   |
| \(UPG\)  | Mean    | 2.982 | 1.951        | 2.275   | 4.486   | 2.498   |
|          | Std. Dev.| 0.420 | 0.141        | 0.475   | 0.359   | 0.447   |

### 4.2 Correlation and CSD test output

Evidence in Table 5 shows a weak correlation between most of the study regressors, except for the correlation between GIDF and GIDJ. Hence, a variance inflation factor (VIF) test was conducted, and the outcome is as captured in the lower panel of Table 5. The mean VIF value for the study regressors is less than 5, thus, indicating the presence of moderate correlation between the study regressors and less severity of multicollinearity issues.

### Table 5: Correlation matrix
An examination of the output in Table 6 reveals that the estimated CSD test provides significant evidence of CSD in the panel analysis. Evidence from the four tests conducted supports the rejection of the null hypothesis of no CSD for the variables in the panel study.

Table 6: CD test output

| Variable | Breusch-Pagan LM | Pesaran scaled LM | Bias-corrected scaled LM | Pesaran CD |
|----------|-----------------|-------------------|--------------------------|------------|
| CO₂      | 187.823***      | 39.762***         | 39.676***                | 4.400***   |
| CH₄      | 109.502***      | 22.249***         | 22.163***                | 7.380***   |
| EFP      | 136.033***      | 28.182***         | 28.096***                | 10.153***  |
| MY       | 131.648***      | 27.201***         | 27.115***                | 10.893***  |
| NY       | 173.034***      | 36.455***         | 36.369***                | 13.102***  |
| OY       | 77.683***       | 15.134***         | 15.048***                | 8.428***   |
| GIDF     | 190.386***      | 40.336***         | 40.249***                | 13.730***  |
| GIDJ     | 250.253***      | 53.722***         | 53.636***                | 15.804***  |
| DOP      | 46.507***       | 8.163***          | 8.077***                 | 4.904***   |
| UPG      | 85.257***       | 16.828***         | 16.742***                | 3.034***   |

Note: *** indicates statistical significance at 1%. H₀: No cross-section dependence
Source: Author’s Estimated Output

4.3 Panel unit root and cointegration test
The validation of CSD in the variables necessitated the application of unit root test techniques that incorporates CSD into the unit root process. Table 7 summarises the unit root results for both the first and second-generation unit root techniques applied. The null hypothesis of Maddala and Wu and Pesaran CIPS unit root tests states that series are integrated at the first order were overwhelmingly accepted for all variables. Similarly, the Pesaran CADF unit root test’s alternative hypothesis of stationary at first difference was also accepted for all series.

Table 7: Unit root test output

| Variable | First generation unit root | Second generation unit root |
|----------|-----------------------------|-----------------------------|
|          |                             |                             |

Note: *** indicates statistical significance at 1%. H₀: No cointegration
Source: Author’s Estimated Output
Table 8 shows the cointegration relationship between the study variables. Despite the fact that the Kao test for the first model reveals weak cointegration between the variables, its output for the other models supports the long-run association. In contrast, the Pedroni cointegration test validates the presence of long-run association in the three models. Likewise, the Westerlund variance ratio test reveals the rejection of the null of no cointegration and the acceptance of the alternative that some of the panels are cointegrated for the three models. Consequently, we can conclude that there is a long-run association in the three study models.

### Table 8: Panel Cointegration Test

| Cointegration Test | Modified Dickey-Fuller t | Dickey-Fuller t | Augmented Dickey-Fuller t | Unadjusted modified Dickey-Fuller t | Unadjusted Dickey-Fuller t | Modified variance ratio | Modified Phillips-Perron t | Phillips-Perron t | Augmented Dickey-Fuller t | CO₂ | lCH₄ | EFP |
|-------------------|--------------------------|------------------|---------------------------|-----------------------------------|--------------------------|-----------------------|--------------------------|-----------------|--------------------------|-----|-----|-----|
| Kao Test          | Statistic                | Statistic        | Statistic                 | Statistic                         | Statistic                |                      |                         |                 |                         |     |     |     |
| Modified Dickey-Fuller t | -1.681**               | -5.423***        | -2.534***                 |                                   |                          |                      |                         |                 |                         |     |     |     |
| Dickey-Fuller t   | -1.078                   | -3.348***        | -2.804***                 |                                   |                          |                      |                         |                 |                         |     |     |     |
| Augmented Dickey-Fuller t | -0.117                  | -2.749***        | -1.825**                  |                                   |                          |                      |                         |                 |                         |     |     |     |
| Unadjusted modified Dickey-Fuller t | -2.105**               | -3.157***        | -7.276***                 |                                   |                          |                      |                         |                 |                         |     |     |     |
| Unadjusted Dickey-Fuller t | -1.256                   | -3.078***        | -4.392***                 |                                   |                          |                      |                         |                 |                         |     |     |     |
| Pedroni Test      |                          |                  |                           |                                   |                          |                      |                         |                 |                         |     |     |     |
| Modified variance ratio | -2.786***               | -3.095***        | -2.524***                 |                                   |                          |                      |                         |                 |                         |     |     |     |
| Modified Phillips-Perron t | 1.484*                   | 2.633***        | 1.507*                     |                                   |                          |                      |                         |                 |                         |     |     |     |
| Phillips-Perron t | -0.254                   | -0.127           | -3.564***                 |                                   |                          |                      |                         |                 |                         |     |     |     |
| Augmented Dickey-Fuller t | -1.980**               | -3.283***        | -3.355***                 |                                   |                          |                      |                         |                 |                         |     |     |     |
| Westerlund Test   |                          |                  |                           |                                   |                          |                      |                         |                 |                         |     |     |     |
| Variance ratio    | 3.464**                  | 2.095**          | -1.350*                   |                                   |                          |                      |                         |                 |                         |     |     |     |

**Note:** a and b represent stationarity at the level and first difference, respectively, while *, **, *** indicates statistical significance at 10%, 5% and 1%, respectively.

**Source:** Author’s Computation.

**4.4 Estimated results**

Contained in Table 9 is the RE and FE output. The result shows that the FE model is considered consistent for the CO₂ and CH₄ models, while the RE estimate is efficient for the EFP model. However, natural resource rents and globalisation have a weak effect in the consistent FE and efficient RE output.

**Table 9: RE and FE output**
In Table 10, the consistent FE and efficient RE model in Table 9 were compared to the FGLS approach using the Hausman test. Estimates from the FGLS models show substantial effects of natural resource rents and globalisation on environmental degradation. The Hausman test further affirms the superiority of the FGLS outcomes to the FE and RE outcomes provided by Table 9.

Similarly, the outcomes of the estimated FGLS models in Table 10 were compared to the outputs of the estimated AMG models, and the results are summarised in Table 11. The FGLS outputs were further considered efficient to the AMG results based on the Hausman test. Hence, this study concludes that the FGLS outputs are most robust to the FE, RE and AMG estimates. Thus, the FGLS outputs are used to derive the study’s inferences.
Evidence from Table 11 reveals that both the MY and NY indicators of natural resource rents have significant positive effects on the CO$_2$ and EFP environmental indicators. In contrast, only OY had a significant positive impact on the CH$_4$ indicator. Consequently, the results show that natural resource rents enhance environmental degradation in the 5-RAEs; particularly mineral and natural gas rents. The result is plausible because in 2019 alone, the 5-RAEs accounted for about 68% of the total mineral output in Africa (UNCTAD, 2021). Some minerals mined in these countries include gold, aluminium, iron-ore, copper, diamond, limestone, etc. Both industrial and artisanal mining techniques are known to have detrimental effects on the environment. Such adverse effects manifest in spreading heavy metals such as arsenic, cyanide, and mercury from artisanal mining. Furthermore, Algeria and Nigeria constitute part of the 7 major countries in the world that account for two-thirds of global gas flaring (GGFR, 2021). When gas flaring occurs, sulphur dioxide is released into the atmosphere, with adverse outcomes in the form of acid rain. Further, the construction of gas pipelines can also alter the ecosystem by creating erosion of minerals, releasing other detrimental pollutants into water bodies, and fragmenting wildlife habitats and movement patterns. Oil production is also known to exclusively account for 40% of CH$_4$ emissions worldwide (IEA, 2021b); hence, the positive effect from OY is seen in Table 11. Aside from the fact that over a 20-year timeframe, CH$_4$ emissions have the potential of warming 80 times more than CO$_2$, it is also a major source of ground-level ozone formation (UNEP, 2021). It is further estimated that globally, exposure to this hazardous GHG causes an annual 1 million premature deaths (UNEP, 2021). Thus, this study aligns with extant studies (Sarkodie, 2019; Bekun et al., 2019; Wang et al., 2019; and Erdogan et al., 2021) that have reported the adverse effect of natural resource rents on the environment.

In contrast, globalisation indicators in Table 11 showed that aside from GIDF having more positive outcomes on environmental degradation indicators, GIDJ and DOP both exhibit overwhelming inverse effects on the three environmental degradation indicators. Consequently, since the GIDF indicator covers actual economic and social trade flows and political activities, the outcome indicates that international trade and investment flows in the 5-RAEs have not been environmentally friendly. Most of the knowledge and technologies being transferred from the developed economies to the 5-RAEs are often cheap and dated and do not promote environmental sustainability. On the other hand, the inverse effect of the GIDF and DOP measure indicates that existing trade and investment regulations, membership of international bodies, international treaties, and receptiveness in the 5-RAEs can significantly reduce environmental degradation in these countries. Therefore, mainstreaming environmental sustainability policies into the economic, social and political liberalisation treaties in the 5-RAEs can effectively lower their environmental degradation. Overall, since the inverse effect

| Indicator | MY | NY | OY | GIDF | GIDJ | DOP | UPG | Cons | Wald Test | No. of Obs | No. of Groups |
|-----------|----|----|----|------|------|-----|-----|------|-----------|------------|--------------|
| MY        | 0.007 | 2.448 | 0.049*** | -0.019 | 0.075 | 2.559 |
| NY        | 0.121*** | 0.009 | -0.015** | -0.005** | 0.989*** | 0.232* |
| OY        | -0.093*** | 0.011 | 0.043*** | -0.0001 | -0.624*** | 0.048 |
| GIDF      | -0.081*** | 0.280 | 0.043*** | -0.0001 | -0.624*** | -0.145 |
| GIDJ      | 0.046*** | -0.242 | 0.348*** | -0.004 | -3.537*** | -0.773* |
| DOP       | 6.494*** | 1.251*** | 8.288*** | 10.473*** | 27.097*** | 3.067 |
| UPG       | 844.14*** | 21.15*** | 494.94*** | 11.06** | 1137.81*** | 243.63*** |
| Cons      | 5 | 5 | 5 | 5 | 5 | 5 |
| Hausman test | 417.13*** | 627.89*** | 608.69*** | 2.559 | 150 | 150 |

Note: *, **, and *** indicate significance at 10%, 5% and 1% respectively.

Source: Author’s Computation.
from the GIDJ and DOP globalisation indicators outweigh the positive impact from the GIDF indicator, this study submits that globalisation is environmental degradation-reducing. The submission aligns with studies (Zaidi et al., 2019; Awan et al., 2020; Xue et al., 2021; and Usman et al., 2022) that have found globalisation to be environmentally enhancing.

From the result, it is evident that the general implication of globalisation on environmental degradation in the 5-RAEs is that actual trade and investment flow into these countries may induce environmental degradation because of the poor nature of the accompanying knowledge and technologies. However, incorporating and enforcing strong environmental friendly trade and investment policies, regulations, and operational guides in these countries can strongly mitigate environmental degradation.

Contrary to most empirical findings, urbanisation is reported to have an inverse and significant effect on environmental degradation (Table 11). Thus, implying that growth in urbanisation reduces environmental degradation for the 5-RAEs. South Africa, Egypt, Algeria and Morocco have been developing smart cities with the goal to cut down on their emissions. Brownfield and greenfield projects are being sponsored in critical sectors of their economy, especially in transportation and real estate development. For instance, since 2006, Algeria has had a national policy tagged Urban Development Master Plan for Algiers 2035. The plan is built on 7 goals meant to achieve a sustainable green urban development for Algiers (the capital city), and ensure the city stands out as a model in the Mediterranean. Egypt was also a UNEP Green Economy “flagship country” between 2007 and 2011, aiming to achieve a future green society. Furthermore, in 2021, the Egyptian government embarked on ensuring sustainable urban development and low-carbon mobility. The goal is to achieve a green and secure urban environment by 2030 in line with the sustainable development goals (SDGs). Hence, the Egyptian government is in collaboration with the European Bank for Reconstruction and Development (EBRD) to initiate the EBRD “Green Cities” programme in Egypt. Similarly, Morocco’s green cities and territories development programme launched in 2017 aims to cut down on GHG emissions for the country by 17% by 2030.

4.6 Robustness check
Captured in Table 12 is the robustness check on the study inferences derived from the FGLS outcome in Table 11. Two robustness check outputs are contained in Table 12. While the first output reveals the effect of economic growth on the adopted study models, the second shows the outcome of economic growth and human capital development. Inferences in output 1 show that with economic growth, the coefficients are not significantly different from what obtains in Table 11. However, economic growth is revealed to have no significant effect on the environmental degradation indicators. By further incorporating human capital development as seen in output 2 (in Table 12), the inferences derived from Table 11 remain valid. Accordingly, this study holds that the inferences derived from Table 11 are valid and reliable for policy formulation.

Although economic growth insignificantly contributes to environmental degradation, human capital is reported to have substantial positive effects on CO$_2$ and CH$_4$ emissions. The result suggests a poor quality of human capital in the 5-RAEs, which exacerbates environmental degradation in these countries. Activities such as indiscriminate tree falling for firewood and charcoal production, bush burning for hunting and agricultural purposes, and poor waste management, especially in rural communities, are common phenomena in these countries.

Table 12: Robust FGLS output
4.7 Panel D-H causality outcome

In line with extant studies (such as Onifade et al., 2021a; Xiaoman et al., 2021; and Usman et al., 2022) that have tried to determine the causal relationship between the subject variables; Table 13 summarises the D-H causality outcomes between natural resource rents, globalisation and environmental degradation indicators used in the study. Submissions from the result are that a unidirectional causal effect flows from natural resource rents (especially from MY and NY) to environmental degradation. However, a bidirectional nexus exists between globalisation (GIDF and GIDJ indicators) and environmental degradation. In addition, the substantial causal impact from environmental degradation to DOP and urbanisation is more than the reverse causal effects from both regressors to the response variables.

Table 13: D-H causality output

Null Hypothesis: No homogenous causality

| Regressor | CO₂ | lICH₄ | EFP | CO₂ | lICH₄ | EFP |
|-----------|-----|-------|-----|-----|-------|-----|
| MY        | 0.707*** | -0.005 | 4.815*** | 0.661*** | -0.023 | 4.850*** |
| NY        | 0.894*** | -0.056 | 3.052*** | 0.557*** | -0.188*** | 3.312*** |
| OY        | 0.008 | 0.050*** | 0.066 | 0.014 | 0.052*** | 0.061 |
| GIDF      | 0.120*** | -0.016** | 1.019*** | 0.096*** | -0.026*** | 1.038*** |
| GIDJ      | -0.092*** | 0.044*** | -0.667*** | -0.111*** | 0.037*** | -0.653*** |
| DOP       | -0.081*** | -0.016*** | -0.670*** | -0.065*** | -0.010*** | -0.683*** |
| UPG       | -0.846*** | 0.350*** | -3.559*** | -0.715*** | 0.401*** | -3.659*** |
| YGP       | -0.005 | -0.08 | 0.245 | -0.012 | -0.002 | 0.232 |
| HC        | 1.719*** | 0.677*** | -1.325 |

Note: **, and *** indicate significance at 5% and 1% respectively.

Source: Author’s Computation.

| W-Stat. | Zbar-Stat. | Decision |
|---------|------------|----------|
| MY → CO₂ | 1.569 | 0.665 | Uni-directional |
| CO₂ → MY | 2.914** | 2.507 |
| NY → CO₂ | 1.669 | 0.802 | No causality |
| CO₂ → NY | 1.721 | 0.873 |
| OY → CO₂ | 0.799 | -0.389 | No causality |
| CO₂ → OY | 0.704 | -0.520 |
| GIDF → CO₂ | 2.294* | 1.658 | Bi-directional |
| CO₂ → GIDF | 2.352* | 1.737 |
| GIDJ → CO₂ | 4.440*** | 4.60 | Bi-directional |
| CO₂ → GIDJ | 5.239*** | 5.690 |
| DOP → CO₂ | 0.727 | -0.488 | Uni-directional |
| CO₂ → DOP | 3.769*** | 3.677 |
| UPG → CO₂ | 2.120 | 1.420 | Uni-directional |
| CO₂ → UPG | 5.675*** | 6.287 |

| lICH₄ = f(MY, NY, OY, GIDF, GIDJ, DOP, UPG) |
|---------------------------------------------|
| MY → lICH₄ | 2.375* | 1.769 | Uni-directional |
| lICH₄ → MY | 0.541 | -0.743 |
| NY → lICH₄ | 4.345*** | 4.465 | Uni-directional |
| lICH₄ → NY | 1.046 | -0.051 |
| OY → lICH₄ | 0.572 | -0.701 | No causality |

Wald test: 844.38*** | 497.82*** | 1150.87*** | 920.08*** | 557.81*** | 1151.98***
No. of Obs.: 150 | 150 | 150 | 150 | 150 | 150
No. of groups: 5 | 5 | 5 | 5 | 5 | 5
5. Concluding remarks

Environmental degradation has continued to be a major global challenge; hence, it is consistently drawing attention from policymakers and academicians. Therefore, this study further contributes to the literature by investigating the contributions of natural resource rents and globalisation to environmental degradation in the 5-RAEs from 1990 to 2019. Four techniques were applied: FE, RE, FGLS and the AMG. The Hausman test was used to affirm the supremacy of the FGLS outcomes and, consequently, its use to derive the study’s inferences. An A-D-H causality test was also employed to determine the direction of causality between the subject variables. Findings from the study showed that natural resource rents significantly contribute to environmental degradation in the 5-RAEs. In contrast, globalisation reduces environmental degradation in the 5-RAEs. Urbanisation, which served as a control measure, enhances environmental sustainability. Robustness checks on the study models revealed the validity and reliability of the models’ inferences. The additional outcomes from the robustness checks revealed that while economic growth has no substantial effect on environmental degradation, human capital development significantly worsens the environment.

In practical terms, this study highlights relevant policy actions that could substantially reduce environmental degradation in the 5-RAEs. First, governments and policymakers of the 5-RAEs should like the developed world, begin to focus on strategies that will lower dependency on the extraction and utilisation of natural gas, fossil fuel, and highly environmentally degrading minerals. Consequently, research and investment in renewable energy sources such as solar, geothermal, wind, tidal, hydropower, etc., should be scaled-up. By embracing these renewable energy sources, environmental degradation can be diminished, thereby ensuring sustainable economic growth and eco-friendly development. Nevertheless, in the interim, conservative
techniques should be included in exploring and exploiting natural resources in the 5-RAEs. It is also vital that methods that improve on natural resources exploration through new technologies be prioritised above their purchasing cost so long as they are environmentally friendly.

Globalisation serves as an avenue for transferring eco-friendly manufacturing technologies to developing countries. It is a means of escalating the need for clean business strategies enabling governments to achieve lower environmental degradation and fashioning a path for a sustainable future. Thus, governments in the 5-RAEs should scale up investment in modern eco-friendly extractive technologies. Investment in emission-free technologies, skills and techniques should be encouraged. For this purpose, the 5-RAEs may adopt legal and regulatory mechanisms to discourage degrading environmental FDI while promoting eco-friendly investment through tax relieves and other incentives. Hence, the campaign for greener and efficient environmental regulations in various sectors of the economy should be adopted. Punitive measures should also be administered to firms found wanting to contaminate the environment during their activities in the 5-RAEs. This may not only eliminate emissions but also maintain conservation. In promoting international trade, there is the need to regulate the exchange of goods and services and enforce only multi and bilateral trade agreements that have a potential lower adverse impact on the environment.

More efforts at achieving green urban development in these countries are required. Hence, more smart cities should be replicated especially in heavily populated communities. The 5-RAEs will also have to start embracing energy-efficient transportation and household appliances. For this reason, improved human capital development is crucial for reducing environmental degradation. The 5-RAEs would have to invest more in their human capital development to help inculcate the conscious need to be mindful of the environment when trying to fulfil their human needs. Educational curriculums that promote environmental sustainability from early learning to advance schooling should be significantly considered.

Compliance with Ethical Standards

Authors’ contributions
The corresponding author conceived the idea, wrote the introduction, collected and analysed the data, and interpreted the results, reviewed the required literature and edited the manuscript, wrote the methodology section, provided the relevant policy directions, read and approved the final manuscript.

Funding Disclosure
There is no funding disclosure.

Disclosure of potential conflict of interest
The author has no conflict of interest.

Research involving human participants and or animals
This study article does not contain any study with human participants or animals performed by the author.

Data Availability Statement
The data that support the findings of the study are available from the corresponding author upon reasonable request.
References

Acheampong, A. O., Adams, S., and Boateng, E. (2019). Do globalisation and renewable energy contribute to carbon emissions mitigation in Sub-Saharan Africa? *Science of the Total Environment*. Vol.677, 436-446.

Ahmad, M., Jabeen, G., and Wu, Y. (2021). Heterogeneity of pollution haven/halo hypothesis and environmental Kuznets curve hypothesis across development levels of Chinese provinces. *Journal of Cleaner Production*. Vol.285, 124898.

Ahmadov, A. K., and van der Borg, C. (2019). Do natural resources impede renewable energy production in the EU? A mixed-methods analysis. *Energy Policy*. Vol.126: 361–369.

Ahmed, Z., Asghar, M. M., Malik, M. N., and Nawaz, K. (2020). Moving towards a sustainable environment: the dynamic linkage between natural resources, human capital, urbanisation, economic growth, and ecological footprint in China. *Resource Policy*. Vol.67, 101677.

Ahmed, Z., Wang, Z., and Ali, S. (2019). Investigating the non-linear relationship between urbanisation and CO2 emissions: an empirical analysis. *Air Quality Atmosphere and Health*. Vol.12(8): 945–953.

Aladejare, S. A. (2021). Energy utilisation, economic prosperity and environmental quality in West Africa: is there an asymmetric nexus? *International Journal of Energy, Environment, and Economics*. Vol.28(3): 166-191.

Aladejare, S. A. (2020). Macroeconomic vs. Resource determinants of economic growth in Africa: a COMESA and ECOWAS study. *International Economic Journal*. Vol.34(1): 100-124.

Awan, A. M., Azam, M., Saeed, I. U., and Bakhtyar, B. (2020). Does globalisation and financial sector development affect environmental quality? A panel data investigation for the Middle East and North African countries. *Environmental Science and Pollution Research*. Vol.27: 45405–45418.

Balsalobre-Lorente, D., Gokmenoglu, K. K., Taspinar, N., and Cantos-Cantos, J. M. (2019). An approach to the pollution haven and pollution halo hypotheses in MINT countries. *Environmental Science Pollution Research*. Vol.26(22): 23010–23026.

Balsalobre-Lorente, D., Shahbaz, M., Roubaud, D., and Farhani, S. (2018). How economic growth, renewable electricity and natural resources contribute to CO2 emissions? *Energy Policy*. Vol.113: 356–367.

Baltagi, B. H., Feng, Q., and Kao, C. (2012). A Lagrange Multiplier test for cross-sectional dependence in a fixed effects panel data model. *Journal of Econometrics*. Vol.170(1):164-177.

Beck, N., and Katz, J. N. (1995). What to do (and not to do) with time series cross section data? *American Political Science Review*. Vol.89:634–647.
Bekun, F. V., Alola, A. A., and Sarkodie, S. A. (2019). Toward a sustainable environment: Nexus between CO2 emissions, resource rent, renewable and nonrenewable energy in 16-EU countries. *Science of the Total Environment*. Vol.657: 1023–1029

Birdsall, N., and Wheeler, D. (1993). Trade policy and industrial pollution in Latin America: where are the pollution havens? *The Journal of Environment and Development*. Vol.2(1): 137–149.

Bond, S., and Eberhardt, M. (2013). Accounting for unobserved heterogeneity in panel time series models. *University of Oxford*

Breusch, T. S., and Pagan, A. R. (1980). The Lagrange multiplier test and its applications to model specification in econometrics. *The Review of Economic Studies*. Vol.47(1):239-253.

British Petroleum (2021). Statistical Review of World Energy.

Curran, D. (2017). The treadmill of production and the positional economy of consumption. *Canadian Review of Sociology*, Wiley periodicals. 29-47.

Danish, Baloch, M. A, Mahmood, N., and Zhang, J. W. (2019). Effect of natural resources, renewable energy and economic development on CO2 emissions in BRICS countries. *Science of the Total Environment*. Vol.678: 632–638.

Destek, M. A., and Okumus, İ. (2019). Does pollution haven hypothesis hold in newly industrialised countries? Evidence from ecological footprint. *Environmental Science Pollution Research*. Vol.26(23): 23689–23695.

Dogan, E., Ulucak, R., Kocak, E., and Isik, C. (2020). The use of ecological footprint in estimating the environmental Kuznets curve hypothesis for BRICST by considering cross-section dependence and heterogeneity. *Science of the Total Environment*. 138063.

Dreher, A., Gaston, N., and Martens, P. (2008). Measuring globalisation-gauging its consequences. New York: Springer.

Dumitrescu, E. I., and Hurlin, C., (2012). Testing for Granger non-causality in heterogeneous panels. *Economic Modelling*. 29, 1450–1460.

Dunlap, R. E., and Jorgenson, A. K. (2012). Environmental Problems. *The Wiley-Blackwell Encyclopaedia of Globalisation*.

Erdogan, S., Demircan Cakar, N., Ulucak, R., Danish, and Kassouri, Y. (2021). The role of natural resources abundance and dependence in achieving environmental sustainability: Evidence from resource-based economies. *Sustainable Development*. Vol.29: 143-154.

Gao, J., and Tian, M. (2016). Analysis of over-consumption of natural resources and the ecological trade deficit in China based on ecological footprints. *Ecological Indicators*. Vol.61: 899–904.

Global footprint network, (2022).
Gyamfi, B. A., Adedoyin, F. F., Bein, M. A., Bekun, F. V., and Agozie, D. Q. (2021). The anthropogenic consequences of energy consumption in E7 economies: juxtaposing roles of renewable, coal, nuclear, oil and gas energy: evidence from panel quantile method. *Journal of Cleaner Production*. Vol.295, 126373.

Gygli, S., Haelg, F., Potrafke, N., and Sturm, J. (2019). The KOF Globalisation Index-revisited. *The Review of International Organisation*. Vol.14: 543-574.

Haseeb, A., Xia, E., Baloch, M. A., and Abbas, K. (2018). Financial development, globalisation, and CO2 emission in the presence of EKC: Evidence from BRICS countries. *Environmental Science and Pollution Research*. Vol.25: 31283–31296.

Hassan, S. T., Xia, E., Khan, N. H., and Shah, S. M. A. (2019). Economic growth, natural resources, and ecological footprints: Evidence from Pakistan. *Environmental Science Pollution Research*. Vol. 26: 2929–2938.

Hausman, J. A. (1978). Specification tests in econometrics. *Econometrica*. Vol.46:1251–1271.

Hussain, H. I., Haseeb, M., Kamarudin, F., Dacko-Pikiewicz, Z., and Szczepa´nska-Woszczyna, K. (2021). The Role of Globalisation, Economic Growth and Natural Resources on the Ecological Footprint in Thailand: Evidence from Nonlinear Causal Estimations. *Processes*. Vol.9(1103): 1-14.

International Energy Agency. (2021a). Greenhouse gas emissions from energy. Available at: [www.iea.org/statistics](http://www.iea.org/statistics) Sourced on 30/01/2022.

International Energy Agency. (2021b) Methane Emissions from Oil and Gas. Available at: [www.iea.org](http://www.iea.org) Sourced on 20/02/2022.

IPCC, (2018). Global Warming of 1.5°C. An IPCC Special Report on the Impacts of Global Warming of 1.5°C above Pre-Industrial Levels and Related Global Greenhouse Gas Emission Pathways in the Context of Strengthening the Global Response to the Threat of Climate Change. Press.

Isiksal, A. Z. (2021). Testing the effect of sustainable energy and military expenses on environmental degradation: evidence from the states with the highest military expenses. *Environmental Science Pollution Research*. Vol.28: 20487–20498.

Kalaycı, C., and Hayalo glu, P. (2019). The impact of economic globalisation on CO2 emissions: The case of NAFTA countries. *International Journal of Energy Economics and Policy*. Vol.9(1): 356–360.

Kao, C. (1999). Spurious regression and residual-based tests for cointegration in panel data. *Journal of Econometrics*. Vol.90: 1-44.

Khan, I., Hou, F., and Le, H. P. (2021). The impact of natural resources, energy consumption, and population growth on environmental quality: fresh evidence from the United States of America. *Science of the Total Environment*. Vol.754, 142222.
Khan, M. K., Teng, J. Z., Khan, M. I., and Khan, M. O. (2019). Impact of globalisation, economic factors and energy consumption on CO₂ emissions in Pakistan. *Science of the Total Environment*. Vol.688: 424–436.

Le, H. P., and Ozturk, I. (2020). The impacts of globalisation, financial development, government expenditures, and institutional quality on CO₂ emissions in the presence of environmental Kuznets curve. *Environmental Science Pollution Research*. Vol.27: 22680–22697.

Levin, A., Lin, C. F. and Chu, C. S. J. (2002). Unit root tests in panel data: Asymptotic and finite-sample properties. *Journal of Econometrics*. Vol.108: 1-24.

Li, R., Jiang, H., Sotnyk, I., Kubatko, O., A., and YA, I. A. (2020). The CO₂ emissions drivers of post-communist economies in Eastern Europe and Central Asia. *Atmosphere*. Vol.11(9), 1019.

Liu, M., Ren, X., Cheng, C., and Wang, Z. (2020). The role of globalisation in CO₂ emissions: A semi-parametric panel data analysis for G7. *Science of the Total Environment*. Vol.718, 137379

Maddala, G. S., and Wu, S. (1999). A comparative study of unit root tests with panel data and a new simple test. *Oxford Bulletin of Economics and Statistics*. Vol.61(S1), 631-652.

Majeed, A., Wang, L., Zhang, X., Muniba, and Kirikkaleli, D. (2021). Modelling the dynamic links among natural resources, economic globalisation, disaggregated energy consumption, and environmental quality: Fresh evidence from GCC economies. *Resource Policy*. Vol.73(102204): 1-9.

Mehmood, U., and Tariq, S. (2020). Globalisation and CO2 emissions nexus: Evidence from the EKC hypothesis in South Asian countries. *Environmental Science Pollution Research*. Vol.27: 37044–37056.

Nathaniel, S. P., Nwulu, N., and Bekun, F. (2020d). Natural resource, globalisation, urbanisation, human capital, and environmental degradation in Latin American and Caribbean countries. *Environmental Science and Pollution Research*. Vol.28(5): 6207-6221.

Nathaniel, S., Anyanwu, O., and Shah, M. (2020a). Renewable energy, urbanisation, and ecological footprint in the Middle East and North Africa region. *Environmental Science Pollution Research*. Vol.27(13): 14601-14613.

Nathaniel, S., Barua, S., Hussain, H., and Adeleye, N. (2020c). The determinants and interrelationship of carbon emissions and economic growth in African economies: fresh insights from static and dynamic models. *Journal of Public Affairs*. Vol.21(1), e2141.

Nathaniel, S., Nwodo, O., Sharma, G., and Shah, M. (2020b). Renewable energy, urbanisation, and ecological footprint linkage in CIVETS. *Environmental Science Pollution Research*. Vol.27(16): 19616-19629.
Onifade, S. T., Gyamfi, B. A., Haouas, I., and Bekun, F. V. (2021a). Re-examining the roles of economic globalisation and Natural resources consequences on environmental degradation in E7 economies: Are human capital and urbanisation essential components? *Resources Policy*. Vol.74(102435): 1-9.

Onifade, S.T., Alola, A.A., Erdogan, S., and Acet, H. (2021b). Environmental aspect of energy transition and urbanisation in the OPEC member states. *Environmental Science Pollution Research*. Vol.28(14): 17158-17169.

Park, H. M. (2011). Practical guides to panel data modelling: a step-by step analysis using Stata. Public Management and Policy Analysis Program, Graduate School of International Relations, International University of Japan, 1-52.

Pedroni, P. (1999). Critical values for cointegration tests in heterogeneous panels with multiple regressors. *Oxford Bulletin of Economics and Statistics*. Vol.61: 653-670.

Pesaran, M. H. (2004). General diagnostic tests for cross-sectional dependence in panels, University of Cambridge, *Cambridge Working Papers in Economics*. Vol.435.

Pesaran, M. H. (2007). A simple panel unit root test in the presence of cross-section dependence. *Journal of Applied Econometrics*. Vol.22(2):265–312.

Pesaran, M. H., (2003). A simple panel unit root test in the presence of cross-section dependence. *Cambridge Working Papers in Economics*. 0356.

Reed, W. R., and Ye, H. (2011). Which panel data estimator should I use? *Applied Economics*. Vol.43:985–1000

Rehman, A. Radulescu, M., Ma, H., Dagar, V., Hussain, I., and Khan, M. K. (2021). The Impact of Globalisation, Energy Use, and Trade on Ecological Footprint in Pakistan: Does Environmental Sustainability Exist? *Energies*. Vol.14(5234): 1-17.

Salahuddin, M., Ali, M. I., Vink, N., and Gow, J. (2019). The effects of urbanisation and globalisation on CO2 emissions: evidence from the sub-Saharan Africa (SSA) countries. *Environmental Science Pollution Research*. Vol.26(3): 2699–2709.

Schnaiberg, A. (1970). Measuring modernism: Theoretical and empirical explorations. *American Journal of Sociology*: Vol.76(3), 399-425.

Shahbaz, M., Balsalobre, D., and Shahzad, S. J. H. (2019). The influencing factors of CO₂ emissions and the role of biomass energy consumption: statistical experience from G-7 countries. *Environmental Modelling and Assessment*. Vol.24(2):143–161.

Shen, Y., Su, Z.W., Malik, M.Y., Umar, M., Khan, Z., and Khan, M. (2021). Does green investment, financial development and natural resources rent limit carbon emissions? A provincial panel analysis of China. *Science of the Total Environment*. Vol.755, 142538.
Tawiah, V., Zakari, A., and Adedoyin, F. F. (2021). Determinants of green growth in developed and developing countries. Environmental Science Pollution Research. Vol.28(29): 39227-39242.

Terzi, H., and Pata, U. K. (2019). Is the pollution haven hypothesis (PHH) valid for Turkey? Panoeconomicus. Vol.67(1): 93–109.

Twerefou, D. K., Danso-Mensah, K., and Bokpin, G. A. (2017). The environmental effects of economic growth and globalisation in Sub-Saharan Africa: A panel general method of moments approach. Research in International Business and Finance. Vol.42: 939-949.

Uluçak, R., and Khan, S. U. (2020) Determinants of the ecological footprint: role of renewable energy, natural resources, and urbanisation. Sustainable Cities and Society. Vol.54, 101996.

United Nation Environment Programme. (2021). Methane emissions are driving climate change. Here’s how to reduce them. Available at: www.unep.org

United Nation Environment Programme. (2022). Our work in Africa. Available at: unep.org/regions/Africa. Sourced on 29/01/2022.

United Nations Conference on Trade and Development, World Investment Report. (2021).

Usman, M., Balsalobre-Lorente, D., Jahanger, A., and Ahmad, P. (2022). Pollution concern during globalisation mode in financially resource-rich countries: Do financial development, natural resources, and renewable energy consumption matter? Renewable Energy. Vol.183: 90-102.

Walter, I., and Ugelow, J. L. (1979). Environmental policies in developing countries. Ambio. Vol.102–109.

Wang, L., Vo, X. V., Shahbaz, M., and Ak, A. (2020). Globalisation and carbon emissions: Is there any role of agriculture value-added, financial development, and natural resource rent in the aftermath of COP21? Journal of Environmental Management. Vol.268, 110712.

Wang, Z., Rasool, Y., Zhang, B., Ahmed, Z., and Wang, B. (2020). Dynamic linkage among industrialisation, urbanisation, and CO2 emissions in APEC realms: evidence based on DSUR estimation. Structural Change and Economic Dynamics. Vol.52: 382-389.

Westerlund, J. (2005). New simple tests for panel cointegration. Econometric Reviews. Vol.24: 297-316.

Westerlund, J. (2007). Testing for error correction in panel data. Oxford Bulletin of Economics and Statistics. Vol.69: 709–748.

World Bank Development Indicator (2022).

World Bank Global Gas Flaring Reduction Partnership, (2020). Available at www.worldbank.org/ggfr accessed on 16/02/2022.
World Meteorological Organization. (2022). 2021 one of the seven warmest years on record, WMO consolidated data shows. Press Release No.:19012022. Available at: public.wmo.int/en/media/press-release/2021. Sourced on 30/01/2022.

Xiaoman, W., Majeed, A., Vasbieva, D. G., Yameogo, C. E. W., and Hussain, N. (2021). Natural resources abundance, economic globalisation, and carbon emissions: Advancing sustainable development agenda. *Sustainable Development*. Vol.29: 1037-1048.

Xue, J., Rasool, Z., Nazar, R., Khan, A.I., Bhatti, S.H., and Ali, S. (2021). Revisiting Natural Resources—Globalisation-Environmental Quality Nexus: Fresh Insights from South Asian Countries. *Sustainability*. Vol.13(4224): 1-19.

Yameogo, C. E. W., Omojolaibi, J. A., and Dauda, R. O. S. (2021). Economic globalisation, institutions and environmental quality in Sub-Saharan Africa. *Research in Globalisation*. Vol.3, 100035.

Yusuf, A. M., Abubakar, A. B., and Mamman, S. O. (2020). Relationship between greenhouse gas emission, energy consumption, and economic growth: Evidence from some selected oil-producing African countries. *Environmental Science and Pollution Research*. Vol.27(13): 15815–15823.

Zaidi, S. A. H., Zafar, M. W., Shahbaz, M., and Hou, F. (2019). Dynamic linkages between globalisation, financial development and carbon emissions: evidence from Asia Pacific economic cooperation countries. *Journal of Cleaner Production*. Vol.228: 533–543.