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ORIGINAL RESEARCH

The Role of Legal System and Socioeconomic Aspects in the Environmental Quality Drive of the Global South

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Abstract

The increasing environmental challenges associated with the Global South is potentially associated with the socioeconomic changes amid potential institutional deficiencies such as the weak or inefficient environmental regulation. Thus, this twenty-first century challenge has increasingly necessitated more climate action from the Global South as championed by the developed economies. On this note, examines the environmental aspects of law and order (LO) vis-à-vis legal system and socioeconomic (SE) indexes of the Political Risk Services for a panel of 80 selected Global South countries over the period 1984–2014. Additionally, by employing the economic growth vis-à-vis the Gross Domestic Product per capita (GDPC) as additional explanatory variable, the study employs the more recent experimental techniques of Mean Group Estimator (MG), the Augmented Mean Group Estimator (AMG) and the Common Correlated Effects Mean Group (CCEMG). Importantly, with the more efficient CCEMG, the study found that the strength of the legal system in the Global South (although not statistically significant) is a crucial factor to mitigated carbon emission in the panel countries. However, the study found that an improved socioeconomic condition and economic expansion is detrimental to the Global South's environmental quality. Furthermore, the Granger causality result implied that each of LO, SE and GDPC exhibits a feedback relationship with carbon emissions. Hence, the study suggests the need for a stronger implementation of environmental regulations through a revitalized legal system and some concerted socioeconomic policies that address poverty and unemployment among other factors.

Keywords Sustainable development · Legal system · Socioeconomic · Environmental quality · Global South

1 Introduction

Considering the risk associated with the changing climate and socioeconomic trends in the Global South (GS), the United Nations initiated the Climate Partnerships for the GS (known as the Southern Climate Partnership Incubator, SCPI) as a framework to drive the

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Extended author information available on the last page of the article cross-country sustainable development of the GS (United Nations Sustainable Development Goals, 2018). The GS (the countries of Africa, Latin America, developing Asia, the Middle East, and BRICS) are largely confronted with increasingly socioeconomic changes, weak institutions such as in the legal system among other factors. Before now studies have illustrated the deplorable climate change and environmental related challenges facing the GS economies such as the Middle East and North African (MENA) and African countries (Ekwueme et al., 2021; Ibrahim & Alola, 2020), the (Mexico, Indonesia, Nigeria, and Turkey) MINT countries (Agbede et al., 2021), and the Asia states (Hettige et al., 1996). Consequently, these challenges reportedly hampers the drive toward achieving the 2030 Sustainable Development Goals and other country-specific goals (Klaasen, 2020; Koirala & Pradhan, 2020; Zhang et al., 2019). Although a larger proportion of the world's wealth in terms of the Gross Domestic Product (GDP) is dominant in the developed countries (mostly in the Northern hemisphere) such as the European and the Northern Americas), several countries (mostly in the GS) are also facing environmental emergencies arising from the global economic activities. For instance, China (a GS country), the United States and Europe (EU-28) are the three largest producer and consumer of the global carbon (CO_2) emissions (Organization for Economic Cooperation & Development, 2019). The Organization for Economic Cooperation and Development (OECD) (2019) further indicated that production and consumption emissions have declined in the United States and Europe significantly since 2005, thus leaving China, India, Japan, the Russia Federation, and other countries (mostly the GS) in the battle to salvage their respective natural environment.

On their own part, many of the countries of the GS have continued to suffer significant environmental damages arising from increasing natural resources exploration and other economic activities. From the oil producing states such as Nigeria, Angola, Sudan and Libya among other African countries to the Middle East countries, the Asia countries, and the Latin American countries, there is existential threat to civil, cultural, and socioeconomic right (Olanipekun & Alola, 2020; Onifade et al., 2021). Health and environmental consequences have continued to account for the threat to life arising from the increasing depletion of the countries ecological and natural resources such as the access to water, food and shelter among others. Thus, the overwhelming evidence of the consequence of environmental damages associated with the GS countries further supports the claim that the climate change hazards disproportionately hampers the low-income countries and the segmented poor in the high-income countries (Franco et al., 2019; Levy & Patz, 2015). Moreover, other socioeconomic factors in the GS countries such as unemployment, poverty and others expectedly influences the environment (Anser et al., 2021). For instance, the socioeconomic changes across Africa is attributed to fast depleting rate of the continent's ecosystems (Bradshaw & Di Minin, 2019). Nevertheless, if the GS governments and the policymakers' drive toward improving the socioeconomic conditions will not improve environmental quality in a significant manner, could the institutional frameworks such as the legal system be a rescue mechanism? Should that be the case, a strong legal and environmental code or regulatory framework such as applicable in Sweden as hinted by Thews et al. (2017) could yield a desirable outcome.

Giving the aforementioned motivations, the current study is primarily aimed at answering two major questions regarding the environmental sustainability of the GS: (1) what is the environmental sustainability effect of socioeconomic conditions in the GS and (2) is there a feasible impact of law and order vis-à-vis the rule of law on the environmental sustainability of the GS? In undertaking this task, this study employs the socioeconomic and law and order indexes from the Political Risk Services (https://www.prsgroup.com/explo re-our-products/international-country-risk-guide/) for 80 selected countries of the GS (See Table 6 for the list of the GS countries). Additionally, to the indexes, the Gross Domestic Product per capita (GDPC) is employed as proxy for economic expansion and as an independent variable that accounts for the unobservable factors while CO_2 is as the environmental variable and a dependent variable. Furthermore, a handful of estimation procedures were employed alongside the second-generation panel techniques of Mean Group Estimator (MG), the Augmented Mean Group Estimator (AMG) and the Common Correlated Effects Mean Group (CCEMG) to provide a novel study. The novelty of the study is derived from the following facts. Firstly, this study according to authors' perspective is the first to provide a comprehensive and empirical study of the GS in the context of environmental sustainability. Secondly, the study uniquely use the law and order and socioeconomic indexes which has not been used at least empirically in the literature. Lastly, the current study has employed the more recent panel study techniques to provide a robust result that could be unachievable with the first generation panel techniques.

Having provided the background of the study, the other remaining part of this study encapsulate presented as follows: A synopsis of related theoretical and empirical literature are presented in the second Sect. 2. In section three and four, the data description with preliminary tests and the empirical methods are respectively presented. Section five presents the discussion of the findings while a concluding remark and policy dimensions are both illustrated in section six.

2 Literature: Theoretical Perspective

In recent time, the challenge of attaining sustainable development amid environmental quality are consistently implied in the existing studies (Marchini et al., 2020; Robaina & Madaleno, 2020; Zhang et al., 2020). For instance, Chapron et al (2017) and Yamineva and Liu (2019) explored the legal boundary of environmental laws in curbing environmental hazard. The studies strongly noted the role of the legal system in protecting environmental regulations and the implementation of climate policies across borders. Specifically, Chapron et al (2017) further posited that when the strength of the legal system is enhanced, it makes the governments and the private and corporate entities to account for environmental laws. For instance, the Swedish environmental law which is believed to have enhanced the environmental aspect of the country's Sustainable Development Goals was strongly adapted from the general principle of the country's civil law (Thews et al. 2017). By so doing, the issues of land and water management, protection of flora and fauna, and other environmental conservation practices are effectively covered by the legal system as the case of environmental code in Sweden. In the literature, the impact of the strength of the legal system on other environmental-related institutions has been examined (Amor-Esteban et al., 2018; Baró et al., 2019; Gani & Clemes, 2016; Granados & Spash, 2019).

Similarly, the changes in socioeconomic aspects has continue to exert intense pressure on the earth's ecological and environmental components (Bradshaw & Di Minin, 2019). In the case of Africa, a continent of the GS, Bradshaw and Di Minin (2019) found that human population density and economic development across the continent is a significant source of environmental degradation. This evidence is not different from the study of Riahi et al (2017) that implied that a shared socioeconomic pathways (SSP) such as sustainable development, non-renewable energy development, regional tension and conflicts, inequality, and middle-of-the-road development constitutes the determinants of environmental quality.

2.1 Empirical Literature: A Synopsis

By examining the case of the European countries, Galinato and Chouinard (2018) opined that environmental regulations or codes become more stringent courtesy of an improved institutional system (include the legal institution). While emphasizing the role environmental regulations, Burby and Paterson (1993) empirically tested the relevant regulations from two theoretical perspectives. Specifically, Burby and Paterson (1993) examined the different role of the environmentally centralized state agencies regulation and those of the corporate enforcement strategies. By using the case North Carolina of the United States, Burby and Paterson (1993) found that cooperative enforcement strategies as compared to the centralized state agencies regulation is more relevant in the improvement of regulations' effectiveness. In the same light, Feng et al (2020) found a significant spillover effect of both local environmental regulations and regulations from neighboring areas on air pollution among the urban areas in China. By employing a dataset for the period 2006–2018, Feng et al (2020) found a different characterization of spatial correlation of PM2.5 among the urban agglomeration in Beijing-Tianjin-Hebei, Yangtze River Delta, and Pearl River Delta. Notably, the study revealed that the socioeconomic factors such as the differences in industrial structure, population demographics, and economic progress e.t.c are largely responsible for the disparity in the impact of the environmental regulations in the examined geographic locations.

Furthermore, among other factors, Muhammad and Long (2021) examined the importance of the rule of law in carbon emissions mitigation approach across 65 countries within the belt and road initiative for the period of 2000 to 2016. Importantly, the study found that effectiveness of the rule of law across the examined countries is critical to the countries' carbon emission approach. Similarly, Muhammad and Long (2021) found that a politically stable country with an effective rule of law (i.e. interaction of rule of law and political stability) is paramount to the reduction of carbon emission among the 65 countries of the belt and road initiative. Additionally, by exerting the role of the rule of law on environmental quality, Castiglione et al (2012) employed an approach for the alternative specification of the environmental Kuznets curve (EKC) for the European countries. Thus, the study found that the rule of law ameliorate damages from environmental pollution by providing preservation to the ecosystem. Importantly, from the perspective of EKC, Castiglione et al (2012) posits that a strong rule of law lowers the turning point of the EKC, thus ensuring environmental quality at a lower level of per capita income. The socioeconomic dimension of environmental quality illustrated by Castiglione et al (2012) louds tat of Ye et al (2018) and other related studies (Alola & Saint Akadiri, 2021; Ozturk & Acaravci, 2010, 2013).

Considering the contribution of the strength of legal system and socioeconomic aspect on environmental sustainability as reflected in the aforementioned studies, the current study is conceptualized on environmental aspects of the categorical indexes of the rule of law and socioeconomic factors especially from the context of the GS.

3 Data and Methods

In studying the environmental effects arising from the strength of the rule of law (law and order) and socioeconomic aspects in the 80 selected GS, a balanced panel dataset over the period 1984–2014. We are constraint to the time period because of data availability for the

Table 1 Data Description, Common Statistics and Correlation Matrix

Data Description				
Variable	Code	Unit of measurement		Source
Carbon emissions	CE	Kilotons		WDI
Gross Domestic Product per Capital	GDPC	constant USD = 2010		WDI
Law and Order Index	LO	index (1 = low, 6 = high)		PRS
Socioeconomic Index	SE	index (1 = low, 6 = high)		PRS
Descriptive Statistics	LnEM	LnGDPC	LO	SE
Mean	9.457	7.357	3.136	4.952
Median	9.250	7.242	3	5
Maximum	16.147	11.351	7.1667	11
Minimum	4.988	4.549	0	0
Std. Deviation	2.036	1.355	1.243	1.957
Skewness	0.332	0.377	0.080	0.25
Kurtosis	2.750	2.500	2.382	3.140
Observations	2474	2474	2474	2474
Variable	LnEM	LnGDPC	LO	SE
Correlation Matrix				
LnEM	1			
LnGDPC	0.453*	1		
LO	0.186*	0.313*	1	
SE	0.333*	0.53*	0.366*	1

The LEM, LGDPC, LO, and SE are respectively the logarithm of carbon emissions, the logarithm of gross domestic product per capita, law and order, and socioeconomic factor. The WDI (https://data.worldbank.org/indicator) and PRS are the World Development Indicator and the Political Risk Services (https://www.prsgroup.com/explore-our-products/international-country-risk-guide/) respectively. Additionally, the * is the 1% statistical Significance level.

member countries, thus the countries investigated in the current case is also limited to 80 countries (see Table 6 for the list of the countries). In addition, the socioeconomic (SE) (account for unemployment, poverty and consumer confidence) and law and order (LO) (account for the strength and impartiality of the legal system and observance of the law) indexes from the Political Risk Services (https://www.prsgroup.com/explore-our-products/international-country-risk-guide/) were employed. However, the gross domestic product per capita (GDPC) was employed as additional variable to account for other unobserved factors. Furthermore, the data description, the common statistics and correlation matrix for the estimated series is presented in Table 1.

3.1 Model and Preliminary Tests

The uniqueness of the current study is the incorporation of indexes that have the components of unemployment, poverty and consumer confidence as socioeconomic (SE) and the strength, impartiality of the legal system and observance of the law as law and Order (LO) in the carbon function. In so doing, the study underpins the contribution or role of the SE and LO in the environmental sustainability of the Global South countries in a panel experimental framework. Thus, the current study follows the existing carbon function modelling that emanated from the work of Dietz and Rosa (1994) and subsequently by York et al. (2003) among other studies. Following these studies, many considerations have been given to other determinants of environmental sustainability such as democracy, corruption, immigration, and political institution (Alola et al., 2019; Alola, 2019a, 2019b; Ozturk et al., 2019; Usman et al., 2019), information and communication technology (ICT), energy technologies (Adedoyin et al., 2020a; Adedoyin et al., 2020b; Alola et al., 2020), energy consumption and economic expansion (Alola et al., 2019; Alola et al., 2019; Alola et al., 2019; Alola et al., 2019; Alola et al., 2019; Alola et al., 2019; Bekun et al., 2019; Bekun, et al., 2019; Bekun et al., 2019; Bekun et al., 2019; Adedoyin et al., 2020b; Usman et al., 2020), and several others.

Therefore, the current study is modelled in respect to Fig. 1 accordingly,

$$CEM_{it} = f\left(LO_{it}, SE_{it}, GDPC_{it}\right) \tag{1}$$

and the above model can further be transformed into a logarithmic form in order to reduce the potential effect arising from heteroskedasticity. Although the series SE and LO are preserved in their original form, the logarithmic expression for Eq. (1) is now presented as

$$\ln CEM_{it} = \theta_0 + \theta_1 \ln LO_{it} + \theta_2 \ln SE_{it} + \theta_3 \ln GDPC_{it} + \varepsilon_{it} \tag{2}$$

where $t = 1984, 1985, \ldots, 2014$ and i = country id = 1, country id = 2, …, country id = 80. The error term ε_{it} is known to be normally and identically independently distributed.

3.1.1 The Cross-Sectional Dependence (CD) Tests

In recent time, the increasing level of uncertainty arising from the economic, financial, social, and political has further deepened the inter-connectedness vis-à-vis interdependence across the nations of the world. Specifically, the evidence of interdependence is expected to be more significant among the countries with similar geographical, economic and other factor-related situations. In essence, there is an assumption of cross-sectional dependence which presumed that the countries that are associated with a panel are vulnerable to a potential macroeconomic shock arising from any of the component country. Giving the potential biasness associated with an econometric panel study that does not consider the potential effect of cross-sectional dependence (De Hoyos & Sarafidis, 2006), the current approach therefore follow the conventional approach of investigating the evidence of cross-sectional dependence in the panel. Hence, the evidence of cross-sectional dependence in the current panel is investigated by using the approaches of Breusch and Pagan (1980) and Pesaran (2004). In the case Lagrange Multiplier (LM) test of Breusch and Pagan (1980), the cross-sectional correlation of the residuals ($\widehat{\rho}_{ij}$) is obtained from the individual the ordinary least squares (OLS) estimates as illustrated in Eq. 3.

$$\text{LM} = \text{T} \sum_{i-1}^{N-1} \sum_{j=i+1}^{N} \widehat{\rho_{ij}^2} \tag{3}$$

Here, T and N are respectively the time (i.e. T = 1984, 1985, …, 2014) and the cross section dimension (i.e. i = 1 = country 1, 2, …, 80). But, since the LM CD estimation

Table 2 The Cross-Sectional Dependence Test

Variables	LM Test	CD_{LM} Test	LM Test	CD Test
LCEM	54,505*	644.862*	643.528*	189.240*
LGDPC	61,746.20*	735.924*	734.608*	241.747*
LO	32,006.58*	361.851*	360.518*	73.103*
SE	18,931.06*	197.376*	196.024*	38.054*
Slope Homogeneity Test	41.93*			

The LM, CD, LCEM, LGDPC, LO, and SE are respectively Lagrange Multiplier, Cross-sectional Dependence, logarithmic value of carbon emissions, logarithmic value of gross domestic product per capita, law and order index, and socioeconomic index respectively. Also, * indicates the 1% statistical significance level

technique illustrated above (Eq. 3) is known to be more appropriate especially when $T > N$, a more robust approach that is considered efficient even when both or either T or N is large has been presented by Pesaran (2004). Following this motivations, the study of Pesaran (2004) further presented CD estimation for two new cases: (1) when T and N are both large and (2) when N is larger than T and these are respectively illustrated in Eqs. (4) and (5)

$$CD_{LM} = \sqrt{\frac{2T}{N(N-1)}} \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} (T\hat{\rho}_{ij}^{\;2} - 1) \tag{4}$$

and

$$LM_{adj} = \sqrt{\frac{2T}{N(N-1)}} \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} T\hat{\rho}_{ij}^{\;2} \frac{(T-K)\hat{\rho}_{ij}^{\;2}\mu_{ij}}{\sqrt{\upsilon_{T_{ij}}^{2}}} \tag{5}$$

The CD test which is suitable for the case of N > T as indicated in Eq. (5) is from a significant adjustment to Eq. 4. Additionally, Pesaran et al. (2008) present a bias-adjusted LMadj CD test that is statistically and asymptotically standard normally distributed. In addition to the Pesaran et al. (2008) that is presented in Eq. (6), the null hypothesis for the aforementioned test is that there is no cross-sectional dependence. Indicatively, the result of CD tests employed in the current study as implied in Table 2 presented that there is cross-sectional interdependence in the panel of the estimated countries.

$$LM_{adj} = \sqrt{\frac{2T}{N(N-1)}} \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} T\hat{\rho}_{ij}^{2} \frac{(T-K)\hat{\rho}_{ij}^{2}\mu_{ij}}{\sqrt{\upsilon_{T_{ij}}^{2}}} \tag{6}$$

3.1.2 The Panel Unit Root and Cointegration Tests

Considering the evidence of interdependence of cross-sectional units as outlined above in addition to the evidence of slope homogeneity bySwamy (1970),[1] the second generation

[1] The estimation and step-to-step illustration of slope homogeneity is provided in the study in Swamy, P. A. V B.(1970). Efficient Inference in a Random Coefficient Regression Model. *Econometrica*, *38*(311–323).

Table 3 Panel Unit Roots and Panel Cointegration Estimations

	Level		First Difference	
	Constant	Trend	Constant	Trend
Harris-Tzavalis Panel Unit Roots				
*ln*CEM	1.050	0.970	0.014*	−0.011*
*ln*GDPC	1.003	0.759	−0.017*	−0.030*
LO	0.882**	0.845	0.124*	0.124*
SE	0.842*	0.749	0.078*	0.074*
Panel CIPS	Level		First Difference	
	Constant	Trend	Constant	Trend
lnCEM	−2.093***	−2.834*	−5.687*	−5.902*
lnGDPC	−1.952	−2.375	−5.658*	−5.836*
LO	−2.055***	−2.717*	−5.398*	−5.473*
SE	−1.931	−2.222	−5.192*	−5.216*

	Value	Z-value	P-value
Westerlund ECM Panel Cointegration			
Gt	−3.052	−3.573	0.000*
Ga	−11.697	4.263	1.000
Pt	−25.587	−3.777	0.000*
Pa	−12.454	−0.337	0.369

H0: no cointegration, 80 series and 3 covariates estimation: lcem lgdpc lo se, with 38 average selected lag length by AIC (Akaike information criteria) constant lags (1 2) and bootstrap of 100. The **CIPS** critical values for 10%, 5%, and 1% are respectively −2.05, 2.12, and −2.23 and for all the estimates the *, **, and *** also respectively indicate the 1%, 5%, and 10% statistical significance level. Additionally, Gt, Ga, Pt, and Pa are the group cointegration G) and Panel (P) cointegration.

panel unit root estimation techniques are employed. Giving this potential problem arising from the potential evidence of cross-sectional interdependence among the countries, the second generation CIPS unit root approach of Pesaran (2007) is employed against the first generation unit root approach of Harris and Tzavalis (1999). The Harris and Tzavalis (1999) is specifically suitable for situation when the ratio of the number of panel i.e. cross-section (*N*) to the time period (*T*) is greater than 0 and tends to infinity. Similarly, the Cross-sectionally Im, Pesaran and Shin (CIPS) unit root approach performs effectively irrespective of the dimensions of T and N i.e. either when N or T is relatively small or when $T > N$ and $N > T$ (Pesaran, 2007). While the result of the two test types are provided in Table 3, the step-by-step estimation approaches are not contained here because of space constraint. However, the result of the unit root generally indicates that all the series are integrated after first difference i.e. I (1).

Giving the statistical evidence that the series are all I (1), the series is further tested for potential evidence of long-run cointegration by using the Westerlund (2007) that was subsequently forwarded by Persyn and Westerlund (2008). Specifically, Westerlund (2007) introduced the normally distributed four-panel long-run relationship test statistics Ga, Gt, Pa, Pt. Unlike the other cointegration techniques, the test statistic are based on the error-correction mode (ECM) and structural dynamics. Importantly, this approach is also suitable for short time dimension (i.e. $T<N$) and relatively sensitive to lag selection (Persyn & Westerlund, 2008). Although, the stepwise approach is not included here because of space constraint, the preliminary step that include the error-correction test is illustrated given as

$$\Delta y_{it} = \partial_i^{'} d_t + \alpha_i (y_{i,t-1} - \beta_i^{'} x_{i,t-1}) + \sum_{j=1}^{p_i} \alpha_{ij} \Delta y_{i,t-j} + \sum_{j=qi}^{p_i} \gamma_{ij} \Delta x_{i,t-j} + \varepsilon_{it} \tag{7}$$

and when a bootstrap is applied in the estimation, the above Eq. (7) now becomes

$$\Delta y_{it} = \partial_i^{'} d_t + \alpha_i y_{i,t-1} + \lambda_i^{'} x_{i,t-1} + \sum_{j=1}^{p_i} \alpha_{ij} \Delta y_{i,t-j} + \sum_{j=qi}^{p_i} \gamma_{ij} \Delta x_{i,t-j} + \varepsilon_{it} \tag{8}$$

where $t=1984$, 1985, …, 2014 and $i=$country id$=1$, country id$=2$, …, country id$=80$. Also, the parameter α_i provides the speed of adjustment of the system when $\alpha_i y_{i,t-1} + \beta_i^{'} x_{i,t-1}$ is corrected to equilibrium in a time of inherent shock. Then y_{it} (carbon emissions, ln*CEM*) and x_{it} (each of ln*GDPC*, *LO*, and *SE*) exhibits long-run relationship when $\alpha_i<0$ which also implies that there is error correction. On the other hand, there is no error correction and no long-run relationship between y_{it} (carbon emissions, ln*CEM*) and x_{it} (each of ln*GDPC*, *LO*, and *SE*) when $\alpha_i=0$.Thus, for at least one cross section (i), H_0: $\alpha_i=0$ (null hypothesis) is tested against H_1^g: $\alpha_i<0$ (alternative hypothesis).

4 Empirical Methods: Cointegration Coefficient Estimates

Although the generalized methods of moments (GMM), the fixed effects (FE), and random effects (RE) are traditionally designed to address the concern associated with the heterogeneity issue, unfortunately the techniques are unable to fix the endogeneity that arises from heterogeneity. However, other cointegration techniques such as the Mean Group Estimator (MG), the Augmented Mean Group Estimator (AMG) and the Common Correlated Effects Mean Group (CCEMG) are further designed to provide a better cointegration and robustness estimations. For instance, Pesaran and Smith (1995) presented the Mean Group estimator that permits potential cross-sectional dissimilarity in the error variances, intercepts, slopes in the panel. The MG approach fits distinct model for each of the component groups such that an arithmetic average of the coefficients is computed. Although the MG estimator is consistent for a large time span (period), the estimator is unable to provide consistent estimate if there is a cross-section dependence. For this reason, the other two estimators: the AMG and the CCEMG are further employed in the current study. Although the AMG and CCEMG are considered to be more robust and similar on many grounds, they also demonstrates significant distinctions.

The CCEMG is employed given the estimator's efficiency in accounting for both cross-sectional dependence and heterogeneous slope in the case of the current study as illustrated in Table 2. Also, the estimator designedly robust for structural breaks and account for non-stationary unobserved common factors. Although the CCEMG was lately advanced by Kapetanios et al. (2011), the study of Pesaran (2006) originally presented the step-by-step estimation procedure. Giving the explanatory variable (x_t) (i.e. x = lnGDPC, LO, and SE) with β_t as the country-specific slope on the observable regressors, the CCE estimator models the dependable (y_t) (i.e. lnCEM) as

$$y_{it} = \alpha_{1i} + \beta_i x_{it} + \psi_i f_t + \varepsilon_{it} \tag{9}$$

where α_{1i} is the group fixed effect that indicates the time invariant heterogeneity groups across, the heterogeneous factor loadings ψ_i is from the unobserved common factors f_t and ε_{it} is the error term. By modifying the Eq. (9), a subsequent Eq. (10) presents an augmented cross-sectional average of the dependent ad independent variable that subsequently estimated each cross section with the Ordinary Least Square (OLS) approach.

$$y_t = \alpha_{1i} + \beta_i x_{it} + \delta_i \bar{y}_{it} + \theta_t \bar{x}_{it} + \psi_i f_t + \varepsilon_{it} \tag{10}$$

In case the OLS residuals is compromised due to the presence of heteroskedasticity and autocorrelation, the estimator by Newey and West (1987) is capable of resolving the problem while the challenge of heterogeneous slope coefficients can be addressed by the MG estimator. Thus, the mean of each coefficient across individual regression is estimated by applying the mean group estimator of the CCE such that

$$CCEMG = N^{-1} \sum_{i-1}^{N} \hat{\beta}_i \tag{11}$$

where the estimate of the explanatory coefficients in Eq. (10) is $\hat{\beta}_i$ (in Eq. (11)).

However, the AMG that was developed and presented in both studies of Eberhardt and Bond (2009) and Eberhardt and Teal (2010) is an improvement on the weakness of the CCEMG approach. Giving that both estimators are robust to parameter heterogeneity and cross-sectional dependence and among other advantages, the AMG estimator include the parameter of the common dynamic effect to estimate the unobserved common dynamic effect by using a two-step approach. In the first step, Eq. (9) is augmented with both the first difference (represented as Δ) and time dummies (represented as τ) such that

$$\Delta y_{it} = \alpha_{1i} + \beta_i \Delta x_{it} + \psi_i f_t + \sum_{t=2}^{T} \tau_t DUMMY_t + \varepsilon_{it} \tag{12}$$

The second step involves is the augmentation of Eq. (9) with a unit coefficient that is imposed on each member of the group (this is done by deducting the AMG estimator from the dependent variable). Hence, by using Eq. (12),

$$AMG = N^{-1} \sum_{i-1}^{N} \hat{\beta}_i \tag{13}$$

where the estimate of the explanatory coefficients in Eq. (12) is $\hat{\beta}_i$ (in Eq. (13)).

Additionally, a robustness perspective is provided in support of the result of the statistical evidence of long-run relationship between the variables of concern (lnCEM, lnGDPC, Lo, and SE) as indicated in Table 4. The second generation Granger non-causality approach of Dumitrescu and Hurlin (2012) is employed as a robustness test such that the implied result in Table 5 suggested additional evidence of relationship between carbon

Table 4 The MG, AMG and CCEMG Coefficient Estimates

Variable	MG			AMG			CCMG		
	Coef	P-value	C.I (95%)	Coef	P-value	C.I (95%)	Coef	P-value	C.I (95%)
*ln*GDP	0.124*	0.000	0.068|0.180	0.915*	0.0002	0.030|0.149	0.089**	0.019	0.014|0.163
LO	0.004	0.822	−0.028|0.356	0.057	0.724	−0.026|0.037	−0.008	0.703	−0.049|0.033
SE	0.020**	0.032	0.002|0.038	0.023**	0.010	0.005|0.040	0.014	0.207	−0.008|0.366
C	7.974*	0.000	7.380|8.560	8.178*	0.000	7.5798|0.777	−1.056	0.741	−7.317|5.204
t	0.032*	0.000	0.026|0.038	0.002	0.537	−0.004|0.008	−0.003	0.840	−0.028|0.022
G(t)	0.750** (60 trends)			0.550** (44 trends)			0.475** (38 trends)		
Wald chi 2(3)	25.50*			18.25*			11.35**		
RMSE (sigma, σ)	0.130			0.129			0.090		
Number of observations	2400			2400			2400		

We represent the 1% and 5% statistical significance level by * and ** respectively. The RMSE is the Root Mean Squared Error. Additionaly, Coef, C.I, P-value are respectively coefficient, confidence interval, and probability value. The GDP, LO, and SE are respectively the Gross Domestic Product, Law and Order, and Socioeconomic indexes. Additionally, MG, AMG and CCEMG are the Mean Group, Augmented Mean Group and Common Correlated Effects Mean Group

Table 5 Granger Causality by Dumitrescu and Hurlin (2012)

Causality	z-bar	Causality	z-bar
*l*cem → *ln*gdpc	19.801*	*ln*gdpc → *ln*cem	21.280*
*ln*cem → lo	21.280*	lo → *ln*cem	3.112**
*ln*cem → se	3.130*	se → *ln*cem	2.333**
*ln*lo → *ln*gdpc	5.557*	*ln*gdpc → *ln*lo	1.241
*ln*se → *ln*gdpc	4.900*	*ln*gdpc → *ln*se	0.367
se → lo	15.270*	lo → se	10.566*

The LEM, LGDPC, LO, and SE are respectively the logarithm of carbon emissions, the logarithm of gross domestic product per capita, law and order, and socioeconomic factor.. Additionally, the * and ** are the 1% and 5% statistical Significance level respectively

emissions, the gross domestic product capita, the socioeconomic and legal orderliness indicators in the global south.

5 Findings and Discussion

Giving the statistical result of the correlation matrix in Table 1, it strongly suggests that there is a significant evidence of correlation among the carbon emissions (CEM), gross domestic product per capita (GDPC), law and order (LO), and the socioeconomic (SE) situations in the panel countries. Because the study has considered 80 supposedly heterogeneously selected countries of the GS, the study found evidence of cross-sectional dependence when the CD test is performed. Specifically, all the four CD test approaches of Breusch and Pagan (1980) and Pesaran (2004) showed evidence of interdependence of cross section in addition to the slope homogeneity as indicated in Table 2. This implies that any potential shock in any of the GS countries is capable of exerting a spillover effect in the other countries. Additionally, while there is a general statistical evidence that the variables exhibits a trend characteristics over time (non-stationarity), a statistical significant evidence illustrates that the variables also shows similar characteristics especially in the long-run (cointegration) (see Table 3). Hence, these evidence triggered the examination of a long-run relationship among the variables through the estimator approaches of the Mean Group (MG), Augmented Mean Group (AMG) and Common Correlated Effects Mean Group (CCEMG). Importantly, a similar result is almost presented by all the aforementioned estimators (See Table 4). Uniquely, the CCEMG presents the lowest Root Mean Square Error (RMSE) of 0.090 against 0.130 and 0.129 for MG and AMG respectively. Thus, the result of the CCEMG is considered most suitable.

5.1 Impact of the Examined Factors

Regarding the impact of LO (effective legal system), the impact of LO on environmental degradation in the long-run is observable negative (see Table 4). Although there is no statistical significance of this impact, the evidence illustrates that when there is an improvement in the legal system (equivalent to high index of law and order), the quality of the environment of the panel of GS countries can be enhanced. This evidence is both desirable and expected because the legal institutions of the GS countries are expectedly weak relative to the legal system of the developed countries (Johnson, 2019). Indicatively, when there is a weak and ineffective legal system, then environmental crimes that are related to wildlife, natural resources, biodiversity and others are likely to be abated, thus increasing environmental damage (Gibbs & Boratto, 2017). While pointing out the role of legal strategies in environmental sustainability, Berger-Walliser et al. (2016) further identified the nexus of proactive law and environmental designs. Additionally,, Castiglione et al (2012), Chen et al (2018), Amor-Esteban et al (2018), Muhammad and Long (2021) are some of the studies that implies the role of the legal system or rule of law in environmental sustainability drive.

However, statistical evidence from the current study implies that the socioeconomic situation of the panel countries worsen the environmental degradation especially in the long-run. Although the result is statistically non-significant, the result is expected since the improvement in the socioeconomic status such as an upward change in the income level might lead to increased economic activities. When the socioeconomic situation of the panel of Global South countries that also happen to be the low and middle income countries change, more economic activities even at detriment of the environment will be undertaken. The likely reason for the increase in environmental degradation arising from the increase in the socioeconomic situation is not unconnected with the low level of awareness or education and poverty sentiments. Interestingly, Hălbac-Cotoară-Zamfir et al. (2019) equally found that socioeconomic aspects negatively affect the environment friendly techniques especially in Romania. However, many studies have also opined that socioeconomic aspects potentially hampers environmental performance, especially of the developing countries. (Bradshaw & Di Minin, 2019; Castiglione et al., 2012; Riahi et al., 2017; Ye et al., 2018).

Similarly, with an elasticity of 0.089, the economic expansion (GDPC) in the panel countries of the GS countries will cause a statistically significant damage to the environment. This observation is expected of the GS countries because economic boom or expansion will spur more non-renewable energy utilization and other non-environmental friendly activities. This assertion, especially for the case of the developing countries has been widely supported in extant studies (Alola & Alola, 2018; Asongu et al., 2020; Saint Akadiri et al., 2019, 2020).

Furthermore, the non-Granger causality approach of Dumitrescu and Hurlin (2012) as illustrated in Table 5 provides a robustness to the aforementioned results. Importantly, there is a significant evidence of Granger causality with a feedback from economic expansion to carbon emissions, from rule of law (LO) to carbon emissions and from socioeconomic (SE) aspects to carbon emissions. The implication is that the previous values of the factors (GDPC, LO, and SE) are significant at explaining the present value of carbon emissions and vice versa. Similarly, the Granger Causality/Block Exogeneity result implies that income, law and order, and socioeconomic factor Granger cause carbon emission (see Table 7). In addition to the statistical information, Figure 1 in the appendix presents the impulse response relationship between the examined variables, especially the responses of GDPC, LO, and SE to carbon emission in the first left graph of each row.

6 Conclusion, Policy Projection and Recommendation

Considering the increasing changes in the socioeconomic amidst institutional uncertainty or instability of the under developed and the developing countries, the current study further examined the determinants of environmental sustainability. Categorically, the case of the 80 selected GS countries that largely comprises of the under developed and developing countries is considered. Additionally, because institutional weakness is mostly associated with the GS countries, the current study examined the impact of socioeconomic and rule of law (legal system) of environmental sustainability in the panel of GS (low and middle income) countries over the period 1984–2014. While the study revealed that the improvement in the socioeconomic condition and economic expansion will cause more harm to the environment, effectual legal system (law and order) is seen as a mechanism that could be used to advance the country's environmental sustainability. Thus, this interesting result possess the capacity of delivering useful policy design for both environmental and government stakeholders of the GS countries.

6.1 Policy Recommendation

In the first place, the indicative negative impact of the rule of law on the environmental degradation in the current study implies that the implementation of environmental regulations and codes turn the tide toward the sustainability of environmental quality in the GS. Thus, the institutions especially the environmental and institution should further be strengthen to perform statutory responsibility of persuading and leading the private, corporate and government agencies in environmental directives. Also, the strength of the legal system and environmental justice is preserve when environmental crimes are not spared from measurable justice especially within the legal framework. Furthermore, more concerted effort through public and private partnerships should be geared at drastically improving both the quality of live and literacy level of the people. In so doing, the people are expectedly moved out of poverty and at the same time knowledgeable and abreast with environmental awareness guidelines. However, the current study could be improved on in the future by considering further groupings of the GS countries by considering the regional, geographical, and socioeconomic categories.

Appendix

See Tables 6, 7 and Fig. 1.

Table 6 List of 80 selected Global South countries

1	Angola	41	Malawi
2	Algeria	42	Malaysia
3	Bahamas	43	Mali
4	Bahrain	44	Mexico
5	Bangladesh	45	Mongolia
6	Bolivia	46	Morocco
7	Botswana	47	Namibia
8	Brazil	48	New Caledonia
9	Brunei	49	Nicaragua
10	Burkina Faso	50	Niger
11	Cameroon	51	Nigeria
12	Chile	52	Oman
13	China	53	Pakistan
14	Columbia	54	Panama
15	Congo	55	Paraguay
16	Congo DR	56	Peru
17	Costa Rica	57	Philippines
18	Cote d'Ivoire	58	Qatar
19	Cuba	59	Romania
20	Dominica Republic	60	Saudi Arabia
21	Ecuador	61	Senegal
22	Egypt	62	Sierra Leone
23	Ethiopia	63	South Africa
24	Gabon	64	Sri lanka
25	Gambia	65	Sudan
26	Ghana	66	Suriname
27	Guatemala	67	Syria Arab Republic
28	Guinea	68	Taiwan
29	Guinea Bissau	69	Tanzania
30	Guyana	70	Thailand
31	Haiti	71	Togo
32	Honduras	72	Trinidad & Tobago
33	India	73	Tunisia
34	Indonesia	74	UAE
35	Iran	75	Uganda
36	Jamaica	76	Uruguay
37	Jordan	77	Venezuela
38	Kenya	78	Vietnam
39	Kuwait	79	Zambia
40	Madagascar	80	Zimbabwe

Table 7 Granger causality evidence

VAR Granger Causality/Block Exogeneity Wald Tests			
Dependent variable: LCEM			
Excluded	Chi-sq	df	Prob
LGDPC	21.485*	2	0.000
LO	6.121**	2	0.047
SE	5.960***	2	0.051
All	39.775	6	0.000

The *, **, and *** represent the 1%, 5%, and 10% statistical significance level. The GDP, CEM, LO, and SE are respectively the Gross Domestic Product, carbon emission, Law and Order, and Socioeconomic indexes

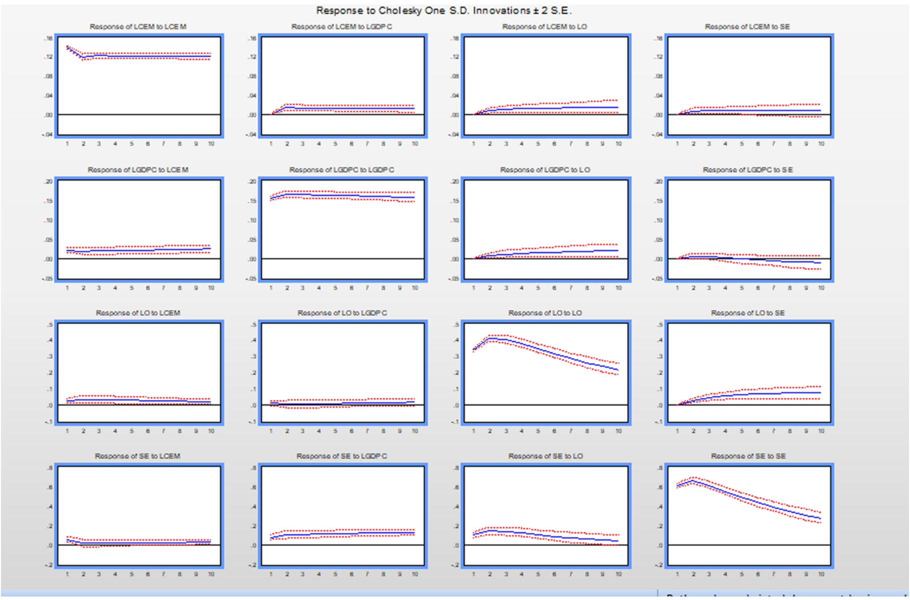

Fig. 1 Series illustration of the relationship between lCEM, lGDPC, LO and SE

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