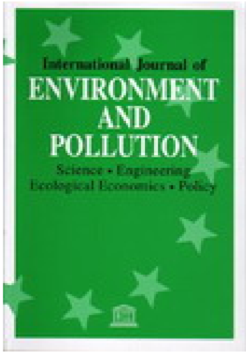

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Vulnerability of sub-Saharan Africa and Southeast Asian countries due to the carbon dioxide emissions: an assessment based on the STIRPAT model

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Vulnerability of sub-Saharan Africa and Southeast Asian countries due to the carbon dioxide emissions: an assessment based on the STIRPAT model

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Abstract: This paper explores factors affecting vulnerability to climate-related CO_2 emissions and options for adaptation to climate change in sub-Sahara African and Southeast Asian countries. The STIRPAT model used in the methodology proves that significant causes of carbon dioxide emissions are different in two regions: agriculture-forestry and fishing. The human development index has solid explanatory power on CO_2 emissions in Southeast Asian countries. The income per capita positively and significantly influences carbon emissions in sub-Saharan Africa but was statistically insignificant in the Southeast Asian countries. The population growth decreases CO_2 emissions in the sub-Saharan African countries while not statically significant in the Southeast Asian countries. Besides, the estimation results showed a lower level of CO_2 emissions in the sub-Saharan African countries relative to the Southeast Asian countries. These regions should not follow the same example to achieve a green economy because the effects of CO_2 emissions are not felt uniformly.

Keywords: carbon dioxide emissions; climate change; vulnerabilities; environmental degradation; disasters; environmental economics; human activities.

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1 Introduction

In addition to the climate variability that has always affected society, anthropogenic climate change poses an additional challenge for vulnerable populations and their lives, especially in the regions of Africa and Southeast Asia (Serdeczny et al., 2017; Yuen and Kong, 2009). Climate-related disasters result from rapidly onset physical stresses that can affect exposed and vulnerable human societies within days or even hours, whatever considered scenario (Seneviratne et al., 2012). Nevertheless, the associated risks, whether natural, health or socio-economic, intensify with climate change. The analysis of current or future vulnerability under different climate scenarios and the study of its causes at multiple scales is the starting point of adaptation planning processes. Climate issues are intrinsically bearing economic inequalities: a crisis induced by the greenhouse gas explosion that hits the poorest (Singer, 2018). It is a factor in leading households to poverty (Hallegatte et al., 2016). While, in absolute terms, the economic losses are immensely more significant in rich countries because of the value of the goods on display. The economic losses as a proportion of wealth are much more important in emerging countries (Diffenbaugh and Burke, 2019). One example would be climate-related disasters like floods and severe storms that can be life-threatening and highly destructive, robbing people of homes and their few assets (Herrera et al., 2018). The green economy could offer a new framework to overcome constraints sustainably.

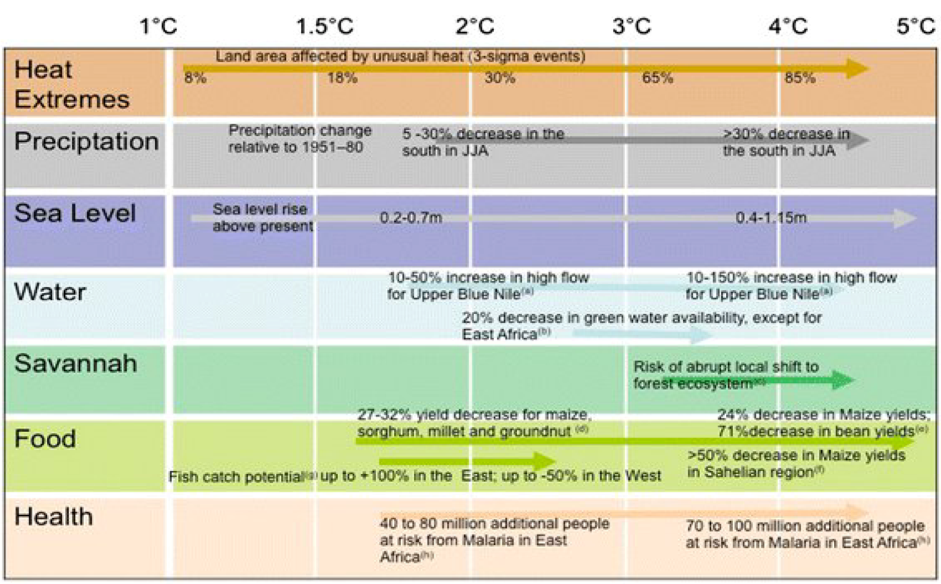
A recent World Bank study posted by Statista Research Department shows that in the 52 countries reviewed, most people live in countries where poor people are at risk of suffering from disasters such as droughts, floods, and heat waves, the population as a whole. It is even truer in many African and Southeast Asian countries (Kesar, 2011). This situation is compounded by the interplay between multiple constraints on the African continent, including heavy dependence on agriculture, widespread poverty, and low adaptive capacity (Žurovec and Vedeld, 2019). From the evidence of science and the scenarios projected by the world's climate experts and the scientific community, it is recognised that Africa as a region bears the tremendous burden and suffers the worst devastating effects caused by externality from the modern world (Figure 2). It represents a real challenge for Africa's socio-economic development prospects, including achieving the objectives of the World Summit on Sustainable Development, the Millennium Development Goals, achieving economic prosperity, and improving the social well-being of citizens (Leal et al., 2018). Unlike African countries, Southeast Asia is responsible for increasing temperatures, causing extreme weather conditions, ranging from severe droughts to heavy rainfall causing flooding (Akhtar, 2016). The Southeast Asia Climate Outlook 2021 reported that the Southeast Asian region is frequently cited as being one of the most threatened by and vulnerable regions to climate change (Seah et al., 2021). Figure 1 reveals various human and economic costs of climate disasters for Southeast Asian countries. Greenhouse gas emissions raise earth temperatures through deforestation and fossil fuel dependence which, in turn, amplifies the frequency of natural disasters (Thomas, 2017). The latter result from the complex and dynamic interaction between, on the one hand, the characteristics (temperature, precipitation, winds) of the climate system (and the impacts they induce on the natural physical environment) and, on the other hand, the characteristics of human societies.

Figure 1 Summary of climate risk indicators for Southeast Asian countries (see online version for colours)

Country	Climate Risk Index Rank (2021)	No. of Climate Disaster Events (2000-2019)	Average Yearly Total Deaths (2000-2019)	Average Yearly Total Affected (2000-2019)	Average Yearly Total Damages in Millions (adj. US dollars) (2000-2019)
Myanmar	2	40	7,753	352,542	278.663
Philippines	4	274	1,135	7,208,145	1,183.930
Thailand	9	82	136	4,063,950	2,845.912
Vietnam	13	143	240	1,938,384	1,096.849
Cambodia	14	23	59	887,260	91.687
Laos	52	20	22	289,084	38.419
Indonesia	72	195	283	363,941	480.810
Malaysia	116	49	10	170,936	94.821

Source: Accessed online at https://www.iseas.edu.sg/articles-commentaries/iseas-perspective/2022-15-examining-climate-conflict-links-in-southeast-asia-by-darren-cheong/

Figure 2 SSA climate changes and impacts across sectors at different levels of warming (see online version for colours)



Source: Serdeczny et al. (2017)

Nevertheless, Hubacek et al.'s (2017) study shows that the richest on the planet are responsible for twice as many GHG emissions as the poorest half of humanity. Mitigation policies attempt to limit human disturbances to the climate system (by reducing GHG emissions, for example) or even deliberately altering the latter to counteract anthropogenic climate change or compensate for some of its effects. The CO_2 model gives a more realistic picture of the absolute emissions of citizens according to their level of income in a country (Oxfam, 2015). These new estimates allow us to dispel some of the myths that have long turned at United Nations climate conferences about who is responsible for climate change. The increasing threat of global warming due to pollutants emissions has focused attention on human activities (Papalexiou et al., 2018). The propellers of environmental issues have been solar output, plate tectonics, volcanism, proliferation, abatement of life, meteorite impact, resource depletion, changes in earth's movement around the sun, and transformation in the tilt of the world on its axis (Gyles, 2019).

The analysis of Chontanawat (2018) on factors that affectCO_2emissions in ASEAN performed on IPAT/Kaya approach combined with the variance analysis technique indicated that population growth and increased income per capita have the most significant contribution to climate variability. In his report, SEA cooperation on climate change revealed that the region is highly vulnerable due to its population and economic activities condensed along coastlines. Besides, the region is heavily reliant on agriculture for livelihoods and highly dependent on natural resources and forestry, and extreme poverty remains high in remotes areas (Atif Nawaz et al., 2019).

Studies have explored numerous arguments using statistical and econometric methods with great care to guarantee a certain level of certainty of the results. Ameyaw and Yao (2018) examine the relationship between gross domestic product and CO_2 emissions in five West African countries based on a panel data model. The causality results revealed a unidirectional causality running from GDP to CO_2emissions. Furtherly, Al-mulali and Binti Che Sab (2012) investigated the impact of energy consumption and CO_2emission on GDP growth and financial development in 30 Sub-Saharan African Countries. The output has shown that energy consumption has played an essential role in increasing economic growth and financial development in the investigated economies and high pollution. Scholars have extended climate change beyond exploring the environmental Kuznets curve (EKC), which binds countries' environmental degradation and economic growth and households (Ajanaku and Collins, 2013; Shahbaz and Sinha, 2019; Tsiantikoudis et al., 2019). Aye and Edoja (2017) explored the effect of economic growth and CO_2 emission using the dynamic panel threshold framework of 31 developing countries has indicated that CO_2 emission varied across the countries based on their level of income and development. There was no support for the EKC hypothesis but a significant causal relationship between CO_2 emission, economic growth, energy consumption, and financial development. The tested EKC hypothesis by Demissew Beyene and Kotosz (2020) on 12 East African countries using the pooled mean group (PMG) approach from 1990 to 2013 attested that the economic activities in East African countries do not lead to CO_2 emissions. There was a bell-shaped relationship between per capita income and CO_2 emissions.

Similar to previous environmental Kuznets curve studies, Baker and Mitchell (2020) have insisted that lower-middle-income countries have the most emission-intensive consumption baskets. The relationship is negative overall to high-income countries. This statement is purely descriptive and cannot infer how emissions will evolve as incomes grow. Yeh and Liao (2017) evaluated the CO_2 emissions due to population economic growth in Taiwan from 1990 to 2014. The STIRPAT model on population and economic growth has proven statistically positive results for each model proposed.

Singer (2018) states that climate change and inequalities are doubly linked. Costa et al. (2011) has shown the relative time-dependent correlation of the Human Development Index and per capita CO_2 emissions from the combustion of fossil fuels. In general, both at the country level and individuals, the less rich are the most vulnerable to climate change, while the richest are responsible for most gas emissions (GHG).

The above discussions confirm the strong correlation between CO_2 emissions and multiple effects on human activities. This concept has been studied through a social vulnerability assessment (Nomura, 2014). The theoretical models consider environmental factors and social, political, economic, and institutional variables that can influence a population's social vulnerability to climate change due to CO_2 emissions. From this perspective, reducing exposure involves altering the context in which climate change occurs so that individuals and social groups can respond more appropriately to changing conditions. However, the climate is not the only determinant of the nature and extent of climate risks. The dilemma is not how to reduce carbon emissions but how to deal with the devastating effects of climate change caused by these emissions. Our study compares variant vulnerabilities due to CO_2 emissions in selected countries of two regions with variables derived from the econometric model. An effort has been made to find the empirical investigation on Carbon dioxide emission and six broad categories of environment variables.

2 Methodology

The theoretical model used in this study is inspired by the STIRPAT approach initially developed by Ehelich and Holdeen (1971). The STIRPAT approach is designed to initially clarify the determinants of CO_2 emissions by involving human behaviour in action. It is expressed by $I = PAT$. It means that the environmental issues (I) are the product of the size of the population (P), its level of wealth (A), expressed in income per capita, and a factor representing technology (T). This equation is equivalent for greenhouse gas (GHG) emissions to Kaya's equation, which decomposes the growth of GHG emissions into a sum of four growth rates: that of the population, GDP per capita, energy intensity, and carbon intensity.

This study incorporates some of the complexity of the linkages of ecological variables and other factors influencing environmental threats. To eliminate the low number of observations in time, we use panel data, and to technically observe the regional disparities, dummy variables are applied.

To comprehensively analyse the effect of the population on carbon dioxide emissions, the STIRPAT formula model, after taking into account corresponding variables, can be written in the following initial form:

$$\mathrm{CO}_{2t} = \alpha_0 \mathrm{GDPC}_t^{\alpha_1} \mathrm{AGRIF}_t^{\alpha_2} \mathrm{PO}_t^{\alpha_3} \mathrm{HDI}_t^{\alpha_4} \mu_t \tag{1}$$

where CO_2 denotes the environmental impact, GDPC is the overall outputs representing the level of wealth per capita, PO is the size of the population. Affluence and technological factors are captured respectively by agriculture, forestry, and fishery (AGRIF), human development index (HDI), μ_t is assumed to be normal distributed, α_0, α_1, α_2, α_3, α_4 are parameters. The index t represents the time. The function, to be estimated, can be written as follows:

$$\ln\left(\mathrm{CO}_2\right)_t = \alpha_0 + \alpha_1 \ln(\mathrm{GDPC})_t + \alpha_2 (\ln\mathrm{PO})_t + \alpha_3 \ln\mathrm{AGRIF}_t + \alpha_4 \ln(\mathrm{HDI})_t + \mu_t \tag{2}$$

Note: $\alpha_0 = \alpha_1 = \alpha_2 = \alpha_3 = \alpha_4 = 1$ (Stachurski, 2007; Wang et al., 2013).

3 Variable's measurement and data source

The study uses data on the spatial distribution of various climate-related hazards in SEA selected countries: Indonesia, Thailand, Vietnam, Malaysia, Brunei, Myanmar, and the Philippines and SSA: Ghana, South Africa, Nigeria, Tanzania, Angola, Kenya, Zambia, and Benin, according to the availability of data that cover the 2000–2016 period. The World Development Indicators, the United Nations, and Global Carbonate Atlas are used for the data source.

4 Empirical results

Empirical work frequently begins with an analysis of the stationarity of the series considered with the application of various unit root tests. The use of panel data thus makes it possible to work on samples of reduced size by increasing the number of available data (in the individual dimension), reducing the probability of facing structural ruptures, and overcoming the low power of small sample tests. We need to test for stationarity of the data before the regression for going beyond the spurious regression (Table 1). To ensure the efficiency and stability of data, we performed a panel unit root test, namely Levin-Lin-Chu (LLC) test (2002), Im-Pesaran-Shin (IPS) test (2003), Fisher-ADF test, and Fisher-PP test (Maddala and Wu, 1999).

Consider Levin-Lin-Chu (LLC) test, for example, which is an extension of the ADF test in the context of panel data, assumes that individual processes are cross-sectionally independent. The general equation takes the following form:

$$\Delta Y_{i,t} = \alpha_i + \theta_t + \delta_i t + \rho_i Y_{i,t-1} + \sum_{k=1}^{n} \varnothing_k \Delta Y_{i,t-k} + \mu_{i,t} \tag{3}$$

where α_i represents the coefficients, ρ_i denotes the fixed effect cross-section and $\mu_{i,t}$ the residual of the estimated panel. This equation is very general because it allows bidirectional fixed effects, one coming from α_i (representing a fixed effect specific to the unit) and the other from θ_t (temporal effects specific to the unit). It also includes distinct deterministic trends in each series across $\delta_i t$, and the lag structure, $\Delta Y_{i,t-k}$ to remove the autocorrelation in $\Delta Y_{i,t}$.

Table 1 Results of panel unit root tests for ASEAN

Unit root test	*Variables*	*LLC*	*IPS*	*Fish-ADF*	*Fish-PP*
Level	CO_2	–0.29735	–0.29902	6.17491	6.34324
	GDPC	–0.13702	0.16647	3.77493	5.12082
	AGRIF	–0.12605	–0.10927	5.11877	7.15496
	PO	–0.32403	–0.87543	9.91477**	16.4744***
	HDI	–0.22125	0.03182	4.40202	4.56859
First difference	CO_2	–7.43754**	–9.97848	66.2173**	80.7582
	GDPC	–13.1714**	–11.1110**	73.5145**	73.7271**
	AGRIF	–13.4675**	–11.4917**	75.8621**	76.1556**
	PO	–1.48875***	–7.800122**	50.120**	80.0449**
	HDI	–14.3168**	–11.7962**	77.6522**	77.6543**

**Indicates significant confidence at 5%.

***Indicates significant confidence at 1%.

The hypotheses tests are:

$$H_N : \rho_i \equiv \rho = 0 \quad \forall_i \tag{4}$$

$$H_A : \rho_i < 0 \quad \forall_i \tag{5}$$

The results for all panel unit root tests in two regions are shown in Tables 1 and 2. The unit root test for ASEAN countries: all given variables, except PO, which is tested stationary at the level in Fish PP, are static at their first difference, trust to rejecting the null hypothesis of non-stationarity at the level of 5%. In the SSA countries (Table 2), HDI is tested stationary at the LLC and Fish-ADF levels. Moreover, HDI is also fixed at its first difference in IPS and Fish-PP. All the rest of the variables are tested stationary significant at 5% level when relevant tests take the first difference into account. Thus, we will conclude after a co-integration test a further relationship between CO_2 and the other variables.

The implementation of the various co-integration tests led to the results summarised in Table 3. The above-conducted study has proved stationary in the same order for all variables. Recent works have been based on a generalisation of Engle-Granger single equation methods following the pioneering work of Pedroni (1999, 2019). In the most general case, according to different test strengths of each statistic, it is described by the inner scale and the group scale, and this may take the form:

$$Y_{i,t} = \alpha_i + \sigma_i t + \beta_{1i} X_{1i,t} + \beta_{2i} X_{2i,t} + \cdots + \beta_{Mi} X_{Mi,t} + \mu_{i,t} \tag{6}$$

Note: $m = 1, 2, ...,$ Mare the explanatory variables in the potentially cointegrating regression $t = 1, 2, \ldots, T$ and $i = 1, 2, \ldots, N$.

Table 2 Panel unit root test for SSA

Unit root	*Variables*	*LLC*	*IPS*	*Fish-ADF*	*Fish-PP*
Level	CO_2	–0.24819	0.9113	11.3376	11.8127
	GDPC	–1.83950**	0.45912	12.3556	9.28227
	AGRIF	0.61918	2.12672	9.54354	8.80124
	PO	–11.4057**	–7.42184**	84.8287**	15.2400
	HDI	–3.95528**	–0.12612	19.6567***	23.7731***
First difference	CO_2	–2.36911**	–3.36257**	38.9262**	82.6010**
	GDPC	–1.79984**	–2.30870**	35.2365**	51.0157**
	AGRIF	–1.98307**	–2.56356**	35.2365**	52.5123**
	PO	–5.46453**	–4.11725**	47.2688**	14.6425
	HDI	–0.58669	–1.47240***	22.4974	59.6950**

**Indicates significant confidence at 5%.

***Indicates significant confidence at 1%.

Table 3 Co-integration test results

Statistic	*SSA*	*ASEAN*
Panel *V*-statistic	–1.808982	–2.320778
Panel rho-statistic	0.079725	1.657602
Panel PP-statistic	–4.698104***	–5.422439***
Group rho-statistic	1.730707	3.197142
Group PP-statistic	–3.313720***	–2.413265***
Group ADF-statistic	–4.186132***	–2.579850**
Panel ADF-statistic	–4.627545***	–3.928824***

**Indicates significant confidence at 5%.

***Indicates significant confidence at 1%.

The autoregressive test for the estimated panel residuals is then subjected to a separate ADF-type test for each group of variables to determine whether they are *I*(0). The test equation is:

$$\Delta\hat{\mu}_{i,t} = \rho_i \hat{\mu}_{i,t-1} + \sum_{j=1}^{p} \varnothing_{i,j} \Delta\hat{\mu}_{i,t-j} + \Upsilon_{i,t} \tag{7}$$

Note: $\Upsilon_{i,t}$ represents the random error term and ρ_i an autoregressive term of the estimated residuals. The null hypothesis is that the residuals from all of the test regressions are unit root processes $(H_N : \rho_i = 0)$, which indicates the absence of co-integration. For the dimension statistics, two possible alternative hypotheses have been proposed by Pedroni:

The autoregressive dynamics are the same stationary process ($H_A : \rho_i = \rho < 0 \forall i$).

The dynamics from each test equation follow a different stationary process ($H_A : \rho_i < 0 \forall i$).

Based on standardised versions of the usual *t*-ratio from equation (7), the Pedroni co-integration result tests presented in Table 3 give out the acceptance of the null hypothesis that the panel *v*-statistic, panel rho-statistic, and group rho-statistic present a co-integration relationship for all variables. The ADF is statistically significant at a 5% level, and its test performs better than others (da Silva Lopes, 2006). We then conclude a co-integration among the variables during the given period.

The diagnostic tests indicate that the specifications adopted are generally satisfactory. The Jarque-Bera tests do not make it possible to reject the hypothesis of normality of the errors. The robust Hausman tests were employed to achieve the fixed-effect model (FE). The modified Wald and Wooldridge test has been used to examine the autocorrelation. The came out results showed a heteroscedasticity and autocorrelation problem in the model.

Further, we find no cross-sectional dependence in the model using a CD test. The Robust standard error estimation and Panel-corrected Standard Errors were performed to solve these problems. Moreover, the VIF values in the multicollinearity test are all less than 10. There is no multicollinearity among our explanatory variables.

The outcome of estimation (Table 4) of ASEAN selected countries shows that agriculture, forestry, and fishing, value-added and human development index have a significant statistic at 5%level and increase CO_2emissions respectively with 1.85 and 208649.0. Worth noting that the effect of per-capita domestic product and population growth is not statistically significant at any level. In SSA selected countries, the per capita gross domestic product significantly affects CO_2 emissions with 2.241854. Agriculture, forestry, and fishing, population growth on CO_2 emissions affect statistically significant but negative output in the region. In contrast, the human development index is not statistically significant to the emission of CO_2.

Table 4 Presentation of the estimation of long-term coefficients

Variables	*ASEAN*	*SSA*
C	–45539.30	2.241854**
	(0.26)	(2.68)
GDPC	–0.0294076	0.000204**
	(–0.05)	(–3.59)
AGRIF	1.85e-06**	–4.52e-12**
	(8.31)	(–3.59)
PO	–3191.144	–0.371977**
	(–1.35)	(1.26)
HDI	208649.0**	–0.101992***
	(0.79)	(–0.32)
R-squared	0.97643	0.995438
Cross-sectional dependence test, CD Stat	–1.1950	–1.6624
Multicollinearity (VIF)	2.33	1.43
Heteroscedasticity	$\chi^2(8) = 7500414$	$\chi^2(8) = 4747.17$
Hausman test	31.896082**	273.036964**
Observations	136	136

**Indicates significant confidence at 5%.

***Indicates significant confidence at 1%.

One of the world's main challenges is to feed a growing world population while reducing the ecological footprint and preserving natural resources for future generations. There is still a lot to do to improve the environmental performance of the agricultural and fisheries sector that limits the adverse effects on the environment and reinforces the positive outcomes to finally ensure the food security of a growing world population while improving environmental performance. However, global food needs are increasing, and agriculture is expanding and occupying more and more space, resulting in significant land-use change. The conversion of those spaces massively destocks the carbon contained in soils and vegetation. The causes of CO_2 emissions due to agriculture, forestry, and fishing in ASEAN countries can be justified by indirect energy consumption: agricultural systems need inputs to function (fertilisers, plant health products, animal feed, equipment, buildings). These inputs also require energy to be produced and are responsible for GHG emissions.

The consistent results of the SSA-selected countries clearly show that CO_2 emissions are closely linked to income growth during 2000–2016. The CO_2 emissions do not correlate with other critical measures of human development, such as life expectancy and education. According to the 2019 Human Development Report (Rdh), inequalities and climate crisis are intimately linked, whether emissions, effects, policies, or resilience. Countries with high human development tend to emit more carbon per person and have a larger ecological footprint overall.

The coefficient of the constant (–142482.5) represents the SSA region (Table 5). It has been considered as a primary region by a dummy variable. Therefore, CO_2 is lower in SSA countries relative to ASEAN countries by 105136.7. Governments should not follow the same example to achieve future sustainable living standards because vulnerabilities seem different at all levels.

Table 5 Least square dummy variable on region (LSDV)

CO_2	*Coefficients*	*P-value (5%)*
AGRIF	2.08E-06	0.000
GDPC	–3.243654	0.000
PO	1809.494	0.666
HDI	230669.3	0.000
ASEAN	105136.7	0.000
SSA	–142482.5	0.000
R-squared = 0.6786		
Root MSE = 66337		
F (5, 266) = 76.60		

5 Conclusion

This study assesses the vulnerability due to the CO_2 emissions through an empirical analysis of the STIRPAT model in selected countries of SSA and SEA. The outcome from the model showed a different influence-factor on carbon dioxide emissions in these two regions. The agriculture, forestry, fishing, and human development indexes have significant explanatory power on CO_2 emissions in the SEA region. In these countries, a large portion of the population derives most of its income from sectors sensitive to climatic conditions, such as agriculture. The per capita domestic product significantly influences carbon dioxide emissions in the SSA selected countries, but not significantly in the chosen SEA countries. The population growth decreases CO_2emissions in the SSA when statically insignificant in the SEA region. Besides, developing countries tend to have lower per capita incomes, weaker institutions, and less access to technology, all of which can contribute to greater vulnerability to disasters.

These findings give insight into future policies for mellowing climatic hazards, causing unequal vulnerabilities for the population living in these regions. Uncontrolled environmental degradation, from drought in sub-Saharan Africa to rising sea levels in low-lying countries and countries in Southeast Asia, could have different consequences. The poorest countries of sub-Saharan Africa, already under the weight of multiple constraints, will pay the heaviest price for the impacts of climate change while paradoxically being the least responsible for its occurrence. They act as a brake on effective action because high levels of inequalities tend to make collective action more difficult. At the same time, it is essential to limit climate change in all countries and within each of them.

As climate change worsens existing social and economic divides, there are nevertheless policies to tackle social/economic vulnerabilities and the climate crisis simultaneously, which would move countries towards unhindered human development exclusive and durable. To help countries improve the viability of their activities, a set of recommendations could be drawn up concerning the means to be implemented to design cost-effective environmental measures, face the challenges of climate change, preserve biodiversity and manage ecosystem services linked to agriculture. The inevitable redistributive effects of carbon pricing can be corrected by providing financial support to the poorest populations hardest hit by natural disasters. In this sense, the interests of justice would be better served if the developed countries provided new and additional resources to African countries for the victim situation it is forced to endure. Dedicated funds should help countries reduce their vulnerability to the impacts of climate change through measures that strengthen their adaptation capacities. It is also essential to consider a broader range of social actions that simultaneously address inequalities and the climate while facilitating income-generating activities in the most vulnerable countries.

References

Ajanaku, B.A. and Collins, A.R. (2021) 'Economic growth and deforestation in African countries: Is the environmental Kuznets curve hypothesis applicable?', *Forest Policy and Economics*, Vol. 129, April 2020, p.102488, https://doi.org/10.1016/j.forpol.2021.102488

Akhtar, R. (2016) 'Climate change and geoecology of south and Southeast Asia: an introduction', *Advances in Asian Human-Environmental Research*, 9783319236834, pp.1–10, https://doi.org/10.1007/978-3-319-23684-1_1

Al-mulali, U. and Binti Che Sab, C.N. (2012) 'The impact of energy consumption and CO_2 emission on the economic growth and financial development in the Sub Saharan African countries', *Energy*, Vol. 39, No. 1, pp.180–186, https://doi.org/10.1016/j.energy.2012.01.032

Ameyaw, B. and Yao, L. (2018) 'Analyzing the Impact of GDP on CO_2 emissions and forecasting Africa's total CO_2 emissions with non-assumption driven bidirectional long short-term memory', *Sustainability*, Vol. 10, No. 9, p.3110, https://doi.org/10.3390/su10093110

Atif Nawaz, M., Azam, M.A. and Bhatti, M.A. (2019) 'Natural resources depletion and economic growth: evidence from ASEAN countries', *Pakistan Journal of Economic Studies*, Vol. 2, No. 2, pp.58–77, https://www.researchgate.net/publication/344332748

Aye, G.C. and Edoja, P.E. (2017) 'Effect of economic growth on CO_2 emission in developing countries: evidence from a dynamic panel threshold model', *Cogent Economics & Finance*, Vol. 5, No. 1, p.1379239, DOI:10.1080/23322039.2017.1379239.

Baker, A. and Mitchell, I. (2020) *Projecting Global Emissions for Lower-Income Countries*, pp.1–12 (Accessed online) https://www.cgdev.org/publication/projecting-global-emissions-lower-incomecoutries#:~:text=Even%20assuming%20the%20lowest%20income,percent%20of%20global%20carbon%20emissions

Chontanawat, J. (2018) 'Decomposition analysis of CO_2 emission in ASEAN: an extended IPAT model', *Energy Procedia*, Vol. 153, pp.186–190, https://doi.org/10.1016/j.egypro.2018.10.057

Costa, L., Rybski, D. and Kropp, J.P. (2011) 'A human development framework for CO_2 reductions', *PLoS ONE*, Vol. 6, No. 12, p.e29262, doi:10.1371/journal.pone.0029262

da Silva Lopes, A.C.B. (2006) 'Deterministic seasonality in Dickey-Fuller tests: Should we care?', *Empirical Economics*, Vol. 31, No. 1, pp.165–182, https://doi.org/10.1007/s00181-005-0029-2

Demissew Beyene, S. and Kotosz, B. (2020) 'Testing the environmental Kuznets curve hypothesis: an empirical study for East African countries', *International Journal of Environmental Studies*, Vol. 77, No. 4, pp.636–654, https://doi.org/10.1080/00207233.2019.1695445

Diffenbaugh, N.S. and Burke, M. (2019) 'Global warming has increased global economic inequality', *Proceedings of the National Academy of Sciences of the United States of America*, Vol. 116, No. 20, pp.9808–9813, https://doi.org/10.1073/pnas.1816020116

Ehelich, P.R. and Holdeen, J.P. (1971) 'Impact of population growth', *Obstetrical and Gynecological Survey*, Vol. 26, No. 11, p.769, https://doi.org/10.1097/00006254-197111000-00014

Gyles, C. (2019) 'Climate crisis', *Canadian Veterinary Journal*, Vol. 60, No. 12, pp.1257–1258.

Hallegatte, S., Fay, M. and Barbier, E.B. (2018) 'Poverty and climate change: introduction', *Environment and Development Economics*, Vol. 23, No. 3, pp.217–233, https://doi.org/10.1017/S1355770X18000141

Herrera, C., Ruben, R. and Dijkstra, G. (2018) 'Climate variability and vulnerability to poverty in Nicaragua', *Journal of Environmental Economics and Policy*, Vol. 7, No. 3, pp.324–344, DOI: 10.1080/21606544.2018.1433070.

Hubacek, K., Baiocchi, G., Feng, K., Muñoz Castillo, R., Sun, L. and Xue, J. (2017) 'Global carbon inequality', *Energy, Ecology and Environment*, Vol. 2, No 6, pp.361–369, https://doi.org/10.1007/s40974-017-0072-9

Kesar, A.S. (2011) *Shock Waves: Managing the Impacts of Climate Change on Poverty*, Vol. 59, No. 1, http://www.journals.cambridge.org/abstract_S0022112081001535

Leal, W., Balogun, A., Yayeh, D., Bethurem, E.M., Murambadoro, M., Mambo, J., Taddese, H., Worku, G., Nagy, G.J., Fudjumdjum, H. and Mugabe, P. (2018) 'Strengthening climate change adaptation capacity in Africa – case studies from six major African cities and policy implications', *Environmental Science and Policy*, Vol. 86, December, pp.29–37, https://doi.org/10.1016/j.envsci.2018.05.004

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, Suppl., pp.631–652, https://doi.org/10.1111/1468-0084.0610s1631

Nomura, J. (2014) Annihilation of selmer groups for monomial CM-extensions', *Journal of Number Theory*, Vol. 144, pp.353–378, https://doi.org/10.1016/j.jnt.2014.05.008

Oxfam (2015) 'Extreme carbon inequality', *Oxfam Media Briefing*, December, pp.1–14, https://www.oxfam.org/sites/www.oxfam.org/files/file_attachments/mb-extreme-carbon-inequality-021215-en.pdf

Papalexiou, S.M., AghaKouchak, A., Trenberth, K.E. and Foufoula-Georgiou, E. (2018) 'Global, regional, and megacity trends in the highest temperature of the year: diagnostics and evidence for accelerating trends', *Earth's Future*, Vol. 6, No. 1, pp.71–79, https://doi.org/10.1002/2017EF000709

Pedroni, P. (1999) 'Critical values for cointegration tests in heterogeneous panels with multiple regressors', *Oxford Bulletin of Economics and Statistics*, Vol. 61, Suppl., pp.653–670, https://doi.org/10.1111/1468-0084.61.s1.14

Pedroni, P. (2019) 'Panel cointegration techniques and open challenges', *Panel Data Econometrics: Theory*, Vol. 1, pp.251–287, https://doi.org/10.1016/B978-0-12-814367-4.00010-1

Seah, S. *et al.* (2021) *Southeast Asia Climate Outlook Survey Report*, ISEAS – Yusof Ishak Institute, Singapore.

Seneviratne, S.I., Nicholls, N., Easterling, D., Goodess, C.M., Kanae, S., Kossin, J., Luo, Y., Marengo, J., McInnes, K., Rahimi, M., Reichstein, M., Sorteberg, A., Vera, C. and Zhang, X. (2012) 'Changes in climate extremes and their impacts on the natural physical environment', in Field, C.B., Barros, V., Stocker, T.F., Qin, D., Dokken, D.J., Ebi, K.L., Mastrandrea, M.D., Mach, K.J., Plattner, G-K., Allen, S.K., Tignor, M. and Midgley, P.M. (Eds.): *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation*, A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change (IPCC), Cambridge University Press, Cambridge, UK, and New York, NY, USA, pp.109–230.

Serdeczny, O., Adams, S., Baarsch, F., Coumou, D., Robinson, A., Hare, W., Schaeffer, M., Perrette, M. and Reinhardt, J. (2017) 'Climate change impacts in Sub-Saharan Africa: from physical changes to their social repercussions', *Regional Environmental Change*, Vol. 17, No. 6, pp.1585–1600, https://doi.org/10.1007/s10113-015-0910-2

Shahbaz, M. and Sinha, A. (2019) *Munich Personal RePEc Archive Environmental Kuznets Curve for CO2 Emission□: A Literature Survey*, Accessed online at https://mpra.ub.uni-muenchen.de/86281/

Singer, M. (2018) 'Climate change and social inequality: The health and social costs of global warming', *Climate Change and Social Inequality: The Health and Social Costs of Global Warming*, Vol. 152, pp.1–247, https://doi.org/10.4324/9781315103358

Stachurski, J. (2007) 'Log-linearization of stochastic economic models', *Journal of Difference Equations and Applications*, Vol. 13, Nos. 2–3, pp.217–222, https://doi.org/10.1080/10236190601069002

Thomas, V. (2017) *Climate Change and Natural Disasters: Transforming Economies and Policies for a Sustainable Future*, Book Published Version ISBN 978-1-138-56735-1, Routledge, London, https://doi.org/10.4324/9781315081045

Tsiantikoudis, S., Zafeiriou, E., Kyriakopoulos, G. and Arabatzis, G. (2019) 'Revising the environmental Kuznets curve for deforestation: an empirical study for Bulgaria', *Sustainability (Switzerland)*, Vol. 11, No. 16, pp.1–16, https://doi.org/10.3390/su11164364

Wang, P., Wu, W., Zhu, B. and Wei, Y. (2013) 'Examining the impact factors of energy-related CO2 emissions using the STIRPAT model in Guangdong Province, China', *Applied Energy*, Vol. 106, No. 2013, pp.65–71, https://doi.org/10.1016/j.apenergy.2013.01.036

Yeh, J.C. and Liao, C.H. (2017) 'Impact of population and economic growth on carbon emissions in Taiwan using an analytic tool STIRPAT', *Sustainable Environment Research*, Vol. 27, No. 1, pp.41–48, https://doi.org/10.1016/j.serj.2016.10.001

Yuen, B. and Kong, L. (2009) 'Climate change and urban planning in South East Asia', *Sapiens*, Vol. 2, No. 3, Accessed online at Online at https://mpra.ub.uni-muenchen.de/86281/

Žurovec, O. and Vedeld, P.O. (2019) 'Rural livelihoods and climate change adaptation in laggard transitional economies: a case from Bosnia and Herzegovina', *Sustainability*, Vol. 11, No. 21, p.6079, https://doi.org/10.3390/su11216079