Financial Development, Human Capital Development and Climate Change in East and Southern Africa

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Abstract

Africa is currently experiencing both financial and human development challenges. While several continents have advocated for financial development in order to acquire environmentally friendly machinery that produces less emissions and ensures long-term sustainability, Africa is still lagging behind the rest of the world. Similarly, Africa's human development has remained stagnant, posing a serious threat to climate change if not addressed. Building on the underpinnings of the Environmental Kuznets Curve (EKC) hypothesis on the nexus between economic growth and environmental pollution, this study contributes to empirical research seeking to promote environmental sustainability as follows. First, it investigates the link between financial development, human capital development and climate change in East and Southern Africa. Second, six advanced panel techniquesare used, and they include: (1) cross-sectional dependency (CD) tests; (2) combined panel unit root tests; (3) combined panel cointegration tests; (4) panel VAR/VEC Granger causality tests and (5) combined variance decomposition analysis based on Cholesky and Generalised weights. Our finding shows that financial and human capital developments are important in reducing CO_2 emissions and promoting environmental sustainability in East and Southern Africa.

Keywords: Financial Development; Human Capital; East and Southern Africa; Climate Change

JEL Classification: G21; I21; I25; O55; Q54

Introduction

This study investigates whether financial and human capital developments matter for climate change. The study examines whether financial development and human capital area nightmare in the East and Southern African regions.The extant literature is unsettled on nexuses between globalisation, financial development and other macroeconomic variables in environmental sustainability (Adebayo, 2020; Kirikkaleli & Adebayo, 2020; Odugbesan & Adebayo, 2020; Le & Ozturk, 2020; Kirikkaleli et al., 2021; Adebayo & Odugbesan, 2021; Baloch et al., 2021). The link between financial and human developments is apparent in the famous Environmental Kuznets Curve (EKC). While the hypothesis has provided an empirical framework for analysing the connection between economic growth and the danger of climate change, findings remain controversial. In a series of studies, Shahbaz et al. (2012, 2013, 2015) provide support for the EKC hypothesis. Odhiambo (2020), Menyah and Wolde-Rufael (2010) are consistent for South Africa. In contrast, Tamazian et al. (2009) maintain that these studies' findings are incomplete as they have failed to account for financial development. Tamazian and Rao (2010) recognised that access to finance could affect potential growth as well as environmental sustainability. This unsettled issue remains a critical concern for East and Southern Africa (Dafe, 2020). It is unclear whether in the attendant regions, financial and human capital developments are relevant for environmental sustainability as apparent in the literature (Asongu et al., 2017, 2018; Bekhet et al., 2017). The rationale for this study is thereforeto investigate whether financial development and human capital matter for environmental sustainability in East and Southern Africa. Hence, thestudy aimsto provide information that can help policy makers take informed decisions.

Four reasons call for the positioning ofan inquiry on East and Southern Africa. First, many reports have linked finance and human development to slow economic growth and vulnerability to climate change. The reports have shown that nearly 73% of the adults in Kenya are financially excluded (Van Hove & Dubus, 2019). This is similar to the report in Tanzania and Uganda as 56% and 46%, of the adult population in respective countries isyet to benefit from formal financial services (Demirgüç-Kunt et al., 2017, 2020; Beck et al., 2007). A similar experience has been documented for Kenya and other East and Southern African countries (Asuming et al., 2019). Second, poor access to finance has been linked to the ease of doing business among African countries (Beck et al., 2007; Asongu et al, 2020). For example, the inability of farmers to access finance needed for smart technology required to improve agricultural output may result in environmental degradation (Liu et al., 2021;

Khaid et al., 2021; Bigger & Webber, 2021). Lack of access to finance has affected the ability of farmers to explore modern technology in order to enhance their agricultural produce (Asongu, 2018a; 2018b, Asongu & Acha-anyi, 2017; Asongu et al., 2016, 2017). Possibly, increase in their CO_2 emissions and vulnerability to climate change could be explained by their inability to access financial resources that are essential for the acquisition of smart agricultural technology. This ultimately leads to heavy reliance on old agricultural practices and environmental degradation. Third, the poor state of education across East and Southern African countries has increased the concern of their vulnerability to climate change. Many reports have already shown that human capital development in East and Southern Africa deserves an urgent intervention owing to health risk and poor educational systems in the region, which may likely endanger the environment (IPCC, 2014; Pachauri & Reisinger, 2007). Fourth, the current call for ensuring improved economic welfare, sound financial reform and a sustainable environment constitute priorities of post-2015 Sustainable Development Goals (SDGs). Such priorities require adequate planning and understanding of the means by which attendant programs would be funded. Hence, financial development is a critical element to be considered. Human capital development for environmental sustainability will further strengthen the relevance of SDGs in rescuing Africa from the danger of climate change (Asongu et al., 2019a 2019b; Asongu & Odhiambo, 2019d, 2020a, 2020b, 2020c; Zivin et al, 2012; Zaidi et al., 2011; Xing et al., 2017; Xiong & Qi, 2018; Zafar et al., 2019). Additionally, the overwhelming evidence on the consequences of climate change has shown that East and Southern Africa are vulnerable and policy makers need information on the basis of which, they can tailor appropriate policies to avert crises related to CO_2 emissions. Fifth, the dearth of empirical studies on finance in East and Southern Africa, make the present study timely.

Our study is related to the empirical literature on the nexus between financial development and environmental degradation, notably: Shahbaz, Shahzad, Ahmed and Alam (2016), Bekhet, Matar and Yasmin (2017), Shahbaz, Tiwari and Nasir, (2015) and Lu (2018), Zaidi, Zafar Shahbaz and Hou (2019), Nathaniel and Iheonu (2019) and Asongu and Odhiambo (2019). These empirical studies have revealed interesting results that have provided a deeper understanding of the link between financial development and CO_2 emissions. It is important to investigate a similar effort for the East and Southern African experience.

Our study contributes to empirical literature as follows: (1) it investigates whether financial development and human development can help in promoting environmental sustainability in East and Southern Africa; (2) the study is framed with a Panel Granger causality approach and uses statistical procedures to uncover information that can be leveraged by policy makers to rescue East and Southern Africa from the unavoidable danger of climate change. First, it explores the previous information on the behaviour of the series using the Levin, Lin and Chu (2002) (hereafter LLC) and Im, Pesaran and Shin (2003)tests. Second, it combines the statistical intuition from Pedroni (2002) and Kao (1999) panel cointegration tests to assess the long-run prospects of the series. Third is the panel VAR/VEC Granger causality approach helps to uncouple the short and long-run dynamics among the variables. The results show that human and financial developments are critical for mitigating CO_2 emissions in East and Southern Africa.

This study is novel in several ways. (a) By controlling for confounders, the study shows the implication of financial development, human capital and environmental sustainability. (b) The study provides evidence on the key social investment needed to achieve environmental sustainability in the African continent. (c) While the study is empirically motivated, the findings on the causation link between factors provide vital information that can aid in the development of policy frameworks to reduce carbon emissions in the short and long terms.

The paper is organised as follows. Section 2 presents the literature review and hypothesis testing, while section 3 describes the panel modelling. Section 4 coversthe data and methodology used, while section 5 concludes with policy recommendations.

Related Literature

This section presents empirical literature on the link between financial development, human capital and environmental sustainability. It begins by exploring arguments in the literature and ends with two research questions.

Financial development and environment

The survey begins with the most recent study by Odhiambo (2020) on the dynamic relationship between financial development, income inequality and CO_2 emissions for a panel of 39 sub-Saharan Africa countries (SSA) between 2004 and 2014. The scholar has combined three main indicators: the Gini coefficient, the Atkinson index and Palma ratio, using the

Generalised Method of Moments (GMM) and reported a negative impact of financial development on CO_2 emissions in SSA. Shahbaz et al. (2016) examined the asymmetric impact of financial development on environmental quality in Pakistan from1985 to 2014. They reported that financial development through investment in the energy sector is crucial for environmental quality. The findings of the studies are relevant to this present one but differ in approach.

Chen et al. (2019) examined the dynamic relationship between financial development, energy consumption, income level and ecological footprints in Central and Eastern European Countries (CEECs) for the period 1991 and 2014, combining the Feasible Generalised Least Squares (FGLS), GMM, and Dimitrscue and Hurlin (D-H) panel causality and reported that financial development significantly contributes to environmental degradation. Their finding and approach are relevant to this present study. Asongu and Odhiambo (2020) assess whether improving governance standards affect environmental quality in 44 countries in Sub Saharan Africa between 2000 and 2012 using GMM and bundled as well as unbundled governance dynamics and reported that governance matters for environmental sustainability in the region. Tamazian et al. (2009) investigated the link between financial development, economic growth, and environmental quality from 1992 to 2014 and reported that economic and financial developments are crucial for environmental quality in the BRIC (Brazil, Russia, India and China) nations.

Guo et al. (2019) examine the role of financial development in climate change in China and its provinces between 1975 and2015. Their study has used an extended STIRPAT model and reported that financial development is crucial for mitigating climate change. Similarly, Mesagan et al. (2018) explore the role of capital investment as a channel for promoting environmental quality in Brazil, Russia, India, China and South Africa (BRICS) countries using the fully modified and dynamic ordinary least squares (DOLS and FMOLS) approaches and reported that it is relevant to complement capital investment with renewable energy to reduce the impact of climate change. Shahbaz et al. (2019) examine the link between foreign direct investment (FDI) and carbon emissions in North African countries using the GMM and Granger causality approaches and reported that FDI cause CO_2emissions. Shahbaz et al. (2013) examined whether financial development reduced CO_2 emissions in Malaysia between 1971 and 2011 using the Autoregressive distributed lag model and reported that long-run relationships exist among the variables. Their results furthershow a bidirectional relationship between financial development and CO_2 emission during the period. Abid (2017) investigate the link between financial and institutional development forthe EU (European Union) and MEA (Middle East and Africa) countries using the GMM approach and discovered a monotonically increasing relationship between CO_2 emission and income.

Asongu and Odhiambo (2019b) investigate how doing business affects inclusive human development in 48 Sub Saharan African countries for the period 2000 - 2012, using Fixed effects and GMM regressions. They reported that increasing constraints to the doing of business have a negative effect on inclusive human development. Ansah and Sorooshian (2019) examine the private sector's response to addressing climate change and reported that access to finance is a major challenge distorting the response of the private sector. Asuming et al. (2019) conduct a comparative analysis of financial inclusion in 31 Sub-Saharan African countries using the Global Findex database for the period 2011 to 2014 and reported that financial inclusion policies should be promoted across the population.

Human development and environment

A study by Sen (1979) provides a remarkable framework for assessing human development and environmental sustainability. Sen (1985) widened the human development hypothesis to account for the need for social investment in the form of education, health, and a higher standard of living, as means of preserving the environment. While much research has been done on the relationship between human development and the environment, the results have been mixed. For example, Costantini and Monni (2008) examined the links between the environment, human development, and economic growth. They concluded that investing in human development will help achieve a path to long-term growth and environmental sustainability. Sheraz et al. (2021) have assessed the effect of globalisation on financial development, energy consumption, human capital and carbon emission for a panel of G-20 countries using the Driscoll – Kraay standard error approach and Dumitrescu and Hurlin panel Granger causality test. They have established that human capital is negatively correlated with CO_2 emission. Bano et al. (2018) analysed the link between human capital and CO_2 emission for Pakistan and confirmed a long run relationship among the factors.

Economic growth and environment

The carrying capacity hypothesis' main argument provides an intuition for explaining the relationship between economic growth and the environment. As a result, an environmental policy must take into account preservation in the pursuit of economic growth. Although the theory has produced a large body of literature, the evidence is still inconclusive and contested (Arrow et al., 1995; Panayotous, 2016). For example, several studies have acknowledged that a continuous quest for economic growth tends to cause environmental degradation (Guo et al., 2018; Boggia et al., 2014; Siva et al., 2016). Another group of studies suggested the need to limit growth in order to improve the environment and maintain environmental quality (Yang et al., 2016; Yu et al., 2015; Twerefou et al., 2017; Acar & Lindmark, 2017). For example, Twerefou et al. (2017) examined the environmental effects of economic growth and globalisation for a panel of 36 Sub-Saharan African countries over the period 1990-2013, using a system generalised method of moments and reported that environmental quality tends to deteriorate as a result of economic growth and globalisation. Acar and Lindmark (2017) analyse the convergence in CO_2 and economic growth for the Organisation for Economic Co-operation and Development (OECD) members from 1973 to 2010 and reported that the environment degrades as economic growth increases. Safi et al. (2021) examined the impacts of financial instability and consumption-based carbon emission in E-7 countries along with the mediating role of trade and economic growth. They confirmed the existence of cross-sectional dependence among variables as well as factor cointegration. Ozokcu and Ozdemir (2017) investigate the link between income and CO_2 emissions in 26 OECD countries and provide support for EKC hypothesis.

Trade openness and environment

The correlates between trade openness and the environment are discussed within the haven hypothesis. According to the theory, trade openness causes emissions as a result of weak environmental policy. While the theory has generated a substantial amount of literature, the evidence has been mixed. For example, Zamil et al. (2019) applied the autoregressive distributed lag (ARDL) model for Oman between 1972 and 2014 and reported a positive relationship. Frutos-Bencze et al. (2017) investigated whether trade openness affected carbon emissions using ARDL and discovered a positive influence of trade openness on carbon emission. Udeagha and Ngeph (2019) empirically examined the link between trade and environmental quality in South Africa from 1980 to 2012 and confirmed the existence of a haven hypothesis in South Africa. Menyah et al. (2014) assessed the causal relationships between financial development, trade openness and economic growth for a panel of 21 African countries and reported that financial development unidirectionally Granger cause trade openness.

Agriculture and environment

Agriculture is one of the most important sources of biomass for human society, but it is also one of the most significant contributors to anthropogenic ecosystem degradation through negative impacts on biodiversity, ecosystem integrity, climate change, and ecosystem services (Foley et al., 2011; Weinzettel, 2019; Penna, 2014). Human Appropriation of Net Primary Production has been proposed as a socioeconomic and ecological indicator of human interference with natural ecosystems (Harberl et al., 2014: Kastner et al., 2015). Likewise, many studies have shown that increased agricultural activities impact environmental quality (Dai, 2012; Hu et al., 2019).

Obviously, a cursory look at the existing empirical studies shows that considerable effort has been made. Most of the studies have provided a valuable contribution to the literature on environmental sustainability in the chosen strands. However, the scholars' findings are still inconsistent and controversial. Hence, further information is required to reach a consensus on the relationship between financial development indicators and environmental sustainability. At best, the fact that the long-run relationship isreported with controversy in the short run prospects (Shahbaz et al., 2013, 2016) motivates the present study to provide more insights into the nexuses.

In the proceeding paragraphs, wehave beamed light on the arguments in the existing literature on the link between financial development, human capital and environmental sustainability. Based on the arguments, we anticipate that financial development should hurt environmental sustainability while human capital should have the opposite incidence. Addressing the hypothetical concerns will provide more information to make informed policies needed for combating climate change. The concerns are deemed important for East and Southern Africa, especially when the region is presented with the dual problem of financial exclusion and poor educational system.

Data and Methodology

This study investigates whether financial and human capital developments matter for environmental sustainability for a panel of 12 East and Southern African countries between 2000 and 2018. The data used are sourced from the World Development Indicators (WDI) and Penn World Table. We use CO_2 per capita to capture environmental sustainability which conforms to previous studies (see Shobande & Shodipe, 2019; Asongu & Odhiambo, 2019a, 2020; Shahbaz et al., 2013, 2016; Shobande & Enemona, 2021). The financial development variable is captured with private domestic credit by deposit money banks (DMBs)(see Shobande & Lanre, 2018; Shobande & Shodipe, 2019; Asongu & Odhiambo, 2019a, 2020b; Shahbaz et al., 2013, 2016; Tchamyou, 2019, 2020, 2021; Tchamyou et al., 2019). The human development index (knowledge, longevity and well-being) available in the Penn World Tableis used to proxy for human capital. Since it is reasonable to capture the level of economic activity as it is likely to affect environmental quality through CO_2 emission, agricultural value added (% GDP) from WDI is used. Shahbaz (2013, 2016) stresses the importance of trade openness to capture globalisation.Based on the appeal, trade (import +export) per capitais also used. Since we have placed some importance on environmental sustainability, it is reasonable to account for demographic factors. The use of urbanisation conforms to existing empirical studies (Ahmed et al. 2020; Nathaniel & Iheonu, 2019; Nathaniel, 2020). Also, investment is captured with the real domestic absorption (real consumption plus investment)and GDP per capita capture income level (see Asongu & Odhiambo, 2019, 2020; Shahbaz et al., 2013, 2016).

Empirical Model

TheAugmented STIRPAT framework, which adapts to other factors connecting financial development and environmental sustainability, is used, and it is specified as:

$$CO2 = f \quad (Fin, \quad Hdi, \quad GDP, \quad Urb, \quad Agr, \quad Tr, \quad Inv)(1)$$

In our model, $CO2$ denotes carbon emissions per capita as an indicator of environmental sustainability; Fin is private domestic credit (DMBs which represents an indicator for financial development; Hdi or human development index constitutes knowledge, longevity and well-being indicators); $GDP\ captures\ income\ per\ capita$; Tr is trade openness or an indicator for globalisation; Urb is a demographic variable; Agr is agricultural value added (% of GDP) which determines economic activity in the East and Southern Africa and investment is captured with the real domestic absorption (real consumption plus investment).

Equation 1 is linearised to capture the stochastic properties in the STIRPAT model and is stated as:

$$\log CO2_{i,t} = \alpha_0 + \alpha_1 \log Fin_{i,t} + \alpha_2 \log Hdi_{i,t} + \alpha_3 \log GDP_{i,t} + \alpha_4 \log Tr_{i,t} + \alpha_5 \log Agri_{i,t} + \alpha_6 \log Inv_{i,t} + \alpha_7 \log Urb_{i,t} + v_{i,t} \qquad (2)$$

As before, i is the index of countries, t is time, α_0 is the intercept parameter, α_{1-6} are not the only parameters associated with the variable but also constitute elasticity, while v is the unobserved.

Panel modelling

The empirical strategy of our study is framed as a Panel VAR/VEC Granger causality model. The approach has gained empirical research superiority across multidisciplinary studies (see Haavelmo, 1944; Holland, 1986; Spanos, 1989; Pindyck & Rotemberg, 1990; Reboredo, 2013). Two reasons motivated the used of the research approach. First, it helps to breakdown the dynamic relationship among the factors into short- and long-run effects. Second, it provides a yardstick for understanding prior behaviour of each series used. Third, it enables the convergence speed of the variables to their equilibrium position, which helps in facilitating cross-country common policies for the East and Southern African countries investigated. Our VAR/VEC Granger causality is model as follows (3-10).

$$\Delta\, CO2_{i,t} = \alpha_{10} + \sum_{k=1}^{q} \alpha_{11ik}\, \Delta CO2_{i,t-k} + \sum_{k=1}^{q} \alpha_{12ik}\, \Delta fin_{i,t-k} + \sum_{k=1}^{q} \alpha_{13ik}\, \Delta\, Hdi_{i,t-k} + \sum_{k=1}^{q} \alpha_{14ik}\, \Delta GDP_{i,t-k} + \sum_{k=1}^{q} \alpha_{15ik}\, \Delta Tr_{i,t-k} + \sum_{k=1}^{q} \alpha_{16ik}\, \Delta\, Agr_{i,t-k} + \sum_{k=1}^{q} \alpha_{17ik}\, \Delta\, Inv_{i,t-k} + \sum_{k=1}^{q} \alpha_{18ik}\, \Delta\, Urb_{i,t-k} + \phi_{1i} ECM_{it-1} + \mu_{1i,t} (3)$$

$$\Delta\, fin_{i,t} = \alpha_{20} + \sum_{k=1}^{q} \alpha_{21ik}\, \Delta fin_{i,t-k} + \sum_{k=1}^{q} \alpha_{22ik}\, \Delta CO2_{i,t-k} + \sum_{k=1}^{q} \alpha_{23ik}\, \Delta\, Hdi_{i,t-k} + \sum_{k=1}^{q} \alpha_{24ik}\, \Delta GDP_{i,t-k} + \sum_{k=1}^{q} \alpha_{25ik}\, \Delta Tr_{i,t-k} + \sum_{k=1}^{q} \alpha_{26ik}\, \Delta\, Agr_{i,t-k} + \sum_{k=1}^{q} \alpha_{27ik}\, \Delta\, Inv_{i,t-k} + \sum_{k=1}^{q} \alpha_{28ik}\, \Delta\, Urb_{i,t-k} + \phi_{2i} ECM_{it-1} + \mu_{2i,t} (4)$$

$$\Delta\, Hdi_{i,t} = \alpha_{30} + \sum_{k=1}^{q} \alpha_{31ik}\, \Delta Hdi_{i,t-k} + \sum_{k=1}^{q} \alpha_{32ik}\, \Delta fin_{i,t-k} + \sum_{k=1}^{q} \alpha_{33ik}\, \Delta\, CO2_{i,t-k} + \sum_{k=1}^{q} \alpha_{34ik}\, \Delta GDP_{i,t-k} + \sum_{k=1}^{q} \alpha_{35ik}\, \Delta Tr_{i,t-k} + \sum_{k=1}^{q} \alpha_{36ik}\, \Delta\, Agr_{i,t-k} + \sum_{k=1}^{q} \alpha_{37ik}\, \Delta\, Inv_{i,t-k} + \sum_{k=1}^{q} \alpha_{38ik}\, \Delta\, Urb_{i,t-k} + \phi_{3i} ECM_{it-1} + \mu_{3i,t} (5)$$

$$\Delta\, GDP_{i,t} = \alpha_{40} + \sum_{k=1}^{q} \alpha_{41ik}\, \Delta GDP_{i,t-k} + \sum_{k=1}^{q} \alpha_{42ik}\, \Delta fin_{i,t-k} + \sum_{k=1}^{q} \alpha_{43ik}\, \Delta\, Hdi_{i,t-k} + \sum_{k=1}^{q} \alpha_{44ik}\, \Delta CO2_{i,t-k} + \sum_{k=1}^{q} \alpha_{45ik}\, \Delta Tr_{i,t-k} + \sum_{k=1}^{q} \alpha_{46ik}\, \Delta\, Agr_{i,t-k} + \sum_{k=1}^{q} \alpha_{47ik}\, \Delta\, Inv_{i,t-k} + \sum_{k=1}^{q} \alpha_{48ik}\, \Delta\, Urb_{i,t-k} + \phi_{4i} ECM_{it-1} + \mu_{4i,t} (6)$$

$$\Delta\, TR_{i,t} = \alpha_{50} + \sum_{k=1}^{q} \alpha_{51ik}\, \Delta Tr_{i,t-k} + \sum_{k=1}^{q} \alpha_{52ik}\, \Delta fin_{i,t-k} + \sum_{k=1}^{q} \alpha_{53ik}\, \Delta\, Hdi_{i,t-k} + \sum_{k=1}^{q} \alpha_{54ik}\, \Delta GDP_{i,t-k} + \sum_{k=1}^{q} \alpha_{55ik}\, \Delta CO2_{i,t-k} + \sum_{k=1}^{q} \alpha_{56ik}\, \Delta\, Agr_{i,t-k} + \sum_{k=1}^{q} \alpha_{57ik}\, \Delta\, Inv_{i,t-k} + \sum_{k=1}^{q} \alpha_{58ik}\, \Delta\, Urb_{i,t-k} + \phi_{5i} ECM_{it-1} + \mu_{5i,t} (7)$$

$$\Delta\, Agr_{i,t} = \alpha_{60} + \sum_{k=1}^{q} \alpha_{61ik}\, \Delta Agric_{i,t-k} + \sum_{k=1}^{q} \alpha_{62ik}\, \Delta fin_{i,t-k} + \sum_{k=1}^{q} \alpha_{63ik}\, \Delta\, Hdi_{i,t-k} + \sum_{k=1}^{q} \alpha_{64ik}\, \Delta GDP_{i,t-k} + \sum_{k=1}^{q} \alpha_{65ik}\, \Delta Tr_{i,t-k} + \sum_{k=1}^{q} \alpha_{66ik}\, \Delta\, CO2_{,t-k} + \sum_{k=1}^{q} \alpha_{67ik}\, \Delta\, Inv_{i,t-k} + \sum_{k=1}^{q} \alpha_{68ik}\, \Delta\, Urb_{i,t-k} + \phi_{6i} ECM_{it-1} + \mu_{6i,t} (8)$$

$$\Delta\, Inv_{i,t} = \alpha_{70} + \sum_{k=1}^{q} \alpha_{71ik}\, \Delta Inv_{i,t-k} + \sum_{k=1}^{q} \alpha_{72ik}\, \Delta fin_{i,t-k} + \sum_{k=1}^{q} \alpha_{73ik}\, \Delta\, Hdi_{i,t-k} + \sum_{k=1}^{q} \alpha_{74ik}\, \Delta GDP_{i,t-k} + \sum_{k=1}^{q} \alpha_{75ik}\, \Delta Tr_{i,t-k} + \sum_{k=1}^{q} \alpha_{76ik}\, \Delta\, Agr_{i,t-k} + \sum_{k=1}^{q} \alpha_{77ik}\, \Delta\, CO2_{i,t-k} + \sum_{k=1}^{q} \alpha_{78ik}\, \Delta\, Urb_{i,t-k} + \phi_{7i} ECM_{it-1} + \mu_{7i,t} \quad (9)$$

$$\Delta\, Urb_{i,t} = \alpha_{80} + \sum_{k=1}^{q} \alpha_{81ik}\, \Delta Urb_{i,t-k} + \sum_{k=1}^{q} \alpha_{82ik}\, \Delta fin_{i,t-k} + \sum_{k=1}^{q} \alpha_{83ik}\, \Delta\, Hdi_{i,t-k} + \sum_{k=1}^{q} \alpha_{84ik}\, \Delta GDP_{i,t-k} + \sum_{k=1}^{q} \alpha_{85ik}\, \Delta Tr_{i,t-k} + \sum_{k=1}^{q} \alpha_{86ik}\, \Delta\, Agr_{i,t-k} + \sum_{k=1}^{q} \alpha_{87ik}\, \Delta\, Inv_{i,t-k} + \sum_{k=1}^{q} \alpha_{88ik}\, \Delta\, CO2_{i,t-k} + \phi_{8i} ECM_{it-1} + \mu_{8i,t} \quad (10)$$

In equation 3-10, $\alpha_{10}, \alpha_{2}, \alpha_{30}, \beta_{40}, \alpha_{50}, \alpha_{60}, \alpha_{70}, \alpha_{80}$, are taken as intercepts associated with an individual model for each variable; $\alpha_{11-18}, \alpha_{21-28}, \alpha_{31-38}, \alpha_{41-48}, \alpha_{51-58}, \alpha_{61-68}, \alpha_{71-78,} \alpha_{81-88}$ are parameters and elasticities for each model associated with endogenous factors; p is the lag length which is selected using the AIC, SC and HQ criteria; $\mu_{1i,t}, \mu_{2i,t}, \mu_{3i,t}, \mu_{4i,t}, \mu_{5i,t}, \mu_{6i,t}, \mu_{7i,t}, \mu_{8i,t}$areshocks arising from each variable transmitted to climate change from each endogenous model; Δ is the difference operator; ϕ, is the short-run dynamic coefficient to be estimated and the serially uncorrelated error term is$\varepsilon_{i,t}$; $q$is the optimal lag length reduced by 1, ϕ is the speed of adjustment parameter with a negative sign, and $ECTt{-}1$ is the error correction term, which is the lagged value of the residuals obtained from the cointegration regressions of the dependent variable on the regressors. Thus, the past disequilibrium term (i.e., ECT) determines if the long-run causality holds.

Empirical Results

This section discusses the empirical results and offers a thorough explanation of the findings. It also contrasts findings with previous studies.

Preliminary Analysis

Descriptive Statistics

This section presents the summary statistics of the series. The goal is to have prior information on the series' past behaviour before undertaking any serious analysis. Table 1 presents the summary statistics of the variables.

Table 1. *summary statistics*

Variables	*Mean*	*Std. Dev.*	*Obs.*
CO2	0.32	0.1	228
Fin	0.47	0.21	228
Hdi	47.8	20.7	228
GDP	394.6	403.5	228
Tr	239	329	228
Urb	930.6	316	228
Agr	3939	4026	228
Inv	391	277.8	228

Notes. *CO2 emission per capita (CO2), financial development (fin), human development index (HDI), income per capita (GDP), Trade openness (tr), Agricultural as the level of economic activities (Agr), real domestic absorption (investment).*

Table 1 displays the summary statistics of the data. The average value (standard deviation) of CO_2 emission and its corresponding long term is 0.32 (0.1). Meanwhile, the mean (standard deviation) for financial development and human capital development are 0.47(0.21) and 47.8 (20.7), respectively.

Correlation Matrix

This section reports the correlation matrix of the variables used. The analysis aims to discover the nature of the relationship between the variables, and the outcome is reported in Table 2.

Table 2. Correlation Matrix

Variables	*CO2*	*Fin*	*Hdi*	*GDP*	*Tr*	*Urb*	*Agr*	*Inv*
CO2	1							
Fin	0.10	1						
Hdi	0.05	-0.10	1					
GDP	0.34	-0.17	-0.26	1				
Tr	0.31	0.03	0.23	0.67	1			
Urb	-0.34	0.25	-0.16	-0.27	0.19	1		
Agr	0.35	-0.18	0.26	0.51	-0.66	-0.27	1	
Inv	0.30	10.19	0.32	-0.44	-0.69	-0.23	0.43	1

Notes. *CO2 emission per capita (CO2), financial development (fin), human development index (HDI), income per capita (GDP), Trade openness (tr), Agricultural as a level of economic activities (Agr), real domestic absorption (investment).*

Based on the correlation results, agriculture is partially correlated with GDP per capita and trade openness, whereas trade openness is partially correlated with GDP per capita.

Cross-section dependence and homogeneity tests

It is important to check the cross-sectional dependence among the variables in panel before any meaningful analysis is carried out. Econometrically, nonstationary panel data have attracted considerable empirical research, given the importance of the series' potential. Similarly, statisticians have developed various panel unit root and cointegration tests to circumvent the problem (Liven &Lin, 1993; Quah, 1994; McCoskey & Kao, 1998; Chieng & Kao, 2002). Despite the efforts by applied econometricians, it appears that the panel unit roots test cannot provide an appropriate account of the cross-sectional dependence problem (Gao et al., 2020; Su& Chen, 2013; Pesaran & Yamagata, 2008; Ando & Bai, 2015; Breitung et al., 2016; Dikgraaf & Vollebergh, 2005). Breusch and Pagan (1979) and Pesaran (2004) are often implemented to resolve the problem. Two unforgiven problems arise if the issue of cross-sectional dependency is overlooked. The first is the loss of efficiency and essential information that would have helped understand the dataset's prior behaviour. The second arises from spurious data that do not follow a normal distribution leading to the insignificance of the t-statistics. Three main statistical methods have been implemented to investigate cross-sectional dependence in our dataset, notably: Breusch and Pagan (1980) and LM, Pesaran (2004, 2018). The results of the cross-sectional dependenceare provided inTable 3.

***Null hypothesis**:* No cross-section dependence (correlation) in residuals

Table 3. Cross sectional dependence and homogeneity test results

Test	*CO2*	*Fin*	*Hdi*	*GDP*	*Tr*	*Urb*	*Agr*	*Inv*
Breush-Pagan LM	226** (0.00)	276.2** (0.00)	265* (0.00)	225.6* (0.00)	255.6* (0.00)	254.6* (0.00)	243* (0.00)	236* (0.00)
Pasaran Scaled LM	13.96* (0.00)	18.3* (0.00)	18.4** (0.00)	13.8** (0.00)	23.7* (0.00)	16.4* (0.00)	19.0** (0.00)	15.1* (0.00)
Pesaran CD	1.7** (0.00)	2.52* (0.00)	1.9* (0.00)	3.09** (0.00)	2.6* (0.00)	9.5* (0.00)	2.8** (0.00)	1.75* (0.00)

Notes.
*** Significant at 5%*
**Significant at 10%*

The results show the presence of cross-sectional dependence among the variables. Both the Breusch and Pagan LM, Pesaran Scaled LM and Pesaran CD admitted the presence of cross-sectional dependence in each variable investigated. There aretwo consequences of the results observed. First, a shock in one country is likely to transmit to the other. Precisely, agriculture which has been the major economic activity in the East and Southern African countries may have a consequence for climate change. However, this depends on the level of agricultural activities and the degree of CO_2 emissions. Fortunately, the result conforms with the existing report that East and Southern African countries are likely to experience a major public health crisis (Owen et al., 2011); no intervention program is designed to rescue the region from climate change. Second, the highly integrated trading network within the region reflects the outcome of the CD test.

Panel Unit root tests

The next step is to conduct the panel unitroottest of the variables before further analysis. The initial investigation of the unitroot properties of the data used is deemed crucial since spurious data is unlikely to provide good estimates. Similarly, knowing the series' prior behaviour provides complementary information to justify the CD test's previous evidence. To assess the stationary properties of the series, we have implemented the first-generation panel unit root test by combining the LLC (2002) and the IPS methodology, and Table 4 presents the results.

Interestingly, the combined LLC and IPS panel unit root tests results indicate that the variables are not stationary at level. To ensure the variables are stationary, we have transformed the variables by taking their first differences. After the transformation, all the variables are stationary. Fortunately, both the LLC and IPS panel unit root tests admitted that the variables are indeed stationary.

Hypothesis Tested:
Null hypothesis: Panel contains unitroots.
Alternative: Panel is stationary.
Table 4. First Generation Panel Unit Roots Tests

Variables	*At level*		*At first difference*		
	No time effect	*Time effects*	*No time effect*	*Time effects*	*Remarks*
LLC tests					
CO2	-3.6	-4.7	-9.3**	13.9**	I (1)
Fin	-3.2	-5.8	-8.7**	-11.7**	I (1)
Hdi	-4.5	-6.6	-10.1**	-11.56**	I (1)
GDP	-3.28	-4.7	-5.8**	-7.6**	I (1)
Tr	-6.8	-9.6	-8.3**	-10.1**	I (1)
Urb	6.0	-9.7	7.3**	-10.3**	I (1)
Agr	-1.3	-5.23	-3.5**	-7.1**	I (1)
Inv	1.8	-4.3	-7.9**	8.5**	
IPS test					
CO_2	2.3	0.5	-5.7**	-6.4**	I (1)
Fin	-1.5	0.79	-3.9**	-6.9**	I (1)
Hdi	2.1	-1.3	-5.9**	6.3**	I (1)
GDP	4.0	1.4	3.5**	-3.2**	I (1)
Tr	3.1	1.2	-5.8**	-5.6**	I (1)
Urb	1.6	1.9	-7.2**	-7.5**	I (1)
Agr	4.4	-0.6	-3.8**	-4.1**	I (1)
Inv	1.2	3.3	-3.7**	-4.0**	I (1)

Notes. *CO2 emission per capita (CO2), financial development (fin), human development index (HDI), income per capita (GDP), Trade openness (tr), Agricultural as the level of economic activities (Agr), real domestic absorption (investment)*
*** Significant at 5%*

One main challenge with the LLC and IPS panel unit roots tests is that they do not account for the cross sectional problem. Thus, the study implemented second-generation panel unit roots tests that account for the cross sectional problem, notably: (a) cross sectional ADF and augmented cross sectional (CIPS) (Im, Peseran, & Shin), (Pesaran, 2007). Table 5 presents the results of the robust panel unit roots tests.

Table 5: Second Generation Panel Unit Root Tests

Variable	Cross-Sectional ADF (CADF)			Cross-Sectional Augmented IPS (CIPS)		
CO_2	Level	First	Order	Level	First	Order
Fin	–1.31	–4.66**	I(1)	–1.39	–6.06**	I(1)
Hdi	–1.37	–3.91**	I(1)	–1.09	–7.61**	I(1)
GDP	–1.29	–3.76**	I(1)	–1.44	–4.30**	I(1)
Tr	–1.15	–4.60**	I(1)	–1.28	–5.81**	I(1)
Urb	–1.39	–5.19**	I(1)	–1.30	–6.71**	I(1)
Agric	–1.01	–3.59**	I(1)	–1.41	–4.88**	I(1)
Inv	–1.25	–5.69**	I(1)	–1.19	–5.23**	I(1)

Notes. *CO2 emission per capita (CO2), financial development (fin), human development index (HDI), income per capita (GDP), Trade openness (tr), Agricultural as the level of economic activities (Agr), real domestic absorption (investment)*
*** Significant at 5%*

Lag Selection Criteria

In the prior section, we have conducted a preliminary check of our dataset using the CD and panel unit root tests. The result confirmed thatthe series are stationary after first differencing. Next, it is important to check the lag length to determine how the variables respond. The Akaike (AIC), Schwartz Bayesian (SC), and Hannan-Quinn (HQ) Information Criteria were used. Details of these criteria are provided in Table 6.

Table 6. *VAR Lag Order Selection Criteria*

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-8651.794	NA	2.27e+38	111.0230	111.1794	111.0865
1	-7045.120	3027.964*	5.86e+29*	91.24512*	92.65275*	91.81684*

* indicates lag order selected by the criterion

LR: sequential modified LR test statistic (each test at 5% level)
FPE: Final prediction error
AIC: Akaike information criterion
SC: Schwarz information criterion
HQ: Hannan-Quinn information criterion

Notes: * indicate the Automatic lag length selection based on AIC, SC, HQ criterion. Each value of LR statistics at 5%

According to Table 6, there is agreement among the criteria on the appropriate optimal lag length. Luckily, the AIC, SC and HQ admitted one lag selection.

Panel Cointegration tests

Testing cointegration in panels has gained considerable support in the empirical literature. Some empirical studies have shown that a variable can have a unit root and still does not exhibit a long-run relationship (Levin et al., 2002; Chang & Nguyen, 2012; Pesaran & Yamagata, 2008; Ando & Bai, 2015; Baltagi & Kao, 2001; Baltagi et al, 2016, 2017). This justifies the need to examine whether the series can converge to their long term mean. Two cointegration approacheshave been used. The Pedroni (1999, 2001, 2004) panel cointegration and Kao (1999) tests were used. The Pedroni (1999) residual-based panel cointegration test is built on seven criteria, which can be specified as follows.

Pedroni (1999, 2002) describe the seven statistical criteria as follows.

(a) Panel $v-.stat$istic

$$Panel\ v\colon\ T^2 N^{2/3}\left(\sum_{i=1}^{N}\sum_{t=1}^{T}\tilde{L}_{11i}^{-2}\,\tilde{e}_{i,t-1}^{2}\right)^{-1}$$

(b) Panel $\rho - Stat$istic

$$T\sqrt{N}\left(\sum_{i=1}^{N}\sum_{t=1}^{T}\tilde{L}_{11i}^{-2}\,\tilde{e}_{i,t-1}^{2}\right)^{-1}\sum_{i=1}^{N}\sum_{t=1}^{T}\tilde{L}_{11i}^{-2}\left(\tilde{e}_{i,t-1}-\Delta\tilde{e}_{i,t}-\tilde{\lambda}_i\right)(b)$$

(c) Panel $t - Statistic\ (non\ parametric)$

$$(\tilde{\sigma}_{N,T}^{2}\left(\sum_{i=1}^{N}\sum_{t=1}^{T}\tilde{L}_{11i}^{-2}\,\tilde{e}_{i,t-1}^{2}\right)^{-1/2}\sum_{i=1}^{N}\sum_{t=1}^{T}\tilde{L}_{11i}^{-2}\ \ (\tilde{e}_{i,t-1}-\Delta\tilde{e}_{i,t}-\tilde{\lambda}_i)$$

(d) Panel $t - Statistics\ (parametric)$

$$(\tilde{s}_{N,T}^{2}\textstyle\sum_{i=1}^{N}\sum_{t=1}^{T}\tilde{L}_{11i}^{-2}\,\tilde{e}_{i,t-1}^{2})^{-1/2}\sum_{i=1}^{N}\sum_{t=1}^{T}\tilde{L}_{11i}^{-2}\ \ (\tilde{e}_{i,t-1}-\Delta\tilde{e}_{i,t})$$

(e) Group $\rho - Statistic$

$$T\ {}^{1}\!/\!\sqrt{N}\sum_{i=1}^{N}\sum_{t=1}^{T}\tilde{L}_{11i}^{-2}\,\tilde{e}_{i,t-1}^{2})^{-1/2}\sum_{i=1}^{T}(\tilde{e}_{i,t-1}-\Delta\tilde{e}_{i,t}-\tilde{\lambda}_i)$$

(f) Group $t - Statistic\ (non\ parametric)$

$$1/\sqrt{N}\sum_{i=1}^{N}(\widetilde{\sigma}_i^2\sum_{t=1}^{T}\tilde{L}_{11i}^{-2}\,\tilde{e}_{i,t-1}^2)^{-1/2}\sum_{i=1}^{T}(\,\tilde{e}_{i,t-1}-\Delta\tilde{e}_{i,t}-\tilde{\lambda}_i)$$

(g) Group $t - Statistics\ (parametric)$

$$1/\sqrt{N}\sum_{i=1}^{N}\sum_{t=1}^{T}\widetilde{S_{11i}^{-2}}\,\tilde{e}_{i,t-1}^2)^{-1/2}\sum_{i=1}^{T}\tilde{e}_{i,t-1}-\Delta\tilde{e}_{i,t}$$

The panel t and $Panel\ \rho$ are called within dimension residual-based cointegrated tests, while the group panel dimension, which is the group t and $group\ \rho$.

The null hypothesis of no panel cointegration in each statistic is expressed as:

$$H_0 :\ \theta_I = 1\ for\ all\ i = 1\ \dots\dots\dots\dots\dots.N,$$

The alternative hypothesis of the between dimension based on the statistics procedure is stated as

$$H_1 :\ \theta_I < 1\ for\ all\ i = 1\ \dots\dots\dots\dots\dots.N,$$

Where a similar value of $\theta_I = \theta$ is not essential.

Tables 7-8 present the results of the cointegration tests with the associated hypothesis.

Hypothesis Tested:

Null hypothesis: No panels are cointegrated.

Alternative: all panels are cointegrated.

Table 7: *Panel cointegration test results*

Pedroni Cointegration Test	$Panel$ $v - stat$	$Panel$ $\sigma - stat$	$Panel$ $\rho\rho - stat$	$Panel$ $adf - stat$	$Group$ $Panel$ $\sigma - stat$	$Group$ $Panel$ $\rho\rho - stat$	$Group$ $Panel$ $adf - stat$
$Statistic$	-4.19**	-10.2**	1.51*	-1.6*	0.84**	-1.5*	1.24**
$p - values$	(0.00)	(0.01)	(0.06)	(0.003)	(0.023)	(0.053)	(0.01)

Notes. *** *Significant at 1%*

*** Significant at 5%*
**Significant at 10%*

Kao Cointegration tests results

Null hypothesis: No panels are cointegrated.

Alternative: all panels are cointegrated.

Table 8. *Kao Cointegration tests results*

Cointegration Test	*Statistic*	*p-value*
ADF	-1.78***	0.0001

Notes. **** Significant at 1%*

According to the panel cointegration test results, both Pedroni (1999, 2001) and Kao (1999) admitted that the variable iscointegrated. To confirm the results of the first-generation panel cointegration and account for cross sectional independency, we applied the second generation Westerlund panel cointegration approach and results are presented in Table 9. The findings confirmed that the variables were cointegrated.

Table 9: Westerlund Panel Cointegration Tests

Statistic	Value	Z-value	P-value
G_a	–3.68**	–6.81	0.00
G_t	–5.54**	4.72	0.00
P_t	–9.67*	–1.91	0.01
P_a	–3.01	1.25	0.50

*Note: The symbols **, and * represent the significance levels at 5%, and 10%, respectively.*

The result has a serious implication for the East and Southern African countries. First, it implies that climate policy must be long term or tailored towards a long-term prospect. Second, the driving factors of CO_2 emissions in these East and Southern African countries need to be carefully managed.

Panel VAR/VEC Granger Causality / Block Exogeneity Wald

As earlier stated, this study is framed on the Panel Granger causality approach which has been widely used in many empirical studies for multidisciplinary analysis (Granger, 1969; Bressier & Seth, 2011; Dimitrescu & Hurlin, 2012; Kuruppuarachchi & Premachandra, 2016). Two reasons justify the use of this approach. First, it provides an avenue to determine the short and long dynamics of the variables. Second, it revealed the vector error correction term (VEC), which determines the convergence speed of the variables to their equilibrium position. Table 10 summarises the results of the VAR/VEC Granger causality approach implemented.

Table 10. *VAR/VEC Granger Causality/Block Exogeneity Wald Tests*

Independent Variable		*The Direction of Causality Dependent variable*							*Long run*
	$\Delta CO2_t$	Δfin_t	Δhdi_t	ΔGDP_t	ΔTr_t	ΔUrb_t	$\Delta Agric_t$	ΔInv_t	$VECT_{t-i}$
$\Delta CO2_{t-k}$	-	2.6 [0.26]	2.17 [0.16]	1.81 [0.36]	0.6 [0.19]	11.7** [0.00]	18.2** [0.00]	1.61 [0.53]	-0.015** (0.00)
Δfin_{t-k}	5.5** [0.00]	-	4.7** [0.00]	0.91 [0.18]	1.4 [0.21]	21.1** [0.00]	1.16 [0.31]	0.13 [0.81	-0.003** (0.01)
Δhdi_{t-k}	6.3** [0.00]	0.29 [0.20]	-	0.3 [0.41]	0.7 [0.66]	3.9* [0.00]	12.0** [0.00]	0.46 [0.47]	-0.85** (0.00)
ΔGDP_{t-k}	6.2** [0.00]	0.59 [0.15]	0.003 [0.72]	-	4.9** [0.00]	0.008 [0.62]	19.9** [0.00]	27.4** [0.00]	-12.8** (0.02)
ΔTr_{t-k}	8.0** [0.00]	2.5 [0.23]	0.11 [0.54]	7.1** [0.00]	-	0.18 [0.15]	6.49** [0.00]	5.6** [0.00]	0.42 (0.41)
ΔUrb_{t-k}	7.5** [0.00]	1.66 [0.19]	1.89 [0.22]	1.04 [0.19]	1.9 [0.45]	-	18.0*** [0.00]	1.39 [0.17]	-0.41** (0.01)
$\Delta Agric_{t-k}$	25.6** [0.00]	0.63 [0.45]	0.06 [0.35]	23.6** [0.00]	9.6** [0.00]	0.07 [0.39]	-	5.3** [0.00]	0.08** (0.01)
ΔInv_{t-k}	0.69 [0.21]	0.4 [0.81]	10.1** [0.00]	17.0** [0.00]	1.3 [0.28]	0.15 [0.24]	22.9*** [0.00]	-	-0.06** (0.01)

Notes. *CO2 emission per capita (CO2), financial development (fin), human development index (HDI), income per capita (GDP), Trade openness (tr), Agricultural as the level of economic activities (Agr), real domestic absorption (investment).*
**** Significant at 1%*
*** Significant at 5%*
**Significant at 10%*

The results of the Panel VAR/ VEC Granger causality applied are discussed as follows.

First, the variable has long- and short-run relations and the speed of convergence is relatively sluggish. Second, financial development (Fin), human capital (Hdl), and GDP per capita unidirectionally Granger cause CO_2 emissions, which conform with earlier findings (Ahmed et al., 2020, Shahbaz, 2013, 2016). Second, bidirectional causality runs through agriculture, urbanisation and CO_2 emissions. The error correction term (ect) that determines the convergence speed among the variables was negative and significant but sluggish for most of the estimated models. Third, GDP per capita, globalisation (Tr) and urbanisation unidirectionally Granger cause agriculture. The medium through which financial development and human development affect environmental sustainability has been identified as agriculture associating factors such as globalisation and urbanisation. Our results are consistent with prior studies in other regions and confirmed the IPCC (2014) report for the East and Southern African on access to finance, poor human capital development and vulnerability to climate change.

Four main implications can be deduced from the results. First, the presence of long and short-run prospects among the climate indicators reflects that policy needed to mitigate CO_2 among countries in the East and Southern Africa must be tailored towards the long term. This is important as the short-term prospect might endanger the future potential human capital in the region due to a foreseeable accumulated effect of CO_2 on the population. Second, the unidirectional causality running from financial development to human capital andCO_2 emissions indicates that investment in human capital development and access to finance can help the East and Southern African countries reduce CO_2 emissions and avert the unavoidable consequence of climate change.

Second, the bidirectional Granger causality observed between agriculture, urbanisation, and CO_2 raises several concerns. East and Southern African regions are predominately agricultural-driven. The urban area is a centre of tourism and hence, intervention programs through smart agricultural technology are urgently needed to promote environmental sustainability.

VAR Forecasting Error Variance Decomposition

In this section, we present the various variance decomposition of the variables. The goal is to determine the contributions of each variable to the other in the autoregressive process. One major importance attached to variable decomposition is the ability to reveal more information on each variable's aggregate contributions that can be by shocks from other variables. Table 11 presents the results of the variance decomposition and impulseresponse function using Cholesky in Fig. 1-5.

Table 11. Variance Decomposition

Variance Decomposition for CO_2									
Period	S. E	CO_2	fin	hdi	GDP	Tr	Urb	$Agric$	Inv
1	0.041212	100.0000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2	0.056113	97.45278	0.011448	0.223813	1.599667	0.126005	0.307728	0.035200	0.243355
3	0.066097	94.40116	0.047224	0.276419	3.385915	0.093682	0.483399	1.019756	0.292447
4	0.073379	90.90361	0.200012	0.299868	4.771694	0.077812	0.660647	2.690388	0.395971
5	0.078930	87.46678	0.469365	0.311510	5.886432	0.071280	0.838079	4.359702	0.596852
6	0.083271	84.24009	0.840192	0.319556	6.837632	0.067283	1.019864	5.775424	0.899962
7	0.086726	81.26081	1.290287	0.328312	7.659985	0.063624	1.207885	6.887482	1.301614
8	0.089512	78.53902	1.797236	0.339850	8.358863	0.060100	1.402878	7.707953	1.794098
9	0.091784	76.07124	2.340643	0.355027	8.932611	0.057164	1.605054	8.273393	2.364865
10	0.093660	73.84530	2.902095	0.374068	9.381046	0.055323	1.814388	8.630349	2.997426
Variance Decomposition for Financial development									
Period	S. E	CO_2	fin	hdi	GDP	Tr	Urb	$Agric$	Inv
1	0.074204	0.334738	99.66526	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2	0.097197	0.432350	97.63245	0.636961	0.277219	0.598035	0.103345	0.171700	0.147944
3	0.114400	0.315936	96.89360	1.184754	0.417531	0.622430	0.128046	0.150299	0.287407
4	0.127798	0.291438	96.40086	1.687384	0.504485	0.507560	0.128260	0.147196	0.332813
5	0.138639	0.391516	95.84786	2.109047	0.574348	0.463435	0.118698	0.145064	0.350027
6	0.147618	0.594696	95.14303	2.461345	0.636396	0.566707	0.106448	0.133272	0.358107
7	0.155206	0.867208	94.26252	2.752862	0.694285	0.843815	0.096391	0.121131	0.361784
8	0.161737	1.177064	93.19781	2.989474	0.751358	1.300879	0.092029	0.129327	0.362054
9	0.167469	1.497789	91.94491	3.175789	0.810652	1.934949	0.095997	0.180955	0.358958
10	0.172604	1.808686	90.50363	3.316095	0.874628	2.738408	0.110303	0.295802	0.352450
Variance Decomposition for Human Capital									
Period	S. E	CO_2	fin	hdi	GDP	Tr	Urb	$Agric$	Inv
1	4.964325	0.126129	0.695302	99.17857	0.000000	0.000000	0.000000	0.000000	0.000000
2	7.488833	0.629793	1.269578	97.93312	0.023522	0.098841	0.041458	0.000583	0.003109
3	9.277426	1.045953	1.059987	97.41720	0.208113	0.189706	0.065973	0.005028	0.008038
4	10.63183	1.385353	0.838258	96.85074	0.616788	0.211749	0.073029	0.016695	0.007383
5	11.70474	1.701624	0.692910	96.09769	1.192106	0.207227	0.072500	0.029810	0.006135
6	12.57982	2.020303	0.633886	95.17757	1.861488	0.197595	0.068899	0.033511	0.006749

7	13.30852	2.353674	0.648792	94.13950	2.563198	0.189754	0.064348	0.030198	0.010534
8	13.92482	2.706036	0.718884	93.02990	3.247965	0.185666	0.059865	0.032260	0.019425
9	14.45256	3.077484	0.825261	91.88642	3.879680	0.185875	0.055890	0.053059	0.036328
10	14.90922	3.466050	0.951365	90.73761	4.435469	0.190430	0.052560	0.101445	0.065077
Variance Decomposition for GDP									
Period	S. E	CO_2	fin	hdi	GDP	Tr	Urb	$Agric$	Inv
1	13530.49	10.67405	0.021258	0.062906	89.24179	0.000000	0.000000	0.000000	0.000000
2	18607.68	7.939967	0.016897	0.041542	91.08660	0.145384	0.023858	0.364663	0.381087
3	21235.78	7.045816	0.018715	0.138006	91.06132	0.111691	0.040215	1.124387	0.459854
4	23116.41	6.308376	0.059433	0.339069	86.50651	0.153113	0.065993	5.912102	0.655409
5	24857.89	5.576491	0.186689	0.530219	78.49644	0.262723	0.090362	13.68373	1.173345
6	26606.02	4.895930	0.414097	0.645713	69.46957	0.365535	0.108819	21.94565	2.154685
7	28367.93	4.307699	0.724246	0.675434	61.17257	0.409530	0.120904	28.94659	3.643026
8	30117.27	3.827777	1.084993	0.643512	54.34446	0.393107	0.127844	33.97919	5.599119
9	31830.43	3.456275	1.462419	0.584387	49.04195	0.352318	0.131204	37.04316	7.928289
10	33495.56	3.187113	1.827958	0.528168	45.00787	0.339320	0.132339	38.46974	10.50749
Variance Decomposition for Trade									
Period	S. E	CO_2	fin	hdi	GDP	Tr	Urb	$Agric$	Inv
1	9220.847	7.377219	2.86E-06	0.736751	48.78208	43.10394	0.000000	0.000000	0.000000
2	13048.84	6.118716	0.043006	0.462685	43.72429	49.13839	0.001125	0.374596	0.137200
3	15668.12	5.477774	0.033602	0.393924	37.95408	55.64357	0.001156	0.281609	0.214290
4	17755.56	4.912573	0.031946	0.340727	32.55409	61.08086	0.001471	0.658824	0.419507
5	19552.65	4.411054	0.062115	0.288057	27.89111	65.24580	0.001560	1.258326	0.841977
6	21151.87	3.972494	0.125529	0.246674	24.10182	68.28205	0.001454	1.761062	1.508924
7	22599.27	3.590330	0.213821	0.233043	21.14104	70.37110	0.001286	2.042745	2.406636
8	23923.32	3.257414	0.315938	0.261767	18.87043	71.68283	0.001156	2.112053	3.498411
9	25144.45	2.968705	0.421546	0.342185	17.12820	72.36653	0.001109	2.036884	4.734842
10	26278.37	2.721527	0.522657	0.477633	15.76788	72.55091	0.001139	1.895662	6.062595
Variance Decomposition for Urbanisation									
Period	S. E	CO_2	fin	hdi	GDP	Tr	Urb	$Agric$	Inv
1	226.6909	1.449564	0.556166	0.239831	0.208185	0.023825	97.52243	0.000000	0.000000
2	327.8985	4.614855	0.424821	0.224063	0.870987	0.078337	93.77629	0.001113	0.009540
3	410.7422	5.157227	0.352324	0.314092	1.038879	0.110086	93.00528	0.005014	0.017097
4	483.2178	5.106394	0.320632	0.394792	0.917188	0.134762	93.09373	0.004401	0.028099
5	549.9396	4.845056	0.306357	0.457572	0.736690	0.148736	93.46037	0.004254	0.040965
6	613.3467	4.515601	0.297950	0.501462	0.592311	0.157784	93.87087	0.006979	0.057046
7	674.8666	4.173390	0.289324	0.529890	0.507526	0.165874	94.24818	0.009425	0.076389
8	735.3881	3.842920	0.277631	0.546699	0.477827	0.175057	94.57228	0.009677	0.097906
9	795.5067	3.534992	0.262105	0.555249	0.489542	0.186122	94.84355	0.008430	0.120007
10	855.6478	3.253671	0.243222	0.558268	0.527879	0.199076	95.06911	0.007698	0.141078
Variance Decomposition for Agricultural									
Period	S. E	CO_2	fin	hdi	GDP	Tr	Urb	$Agric$	Inv

1	13193.78	10.71780	0.026941	0.047152	89.08984	0.001715	5.28E-05	0.116500	0.000000
2	18112.40	7.968028	0.025643	0.030067	91.11112	0.191628	0.026492	0.189759	0.457265
3	20691.26	7.038123	0.031196	0.139897	90.62977	0.151149	0.043808	1.382339	0.583714
4	22581.82	6.255531	0.083778	0.349176	85.39399	0.159477	0.070267	6.841749	0.846037
5	24361.03	5.484597	0.229469	0.539496	76.80299	0.222904	0.094636	15.16041	1.465503
6	26157.59	4.778985	0.476326	0.648131	67.43506	0.280792	0.112554	23.69608	2.572068
7	27970.59	4.179649	0.802342	0.669814	59.01300	0.293708	0.123851	30.72752	4.190113
8	29770.73	3.699472	1.173156	0.631909	52.19484	0.267940	0.129970	35.63899	6.263730
9	31533.70	3.335395	1.554567	0.569914	46.96550	0.242446	0.132581	38.51240	8.687194
10	33247.79	3.078927	1.918829	0.513541	43.02311	0.268540	0.133071	39.73222	11.33177
Variance Decomposition for Investment									
Period	S. E	CO_2	fin	hdi	GDP	Tr	Urb	$Agric$	Inv
1	9612.872	9.444857	0.097800	0.215726	82.27504	0.245974	0.001658	0.167647	7.551295
2	13123.07	7.157562	0.120025	0.141736	80.46584	0.171093	0.011617	0.140934	11.79119
3	15014.91	6.119496	0.151924	0.148788	76.91767	0.378703	0.021607	1.931098	14.33071
4	16628.37	5.096996	0.267502	0.201905	68.66566	0.706977	0.038137	8.286306	16.73652
5	18336.37	4.191683	0.493744	0.228208	58.15805	0.973440	0.051438	16.63905	19.26438
6	20163.34	3.519844	0.808125	0.214084	48.29420	1.080789	0.058934	24.05646	21.96757
7	22060.53	3.093775	1.171246	0.180936	40.37117	1.037258	0.061613	29.26030	24.82371
8	23978.42	2.880003	1.546005	0.158238	34.49358	0.910416	0.061186	32.18438	27.76620
9	25883.45	2.838067	1.904155	0.168329	30.27209	0.781540	0.059078	33.27651	30.70024
10	27757.87	2.933844	2.227207	0.222253	27.23060	0.721500	0.056247	33.08453	33.52381
Cholesky Ordering: CO_2 Financial development Human Capital GDP Trade Openness Urbanisation Agriculture Investment									

Fig1. Historical Decomposition using Generalised weights

Fig 2. Variable responses using Cholesky

Fig 3. Variance decomposition using Cholesky

Fig. 4. Historical Variance Decomposition using Cholesky

Fig. 5. VAR Structural Residual using Cholesky

Table 11 shows the variance decomposition variables. It displays the effects of unit shocks that are applied separately to the error of each VAR equation.The past value of CO2 has a stronger influence on itself as it contributed higher to the forecasting error compared to other factors in short term. Similarly, there is never a shock of more than 10% of the series' contribution to carbon emissions from other factors with agriculture having the highest. Figs. 1-5 show the impulse responses analysis and variable decomposition using the Cholesky one deviation innovation. The impulse response function traces the long-run response in the equation system for each variable to one standard deviation shocks. Agricultural value-added and real GDP appear to contribute more to the shocks observed in carbon emission but differ in magnitude.

Concluding implications and future research directions

The STIRPAT paradigm provides a rich framework for inference policy-making regarding how financial development and human capital influence reduction in CO_2 emissions and by extension, informs policy marking forenvironmental sustainability, despite having an unavoidable consequence on the global population. This study has combined the STIRPAT framework and advanced panel VAR/VEC Granger causality tests to examine the underlyingrelationship in order make relevant contributions to the extant literature. We have investigated the criticality of financial development and human capital inreducing CO_2 emissions in East and Southern Africa. The study has also used six advanced panelapplications which include: (a) the cross-sectional dependency test (Breusch & Pagan, 1979), LM (Pesaran, 2004) , Scaled LM (Pesaran, 2004) CD tests; (b) combined LLC (2002) and IPS (2003) panel unit root tests; (c) combined Pedroni (1999, 2004) and Kao (1999) panel cointegration tests; (d) different lag criteria ranging from the AIC, SC, andHQ for selecting the optimal lag lengths of the variables; (e) implementing an advanced panel VAR/VEC Granger causality approach to uncouple the short and long-run relationships among the factors; (f) employing variance decomposition within the framework of Cholesky in order to explore the contributory information of each variable in the autoregressive process. Our finding shows that financial development and human capital development are crucial factors in carbon abatement. The channelsthrough which financial development and human can affect CO_2 have been identified as agriculture and urbanisation. Our result is consistent with previous finding in other regions of the world (Asongu et al., 2020; Shahbaz, 2013, 2016; Odhiambo, 2020).

Two policy measures are urgently required to promote financial development and human capital development in East and Southern Africa. First, financial inclusion among the unbanked population needs to be promoted urgently, and this should not be related to bank profitability but to the fundamental role of the bank in financial intermediation which is to facilitate the transformation of mobilised deposits into credit for both clients with bank accounts and a previously unbanked population. Second, the study recommends critical investments in social change through greater access to knowledge, financial services and loanable funds, opening up investment opportunities and fostering well-being.

Policy recommendations pertaining of the above frameworks of financial development and human capital improvements should be considered by policy makers concurrently with agricultural and urbanisation measures which have been established in this study as the main channels by which human capital and financial development influence CO_2 emissions. It follows that the attendant financial development and human capital measures should be oriented toward favouring more environmental-friendly agricultural and green urbanisation. Financial development and human capital improvements for green urbanisation and sustainability of the environment should therefore be the main policy framework.

It is would be worthwhile for future studies to assess the relevance of established findings in other regions of Africa and by extension, other regions in the developing world. Moreover, engaging other variables of financial development, human capital and environmental sustainability would also provide more insights into what is known so far about the established nexuses.

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Appendix

East and Southern African Countries Examined			
1	Kenya	8	South Sudan
2	Tanzania	9	Mozambique
3	Uganda	10	Zambia
4	Ethiopia	11	Mauritius
5	Rwanda	12	Burundi
6	Djibouti		
7	Madagascar		