GVCPs in Zimbabwe's Critical Sectors in the Face of Environmental Pollution and Climate Change: The Case of Agriculture and Mining Sectors

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GVCPs in Zimbabwe's Critical Sectors in the Face of Environmental Pollution and Climate Change: The Case of Agriculture and Mining Sectors

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List of abbreviations and acronyms

ARDL	Auto Regressive Distributive Lag
CO2	Carbon Dioxide
DVX	Domestic Value Added
FVA	Foreign Value Added
GCP	Global Carbon Project
GDP	Gross Domestic Product
GHGs	Green House Gases
GMB	Grain Marketing Board
GVCP	Global Value Chain Participation
I-O	Input-Output
LCA	Life Cycle Assessment
MRIO	Multi-Regional Input-Output
OECD	Organisation for Economic Co-operation and Development
WIOD	World Input-Output
ZIMSTAT	Zimbabwe National Statistics Agency

Abstract

This study analyses global value chain participation (GVCP) in Zimbabwe's two critical sectors of agriculture and mining in the face of environmental pollution and climate change. Mining and agriculture are Zimbabwe's largest export sectors by value, and the later plays a critical role towards food security. However, the two sectors have potential conflicting interests on land as well as environmental pollution. The study employs the Auto Regressive Distributive Lag (ARDL) and ARDL-EC (error correction), to analyse short-run and long-run relationships. The results indicate that, in the short run, lagged GVCP agriculture exerts positive pressure on GVCPagriculture by 0.66% while, climate change (droughts) and pollution (CO2 emissions) exert negative pressure on GVCP agriculture at 5% and 1% level of significance, respectively. However, GVCP mining and population growth did not significantly reduce GVCP agriculture. Moreover, GVCP mining and population growth increase transport CO2 emissions both in the short run and long run at 5% and 1% level, respectively. Thus, mining is not environmentally neutral. In the long run, interaction between population growth and mining rents reduce transport CO2 levels at 5% level. The study recommends government to raise mineral taxes for those participating in mining and use the revenues to subsidise the agriculture sector. In the agriculture sector, government can remove import tax on agriculture equipment such irrigation equipment as well as the removal of other restrictions including opening up grain price to market forces to increase quality and level of participation. The government should continue enacting and enforcing policies which minimize pollution, such as limits on carbon emissions.

Key words: *Global value chain participation; Agriculture; Mining; Environmental pollution; Zimbabwe.*

JEF Classification codes: *C01; F13; F17; F18.*

1. Introduction and background

Global value chain (GVC) is considered a vehicle for development in Africa and the world over. Extant literature shows that GVC participation influences economic performance via various channels, including through effects on diversification (Avom et al., 2020), jobs (Ndubuisi and Owusu, 2023, 2021), and volatility (Dalhermer et al., 2023). Gains associated with value chain trade are not symmetrically distributed (Common Market for Eastern and Southern Africa [COMESA], 2020) and, to some extent, are a mixed blessing for the environment (Ali et al., 2022). On the negative side, scale effects of trade and growth increase the environmental footprint of economic activity, producing more shipping costs across countries and more waste in the aggregate (Ali and Ginique, 2022; Ali, 2021; Bataka, 2021). However, participation in global value chains does appear to lead to positive outcomes (Hua et al., 2021; Fei et al., 2020; Song & Wang, 2017), even when there is significant heterogeneity across income groups (Organisation for Economic Co-operation and Development [OECD], 2015). These conflicting results motivated our study to assess the extent of shipping environmental impacts borne by Zimbabwe in the mining and agriculture global value chain participation (GVCP), given that its structure is largely characterized by supply or export of raw materials. Moreover, Zimbabwe's participation in global value chains is not well documented compared to other sub-Saharan African countries and the developed world (Angella et al., 2023). We also noted that various studies employed different proxies for environmental pollution without necessarily disaggregating GVC participation by sector at macro level, the studies which included sectoral disaggregation mainly focused on micro level or firm-level participation. It is this knowledge gap that this paper seeks to fill by looking at global value chain participation (GVCP) in Zimbabwe's two critical sectors of agriculture and mining at macro level.

In retrospect, Zimbabwe used to be the bread basket of Africa reflecting its significance in global value chain participation (GVCP) in agricultural products and food in general. However, with climate change as manifested by increased frequency of natural disasters like floods, droughts and cyclones, the country's food security status significantly declined. As the country lost its bread basket status, a surge in GVCP in minerals started to emerge in the country. Yet the two sectors are intertwined. On one hand, farmers generally utilize the top soil while miners make use of the layers below. In some instances, conflicts between farmers and miners hog the limelight and these are solved using the Mines and Minerals Act of 1983 which makes it clear that mining supersedes farming. On the other hand, agriculture provides food and sustenance for the miners whilst some miners invest their earnings in agriculture (Ministry of Lands, Agriculture, Water, and Rural Resettlement, 2022). Thus, a formal analysis of the relationship between global value chain participation of these two critical sectors, in the context of environmental pollution and climate change in Zimbabwe, could add value to various stakeholders within or across value chains.

It is against this milieu that, specifically, the study sets to, firstly, analyse the impact of a surge in Zimbabwe's GVCP in the mining sector on GVCP in agriculture and secondly, investigate the extent to which GVCP in mining and GVCP in agriculture influences environmental pollution through shipping (transport) activities in Zimbabwe. In line with the above objectives, the study poses the following research questions: (i) Is the increased GVCP in mining impacting GVCP in agriculture in any way? (ii) To what extent do GVCP in mining and GVCP in agriculture influence the level of transport environmental pollution in Zimbabwe?

To achieve this, we adopted a macroeconomic level approach, based on sectoral data for the agriculture and mining sectors; however, the adopted approach is limited by data availability. Our macroeconomic approach draws motivation from other developing countries' and sub-Sahara Africa studies which omitted or dropped Zimbabwe in their analysis due to EORA MRIO I-O data inconsistences, such as Ali et al. (2022), Organisation for Economic Co-operation and Development [OECD] (2019), and Yasmeen et al. (2019Therefore, GVC participation variables are computed by the researchers using data from the World Bank database since the data and variables are not available on the EORA MRIO I-O database. The estimation follows the Borin and Mancini (BM) (2016) refinement of the Koopman, Wang and Wei (KKW) (2014) breakdown of aggregate exports in GVCP estimation, as well as from Ndubuisi and Owusu (2023), Amendolagine et al. (2019), Carril-Caccia and Pavlova (2020), and Ndubuisi and Owusu (2021).

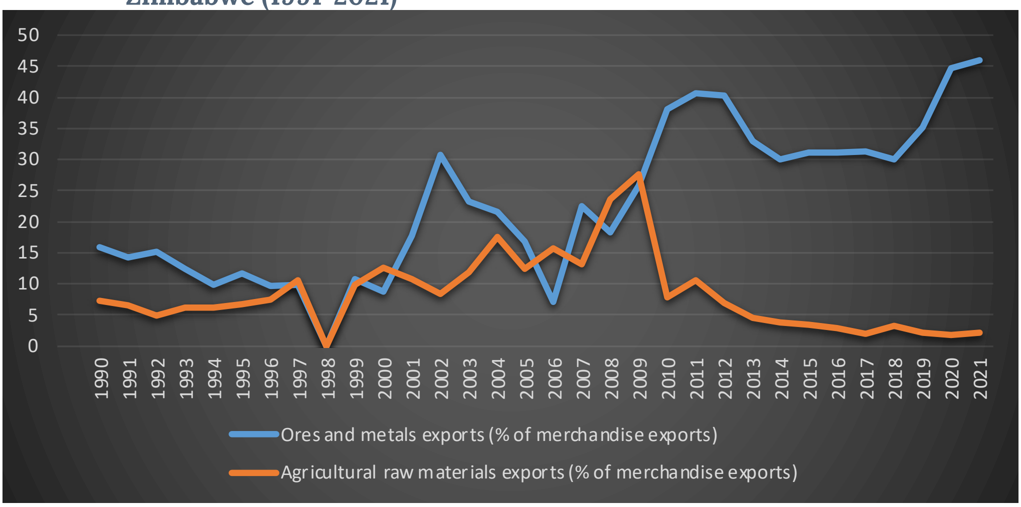
Using annual data sourced from the World Bank databases and Global Carbon Project (GCP) for CO2 emissions for the period 1990–2021, and an empirical model borrowed from Ali et al. (2017), Pata (2018a, b), Attiaoui and Boufateh (2019), Malik et al. (2020), Adom and Bekoe (2020), and Bosah et al. (2021), as well as the application ARDL estimation technique, we tested the following hypothesis: firstly, that there exists a trade-off between GVCP in mining and GVCP in agriculture in Zimbabwe, and secondly, that GVCP in mining and agriculture does not influence the level of transport environmental pollution in Zimbabwe.

The remainder of this study is structured as follows. Section 2 provides an overview of the significance of Zimbabwe's agriculture and mining sectors. Section 3 presents a brief literature review. Section 4 discusses the empirical methods. Section 5 presents the results and their discussion, while we conclude the study in Section 6.

2. The significance of Zimbabwe's agriculture and mining sectors in export trade

Agriculture, mining, and tourism are the main pillars of the Zimbabwean economy, which has succeeded in developing strong export industries in each of these sectors, and GVC forward participation for the country is more skewed towards agriculture and mining. For example, exports of agricultural commodities and minerals (led by platinum, gold, nickel, and tobacco) account for nearly 90% of total merchandise exports (Zimbabwe National Statistics Agency [ZIMSTAT], 2021). More recently, exports in lithium are also gaining significant traction due to increased global demand. Agricultural activities provide employment and income for 60–70% of the population, supplies 60% of the raw materials required by the industrial sector, and contributes 40% of total export earnings (ZIMSTAT, 2020). Underscoring this decrease are elements attributable to a combination of economic and climatic change related factors. In the past decade and half, Zimbabwe has remained a highly food-insecure country, with millions of people in need of food aid. Figure 1 summarizes the trends in contribution of the mining and agriculture sectors to merchandise exports for the period 1991–2021.

Figure 1: Merchandise exports (%) from agriculture and mining sectors in Zimbabwe (1991–2021)



Source: World Bank Data, 2022.

In 2023, Zimbabwe instituted a "beneficiation" (any process that improves (benefits) the economic value of the ore) policy to encourage local downstream processing through export taxes on "un-beneficiated" platinum group metals, diamonds, and lithium. This encourages local firms in mining to participate in mining value chains. For the agriculture sector, policy and programmes (such as Pfumvudza and other presidential inputs scheme) effort are centralized around the staple crop, maize, in the presence of other key commodities such as tobacco. Policies are essential to control supply, trade, and prices of strategic cereals such as maize and wheat. These include temporary import and export bans (depending on the domestic supply situation), an input subsidy scheme called "Command Agriculture", price support, consumer subsidies, and the single-buyer regime. With the latter measure, the Grain Marketing Board (GMB) administers the Strategic Grain Reserve and acts as buyer of last resort for all grains and cotton. Moreover, policies that link the agriculture and mining sectors such as the Communal Land Act of 1983 and the Mines and Minerals Act Chapter 21:05 gives more power to land users in the mining sector than those in the agriculture sector. As such, the development of policies that favours both sectors may be necessary to mitigate the effects of global value chain activities of the mining sector to GVC activities of the agricultural sector as they compete on their use of the resources and the environment in general.

Given the context of conflicting outcomes between the two sectors which are both of significance to the economic structure of Zimbabwe, this study intends to provide a formal analysis to the relationship between the two sectors and establish how GVCPs in the two sectors are likely to contribute to shipping or transport environmental pollution.

3. What literature says

The conceptual framework and the relevant Zimbabwe legal framework

We build our conceptual framework and variables linkage from the cobweb theory, whose contributors include Moore and Smith (1922), Moore (1925), Hass and Ezekiel (1926), Working (1922), Working (1927), and empirical work by Bean (1929), Gouel (2012), Glöser-Chahoud et al. (2016), and Chaudhry and Miranda (2018), which indicated that the dominant factor explaining changes in acreage (agriculture land size for a crop) was the price received by farmers in the preceding season or price received two seasons prior (Myers et al., 2010). Other variables impacting production for field crops include weather, the price of competing products, propensity to consume from income, transportation costs, and foreign supply (Shen et al. 2022; United Nations Conference on Trade and Development [UNCTAD], 2013; Schultz, 1932). We draw from the model contributions of the importance of prices or returns from other competing products, that suggests a link between mining produce and agriculture produce as competing products. Hence the importance of global value chain mining in determining global value chain in agriculture, thus endogenous cycles in commodity markets.

The conceptual framework is also influenced by two key legal frameworks in Zimbabwe which are relevant to this study. These are the Communal Land Act of 1983 and the Mines and Minerals Act Chapter 21:05. The former is important because it plays a pivotal role to Zimbabwe's land tenure system which is approximately 42% of the land areas and where around 66% of the country's population resides. While all the communal land is vested in the State President who has powers to permit its occupation and use in accordance with the Communal Land Act, Section 179 of the Mines and Minerals Act of 1983, makes it clear that mining supersedes farming. In the presence of competing interests between mining and agriculture, the usufruct rights of farmers leave them unprotected when a mining project comes up, hence a linkage between GVCP mining and GVCP agriculture is suggested.

GVCPs and the environment

As the world grapples with environmental crises and climate change, sustainable development has become the central issue, with global value chains at the core of economic development. The increased recognition of the literature on causal effects of environmental pollution and climate change continues to give weight to the discussions on GVCP. Significant contribution to the discussions that is relevant to this study on GVCP and the environment include that of Ali et al. (2022), Ali and Gninigué (2022), Asia Development Bank (2021), Bennett et al. (2019), Gaylor (2015), OECD (2019), Wang et al. (2021), and Yasmeen et al. (2019).

The study by Ali et al. (2022) conducted for 112 developing countries for the period 1990–2018, for the ICT industry, which employed the second-generation panel analysis and Driscoll and Kraay estimation technique found that, GVCPs increases environmental pollution while digitalization reduces CO2 emissions. Our study contributes further to the debate by determining whether GVCPs are indeed a mixed blessing in the case of Zimbabwe's two critical sectors of agriculture and mining in the context of environmental pollution and climate change. Another study by Ali and Gninigué (2022) done for 41 African countries for the period 1990–2018 on global value chains participation and structural transformation in Africa, utilising the second-generation panel data and Driscoll and Kraay estimation technique, also established that environmental pollution is highly correlated with GVCs participation and the U-inverted hypothesis between GDP and CO2 emissions is verified, adds to GVCPs and environmental pollution literature.

Furthermore, the study and annual report by the Asia Development Bank (2021) on “Towards a green and inclusive recovery” which used mixed methods, desk review, and technical studies, suggest that 2.1 gigaton of carbon dioxide (CO2) equivalent (〚CO〛_2e) emissions are associated with international trade, and of concern from this study is that environmental impacts of international trade are borne upstream by African countries while value creation takes place downstream. It is, therefore, important to assess the impact of GVCPs in mining and GVCPs in agriculture on environmental pollution in Zimbabwe.

Bennett et al. (2019) also attempted to make an analysis for Zimbabwe value chains for a period of six months, between October 2017 and March 2018 specifically on “Beef value chain analysis in Zimbabwe”. Environmental analysis in the study was conducted using Life Cycle Assessment (LCA), and the findings were that beef VC has a low environmental impact on human health and resource depletion, and that global warming is the main contributor to damages on human health in the Zimbabwean beef VC. Therefore, there is need to consider impact of other global value chains such as the mining value chain participation on the environment as well and on a larger scale beyond that of six months.

Gaylor (2015) conducted a study on mining value chains and green growth in South Africa, utilizing desk review, secondary data analysis, and policy perspectives. The findings of the study were that mining operations and downstream activities continue to result in the pollution, degradation or complete loss of ecosystems, species' habitat and biodiversity, with detrimental consequences on local economic structures (such as agriculture and tourism) and communities (from a health perspective notably). This further supports the findings of Ali et al. (2022) that GVC participation could be a mixed blessing, and we intend to examine this for Zimbabwe.

Moreover, a study by the OECD (2019) which included OECD member countries on “Mining and green growth in the EECCA region”, suggested that the mining sector has substantial backward and forward linkages to other parts of the economy. Shifting mining to a more sustainable path can potentially improve environmental performance in existing linkages as well as develop new ones. This includes acting as a conduit for new technologies, such as automation and digitalization, as well as a driver for environmental service providers. Mining also contributes to climate change through the release of Green House Gases (GHGs) in the beneficiation and smelting processes, as well as fossil fuels for transportation, operation, and power generation. This evidence supports the proposition by Ali et al. (2022), that GVC participation could be a mixed blessing. Therefore, this study intends to check whether GVCP in mining is indeed a mixed blessing or not with regards to transport emissions in the case of Zimbabwe.

Wang et al. (2021) also conducted a study on developing countries, namely, Brazil, Russia, India, China, and Mexico (1995–2009) on global value chains, technological progress, and environmental pollution utilizing WIOD database, and the findings were that there is a threshold in value chain development that influences environmental quality. When the degree of participation in a value chain is lower than the threshold, technological progress can result in an increase in pollution; otherwise, technological progress can reduce emissions. These results provide a theoretical basis and practical suggestions for developing countries to realize their own energy conservation, emission reductions, and green development while participating in globalized value chains. Hence the need to analyse impact of GVCPs in Zimbabwe's two sectors on environmental pollution and climate change.

Yasmeen et al. (2019) conducted a study for 39 countries for the period 1995–2009, tracing the trade–pollution nexus in global value chains, evidence from air pollution indicators utilizing the World Input-Output (WIOD) classifications database. The study established a nonlinear relationship between the value-added trade and eight air pollution indicators. The study results contribute to conflicting findings on GVCPs and environmental pollution; therefore, motivating us to research the topic further for Zimbabwe.

Why GVCP mining and agriculture for Zimbabwe?

Although African countries are trying to revive national and regional level industrialization through value chains, this is characterized by the dominance of agricultural and raw materials. African exports tend to enter at the very beginning of GVCs. A high share serves as inputs for other countries' exports, reflecting the still-predominant role of agriculture and natural resources in African exports (COMESA, 2020). Even for South Africa, the most industrialized economy in the region, exports from the mining value chain and agricultural products made up 60% of total exports in the late 2010s. For the rest of southern African countries such as Zimbabwe, commodities accounted for 95% of exports, with extractive industries contributing over 85%. This therefore proves that global value chain participation in agriculture and mining is crucial for the growth of African countries like Zimbabwe (UNCTAD, 2021).

The slow growth in the SADC region compared to other peer economies can be explained in large part by its high degree of dependence on commodity exports, especially minerals, fuels, and agricultural produce. Dependence especially on agriculture, mining, and fuel exports is associated with vulnerability to climate change and international commodity price cycles. It leads to rapid expansion when favourable climatic conditions are experienced and when international prices spike (United Nations Conference on Trade and Development (UNCTAD), 2021). It is, therefore, important to ensure sustainability of the agriculture and mining sectors in the case of Zimbabwe through the design of informed polices to minimize the down phase in the country's progress and value chain participation.

4. Empirical methods

Data and measurements

The data employed in this study is secondary data sourced from the World Bank databases and Global Carbon Project (GCP) for CO2 emissions. To establish whether a surge in Zimbabwe's GVCP in the mining sector has impact on GVCP in agriculture, and how GVCPs contribute to the levels of transport environmental pollution, the study utilized annual data from 1990 to 2021. Detailed below are the variables used in this study and their measurements.

Sectoral global value chain participation estimation for Zimbabwe

We source GVC estimation methods from Ndubuisi and Owusu (2023), Amendolagine et al. (2019), Carril-Caccia and Pavlova (2020), and Ndubuisi and Owusu (2021), to define the sector's GVC participation level in period t in the intermediate and value-added trade as:

$$\text{GVC participation} = \frac{FVA_{it}}{TE_t} + \frac{DVX_{it}}{TE_t}$$

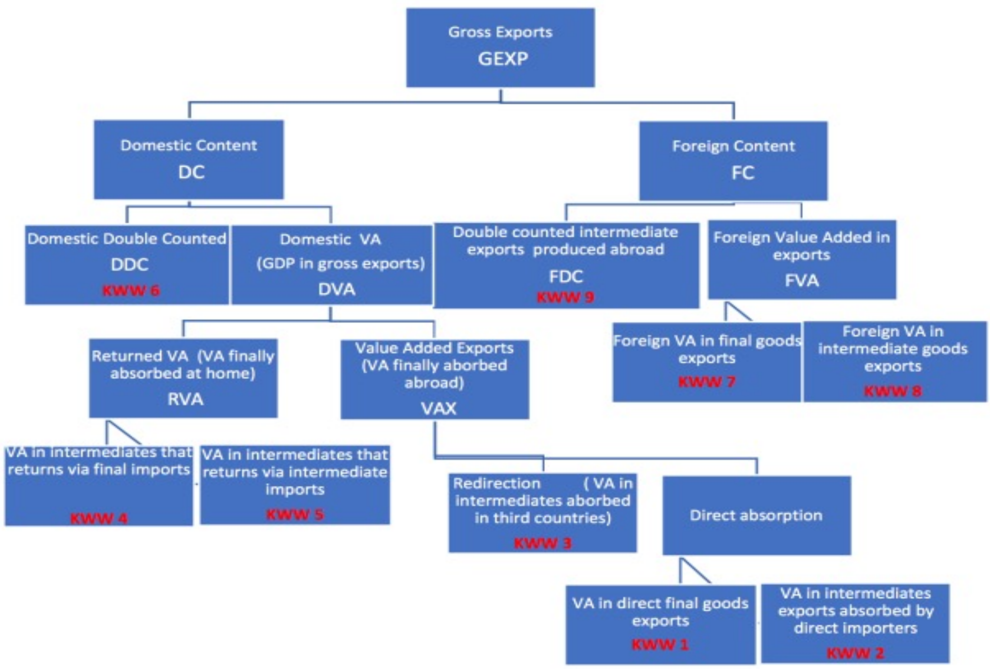
Where: FVA_{it} is the share of foreign value-added used in Zimbabwe's sectoral exports, DVX_{it} is the share of Zimbabwe's sectoral domestic value-added that enters as inputs in the exports of other countries, and TE_t is the country's gross export. The first term in the right-hand side of the equation (FVA) captures the extent of the country's backward integration in GVC, while the second term (DVX) captures the extent of its forward GVC integration. Backward participation or vertical specialization would imply importing semi-processed or primary products, adding value to produce a consumable or processed product and exporting it for further value addition or final consumption. Forward participation would imply exporting primary products, such as metal ores, agricultural products or textile raw materials, and less processed material for value addition by the trading partner (Hummels et al., 2001).

GVC literature acknowledges that a country participates in GVC either as a "buyer" and/or "seller" of intermediate inputs. A country is considered upstream if it primarily supplies inputs to others, while it lies downstream if it uses a large portion of intermediates from others to produce final goods for exports (i.e., activities closer to final demand). Since Zimbabwe's agriculture sector and mining sector primarily supplies inputs to other countries in the value chain, it is considered upstream and its DVX tends to be higher than the FVA components in GVC participation. Furthermore, for the mining sector, we make the rational assumption that only machinery is imported and there are no inputs to be converted to a final product for this sector, rather the minerals are supplied in their raw form to other countries hence the sector is very upstream and its exports for the sector are mainly DVX. Although backward participation is very weak (Shepherd, 2022), both forward and backward participation will be considered for the agriculture sector and mining sector.

For this study, GVC participation in each sector = $\frac{FVA_{it}}{TE_t} + \frac{DVX_{it}}{TE_t}$

The estimation of GVC participation variables follows the Borin and Mancini (BM) (2016) refinement of the Koopman, Wang and Wei (KKW) (2014) breakdown of aggregate exports in GVCP estimation to obtain the sectors' FVA and DVX, presented in Figure 2.

Figure 2: Borin and Mancini (BM) refinement of the Koopman, Wang and Wei (KWW) breakdown of aggregate exports in GVCP estimation



Source: Nenci, S. 2020. Food and Agriculture Organization of the United Nations (FAO)

Pollution measure

To examine the extent to which *GVCPs* contributes to the level of transport environmental pollution [objective (ii)], transport Co2 emission (*co2t*) was used as a dependant variable as GVCP mining and GVCP agriculture both contribute to Co2 emissions through transportation of the produce, raw materials, and labour. The use of transport CO_2 is borrowed from a suggestion by Ali et al. (2022), that the CO2 emissions (pollution) are strongly associated with international transport along the GVCPs.

Control variables

The control variables used in this study were informed by literature, with population growth and mining rent identified by Ali et al. (2022), Liu et al. (2019), and Bataka (2021) as key variables in the analysis of the effects of GVCPs on environmental pollution; while climate and pollution are considered important variables in determining GVCP in agriculture[1], hence their inclusion also in this study. Table 1 is a summary of the variables and their measurements.

Table 1: Study variables

Variable	Measurement	Definition	Source
Global value chain in agriculture (*gvcpa*)	Agriculture domestic value added (DVX) expressed as a ratio of the country's gross exports (TE) plus foreign value added (FVA) expressed as a ratio of the country's gross exports (TE) gvcpa= $\frac{DVX}{TE}+\frac{FVA}{TE}$	Decomposition of agriculture exports SITC section 2[2]	World Bank Yearly 1990–2021
Global value chain in mining (*gvcpm*)	Mining DVX expressed as a ratio of the country's gross exports and FVA expressed as a ratio of the country's gross exports gvcpm= $\frac{DVX}{TE}+\frac{FVA}{TE}$	Decomposition of mineral and metal ores and exports, comprise the commodities in SITC sections 27, 28 & 68[3]	World Bank Yearly 1990–2021
Climate change (*climate*)	Dummy variable (1 = climate change, 0 otherwise)	Climate change is defined as the period when drought is experienced	SADRI Drought Resilience Profile for Zimbabwe

continued next page

Table 1 Continued

Variable	Measurement	Definition	Source
Environmental pollution (co2)	Total CO2 emissions equivalent for the agriculture sector (metric tons) [Summation of agriculture methane emission (co2 equiv), agric nitrous oxides emission (co2 equiv) and greenhouse gas emissions (co2 equivalent)]	Total carbon dioxide equivalent emissions are/refer to emissions stemming from the burning of fossil fuels and include carbon dioxide produced during consumption of solid, liquid, and gas fuels and gas flaring	World Bank Yearly 1990–2021
Transport carbon emissions *Co2t*	Transport CO2 emissions (% of total fuel combustion)	Transport carbon dioxide equivalent emissions are/refer to CO2 emissions from the combustion of fuel for all transport activity[4]	World bank Yearly 1990–2021
Population (pop)	Annual population growth rate for Zimbabwe (percentage)	Annual population growth rate is the exponential rate of growth of midyear population from year t-1 to t, expressed as a percentage and it counts all residents regardless of legal status or citizenship	World Bank Yearly 1990–2021
Mining Prosperity (minpros)	Mineral rent (% of gross domestic product)	Mineral rent is the difference between the value of production for a stock of minerals at world prices and their total costs of production. Minerals included in the calculation are tin, gold, lead, zinc, iron, copper, nickel, silver, bauxite, and phosphate	World Bank Yearly 1990–2021

Econometric model

To analyse the effects of GVCPs in mining on GVCP in agriculture, we used an empirical model borrowed from Ali et al. (2017); Pata (2018a, b), Attiaoui and Boufateh (2019), Malik et al. (2020), Adom and Bekoe (2020), Bosah et al. (2021), and Charemza and Deadman (1997) and is presented as Equation 1 as follows:

$$\ln gvcpa_t = \sigma_0 + \sigma_1 \ln gvcpm_t + \sigma_2 \ln co2_t + \sigma_3 climate_t + \sigma_4 \ln pop + \varepsilon_t \quad (1)$$

Where: *gvcpa* is global value chain participation in agriculture, *gvcpm* is the global value chain participation in mining, while the control variables are: *climate*, which represents changes in climate or the prevalence of drought over the years and is identified as a determinant of gvcpa since agriculture in Zimbabwe is mainly rainfall dependent among small scale farmers and can affect agriculture production levels (Avom et al., 2020; Asongu et al., 2017; Khan et al., 2018); *Co2*, which is an annual measure of pollution emanating from the agriculture sector; and *pop* captures annual population growth for Zimbabwe. ε_t is the error term, assumed to be spatially and temporally correlated while t is time period and σ_0, σ_1, σ_2, σ_3 are parameters to be estimated. Therefore, objective (i) was achieved through analysis of this model and results are presented in Table 4 column (1).

To examine the extent to which GVCPs contributes to transport environmental pollution [objective (ii)], transport CO2 emission (*co2t*) was used as a dependent variable since GVCP mining and GVCP agriculture both contribute to CO2 mainly through transportation of the produce, raw materials, and labour. The control variables, population growth rate (*pop*) and prosperity in mining (*minpros*) were also considered as determinants of transport CO2 emission and the model (2) was specified as follows:

$$\ln co2t_t = \sigma_0 + \sigma_1 \ln gvcpm_t + \sigma_2 \ln gvcpa_t + \sigma_3 \ln pop_t + \sigma_4 \ln popminpros_t + \varepsilon_t \quad (2)$$

The results for model (2) are presented in Table 4 columns (2) and (3).

5. Results and discussion

This section presents the preliminary results of the study. Table 2 presents the summary statistics of the main variables included in the model. Variables were linearized for compactness before analysis, and all the results were generated using STATA 15.

Table 2: Summary statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Lngvcpa	32	-2.840522	.8109307	-4.290469	-1.09895
Lngvcpm	32	-1.775747	.607279	-2.729682	-.9551373
Lnminpros	32	.7610276	.7296964	-.5712429	1.94732
Lnpop	32	.3104732	.489921	-.6465487	.986175
lnco2	32	10.61978	.0674161	10.48766	10.75
Climate	32	.65625	.4825587	0	1
lnco2t	32	2.81132	.321623	2.181871	3.295386
lnpopminpros	32	.276252	.5768329	-.9476358	1.791402

In effect, 32 observations were used in this analysis with climate change as a dummy variable.

Pre-estimation tests

Pre-estimation tests were conducted prior to estimation of the regression model, and results are attached in the appendix as Table A1. The results of the pre-estimation tests informed the choice of the ARDL estimation techniques as the appropriate estimation technique. Time series tests such as stationarity, cointegration, correlation, and lag length selection were performed. Serious multicollinearity issues exist when $|x| \geq 0.85$ where x is the respective variable, the correlation matrix tests presented in Table A3 and Table A4 (in the appendix). Overall, no problem of multicollinearity was observed among the variables to be used in both the gvcpa and the co2t models. The optimal estimates using the Akaike Information Criterion (AIC) were ARDL (1, 0, 0, 0, 1) for the gvcpa equation, and ARDL (2, 0, 1, 0, 1) for the co2t equation for the optimal lag selection.

The results of the Augmented Dickey Fuller (ADF) test presented in Table A1 (in the appendix) show that gvcpa, gvcpm, mining prosperity (minpros), co2, population (pop), co2t and the interaction variable, popminpros were stationary at 1st difference I (1), while climate change (climate) was stationary at level I (0). Therefore, the model contains variables which follow an I (1) and I (0) process and the responsiveness of gvcpa to the independent variables need to be estimated, an ARDL model becomes appropriate. This was followed by testing whether or not a long-run relationship exists among the variables.

An ARDL bounds cointegration test proposed by Peseran et al. (2001) was performed for the two equations and the results showed that there is cointegration in the co2t equation only; therefore, the need to estimate both the short-run and long-run relationships for co2t equation, and a short-run relationship for the *gvcpa* equation. Table A2 (in the appendix) informed the results of the ARDL Bounds Test. The value of F-statistics was 6.282 and is greater than the II bound therefore long-run cointegration was present in the co2t equation at 1% significance level.

A number of post-estimation tests were also conducted including heteroscedasticity tests, normality, and stability tests among others. The tests presented in the appendix show that there is no problem of heteroscedasticity and the models are stable as indicated in the CUSUM results presented in the appendix. Thus, a discussion of results then follows in the subsequent section.

Discussion of results

The short-run ARDL for GVCP agriculture (gvcpa) analysis results of the estimation are indicated in Table 3 column (1). The past values of global value chain participation in agriculture (gvcpa) are significant at 1% significance level. The lagged values of GVCPagric exert positive pressure on GVCPagric whereby a 1% change (increase) in the past value in GVCPagric will increase current period GVCPagric by 0.66% in the short run. This can be supported by the cobweb cycle in agricultural produce marketing, which explains the importance of past earnings or prices in determining the current level of production by farmers, where higher earnings in the previous period motivates farmers to produce more in the current period (Chaudhry and Miranda, 2018; Glöser-Chahoud et al., 2016). Therefore, higher returns in the previous period's participation in global value chain positively influence current levels of GVCPagric. Climate change (droughts) and pollution (CO2 emissions) are also significant at 5% and 1% levels of significance, respectively. The two variables exert negative pressure on gvcpa, with a 1% increase in pollution in the agriculture sector resulting in 3.52% decrease in gvcp agric at 1% level of significance, while the presence of drought in a given period results in a 0.42% decline in global value chain participation in agriculture for the Zimbabwean economy.

However, GVCP mining (gvcpm) and population growth were found not to significantly reduce GVCPagric. Therefore, the findings refute the hypothesis of this study that, there is a trade-off between GVCP in mining and GVCP in agriculture. The results indicate that climate change and environmental pollution are among the key factors that affect the level of GVCP agriculture in Zimbabwe. Therefore, implementing policies that would promote the acquisition of irrigation equipment, borehole drilling, and construction of dams, and environmentally friendly methods of farming would increase global value chain participation in agriculture for Zimbabwe.

Regression results:

(1) *Impact of gvcp mining, pollution, climate, and population growth on gvcp agriculture,*

(2) & (3) *Short-run and long-run impact of gvcp mining, gvcp agriculture, population growth, and mining prosperity on the level of transport CO2 emissions.*

Table 3: Regression results

Independent regressors	GVCP agriculture/ gvcpa	CO2t Emission *(transport CO2 emissions)* **Short-run Estimates**	CO2t Emission *(transport CO2 emissions)* **Long-run Estimates**
	(1990–2021)	**(1990–2021)**	**(1990–2021)**
	(1)	**(2)**	**(3)**
gvcpa (-1)	0.66***		
	(0.09)		
Gvcpm	−0.09	082**	0.16**
	(0.11)	(0.04)	(0.06)
CO2	-3.52***		
	(1.23)		
Climate	-0.42**		
	(0.16)		
Pop	-0.03	0.30***	0.62***
	(0.22)	(0.07)	(0.18)
Pop(-1)	-0.24		
	(0.22)		
Popminpros		-0.06	-0.29**
		(0.06)	(0.10)
Gvcpa		0.06	-0.12
		(0.05)	(0.07)
CO2t(-1)		0.27*	
		(0.13)	
ECT		-0.48***	
		(0.11)	
C	36.6***	1.33***	1.33***
	(13.09)	(0.29)	(0.29)
R-squared	0.8827	0.9327	0.9327
Adjusted r-squared	0.8534	0.9070	0.9070
Prob(f-statistic)	0.000	0.000	0.00
Durbin–Watson stat	2.1368	2.0523	2.0523

Note: ***, **, and * significant at <1%, <5%, and <10%, respectively.
Source: Authors' own calculation.

The ARDL-ECM estimation for the CO2t (transport CO2 emissions) equation results showed the short-run and long-run relationships between the independent variables and the dependent variable. The estimation results of ARDL-ECM short-run coefficients can be seen in Table 3 column (2). One of the important variables in the model is the error correction term (ECT (-1)), which was negative and significant, which means the ARDL-ECM model in the short-run estimates was robust. In addition, ECT (-1) can also be referred to as the speed of adjustment. This means the variables had a significant influence on environmental pollution with a speed of adjustment of 0.48%.

The results of both the short-run and long-run CO2t model from the ARDL-ECM analysis indicated that GVCP in mining and population has the effect of increasing transport CO2 emission in Zimbabwe at 5% and 1% level of significance, respectively. This is likely because mining in general involves substantial levels of transporting mineral ores from mines to processing plants, as well as employees from residence to mines and processing plants on a daily basis. Furthermore, the increase in population implies an increase in economic activities and increased use of transport hence transport CO2 emissions are likely to be high (Akcil and Koldas, 2006). The results support the findings of studies by Ali and Giniguè (2022), Ali (2021), and Bataka (2021) that, indeed the international trade activities in the context of globalization, including GVCPs, is subject to environmental pollution at some point (Ahmed et al. 2021; Aker et al. 2016).

Furthermore, the results indicate that a 1% increase in GVCP mining increases transport environmental pollution by 0.08% in the short run and 0.16% in the long run, while a 1% increase in population leads to an increase in transport environmental pollution by 0.30% in the short run and 0.62% in the long run. Therefore, the null hypothesis of this study that, GVCPs does not influence the level of transport pollution in Zimbabwe is rejected and, from the findings, it can be concluded that the mining activities in Zimbabwe are not environmentally neutral. The results also support the findings of a number of other studies (World Bank, 2014; OECD, 2015; Gaylor, 2015) that were conducted, which indicated that global value chain participation in mining results in negative impacts to the environment and climate in general.

However, the results of the long run relationship indicate that the interaction between population and mining prosperity (*popminpros*) has the effect of reducing CO2 levels in the atmosphere at 5% level of significance. Thus, a unit increase in population and mining rents results in a 0.29% reduction in CO2 levels in the atmosphere. These results may be used to explain the induced investment hypothesis, where increased mineral rents play an important role in the acquisition of clean technologies such as vehicles that are environmentally friendly and more efficient in burning of fuels (Bataka, 2021; Fei et al., 2020; Chen et al., 2021; Song and Wang, 2017; OECD, 2019). Both the short-run and long-run results indicate that GVCP agriculture does not significantly affect the level of pollution (transport CO2 emissions). This supports the study by Bennett et al. (2019), on beef value chain analysis in Zimbabwe, which indicated that the Green House Gases (GHGs) emissions from Zimbabwean beef production systems are low in comparison to external Life Cycle Assessment (LCA) studies. The study, therefore, infers the conclusion that the VC in agriculture has low negative impacts on the environment, human health, and resource depletion.

6. Conclusion and recommendations

The results indicate that pollution and climate change play a significant role in influencing the level of GVCP agriculture, while GVCP mining has no significant influence on GVCP agriculture. The results also indicate that GVCP mining and population growth contribute more to pollution than GVCP agriculture, both in the short run and long run, while mining prosperity with population growth have the effect of reducing pollution levels in the long run. This presents several opportunities in which policies can be tailored to improve the level of GVCP in agriculture. The policy recommendations derivable thereof from the preliminary results include but not limited to the following.

Firstly, government can raise mineral taxes for those participating in mining and use the revenues to subsidize the agriculture sector. The incentives to the agriculture sector can take various forms such as removal of import duties for agriculture equipment such as irrigation equipment and other inputs given that most inputs in the sector are still being imported (these include seed, fertilizer, and mechanization such as tractors). This can be complemented by also removing export taxes on agriculture exports in order to promote foreign currency generation and participation in the global value chains. In general, there are several restrictions which currently exist in the country which make it difficult for exporters to participate in the international market such as food export taxes and a sole buyer in the market. Whilst the rationale behind this policy stance is ensuring food security in the country, the lack of international competition has stifled the market price for grains since the government backed Grain Marketing Board (GMB) as the sole authorized buyer of such commodities. Opening the pricing of grains to market forces is likely to increase both the level and quality of participation in global value chains in the agriculture sector.

Government should also continue enacting policies which minimize the impact of climate change and pollution emanating from mining activities. This can be attained through revising the incentive structure around encouraging the use of clean fuels in processes such as mineral extraction and transportation. For example, the use of solar powered irrigation systems may be encouraged through tax cuts on imported solar equipment. The significant pressure of GVCP mining on pollution (where increases in GVCP mining leads to increased transport CO_2 emission) level reflects the need for stringent pollution polices in the sector. The country can adopt a number of policies which include but not limited to carbon emission limits and checks on all equipment and vehicles to be used in the mining sector, among others. This should be relatively easy to implement given that the country is a participant of the Paris Agreement and other subsequent international agreements on climate change.

Notes

1. Climate and Clean Air Coalition (2023), found that agriculture is the largest human-derived source of methane emissions (40%), and methane is second to carbon dioxide in driving climate change. Methane also increases the production of tropospheric ozone, an air pollutant that reduces plant productivity and crop yields, as well as harming human health.

2. All crude materials except fuels excluding divisions 22, 27 (crude fertilizers and minerals excluding coal, petroleum, and precious stones), and 28 (metalliferous ores and scrap).

3. 27 (crude fertilizer, minerals); 28 (metalliferous ores, scrap); and 68 (non-ferrous metals). Mineral rents are the difference between the value of production for a stock of minerals at world prices and their total costs of production. Minerals included in the calculation are tin, gold, lead, zinc, iron, copper, nickel, silver, bauxite, and phosphate.

4. Except for international marine bunkers and international aviation. This includes domestic aviation, domestic navigation, road, rail and pipeline transport

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Appendix

Table A1: Result of unit root test

Variables	Augmented Dickey–Fuller (ADF) test				Comments
	Level		First Difference		
	Intercept	P-value	Intercept	P-value	
Gvcpa	-0.93	0.777	-6.714***	0.0000	Stationary 1st difference
Gvcpm	-1.498	0.5344	-6.711***	0.0000	Stationary 1st difference
co2	-0.817	0.8140	-5.471***	0.0000	Stationary 1st difference
co2t	-1.097	0.7163	-5.968***	0.0000	Stationary 1st difference
Pop	-1.590	0.4884	-7.274***	0.0000	Stationary 1st difference
Minpros	-2.417	0.137	-5.885***	0.0000	Stationary 1st difference
Climate	-3.857***	0.0024			Stationary at level

Note: *, **, *** means 10%, 5%, and 1% confidence level, respectively.
Source: Authors' estimation.

Table A2: ARDL bounds test for the CO2t equation

Test Statistic	Value	K
F-statistic **Critical Value Bounds**	**6.282**	**4**
Significance	I0 Bound	I1 Bound
10%	2.45	3.52
5%	2.86	4.01
1%	3.74	5.06

Table A3: Correlation matrix for GVCPagri equation variables

	lngvcpa	Lngvcpm	lnminpros	lnco2	climate
Lngvcpa	1.0000				
Lngvcpm	-0.1768	1.0000			
Lnminpros	-0.1360	-0.0870	1.0000		
lnco2	0.4208	-0.2188	-0.1597	1.0000	
Climate	-0.2661	0.3952	0.3286	-0.4820	1.0000

Table A4: Correlation matrix for CO2t equation variables

	lnco2t	Lngvcpm	Lngvcpa	lnminpros	Lnpop
lnco2t	1.0000				
Lngvcpm	0.5156	1.0000			
Lngvcpa	-0.6351	-0.1768	1.0000		
Lnminpros	-0.2619	-0.0870	-0.1360	1.0000	
Lnpop	0.5021	0.1730	-0.6396	0.1154	1.0000

Table A5: ARDL GVCPagric model: Impact of GVCP mining, pollution, climate, and population on GVCP agriculture

Variables	Constant	lngvcpa (-1)	lngvcpm	lnco2	Climate	lnpop
Coefficients	38.20***	0.62***	-0.06	-3.67***	-0.48***	-0.07
Std. Error	13.13	0.11	0.11	1.23	0.17	0.22
T-statistic	2.91	5.87	-0.56	-2.96	-2.87	-0.32
P-value	0.008	0.000	0.57	0.007	0.009	0.74
R-squared		0.8881		Prob(F-statistic) 0.0000		
Adj. R-square		0.8589		Observations 30		
F-statistic		30.43		Durbin-Watson 2.136823 (7, 31)		

Note: ***, **,* means significant at 1%, 5%, and 10% confidence level, respectively
Source: Authors' estimation.

Table A6: ARDL Pollution model: Short-run impact of GVCP mining, GVCP agriculture, population, and mining prosperity on the level of transport CO2 emissions

Variables	Constant	ECT	LD(lnco2t)	D(lngvcpm)	D(lngvcpa)	D(lnpop)	D(lnpopminpros)
Coefficient	1.33***	-0.48***					
-0.27**							
	0.08**	0.06	0.30***				
-0.06							
Std. Error	0.29	0.12	0.13	0.03	0.05	0.07	0.06
T-statistic	4.61	-4.14	-2.08	2.34	1.11	4.32	-1.00
P-value	0.000	0.000	0.050	0.029	0.279	0.000	0.329
R-squared	0.9285		Durbin-Watson (9,30)			2.052341	
Adj. R-square	0.9013		Prob(F-statistic)			0.0000	
F-statistic	34.11		Observations			30	

Note: ***, **,* means significant at 1%, 5%, and 10% confidence level, respectively.
Source: Authors' estimation.

Table A7: ARDL Pollution model: Long-run impact of GVCP mining, GVCP agriculture, population, and mining prosperity on the level of transport CO2 emissions

Variables	Lngvcpm	Lngvcpa	lnpop	lnpopminpros	Constant
Coefficient	0.17**	-0.12	0.63***	-0.29**	1.33***
Std. Error	0.06	0.07	0.18	0.11	0.29
T-statistic	2.70	-1.67	3.58	-2.70	4.41
P-value	0.013	0.109	0.002	0.013	0.000

Note: ***, **,* means significant at 1%, 5%, and 10% confidence level, respectively.
Source: Authors' estimation.

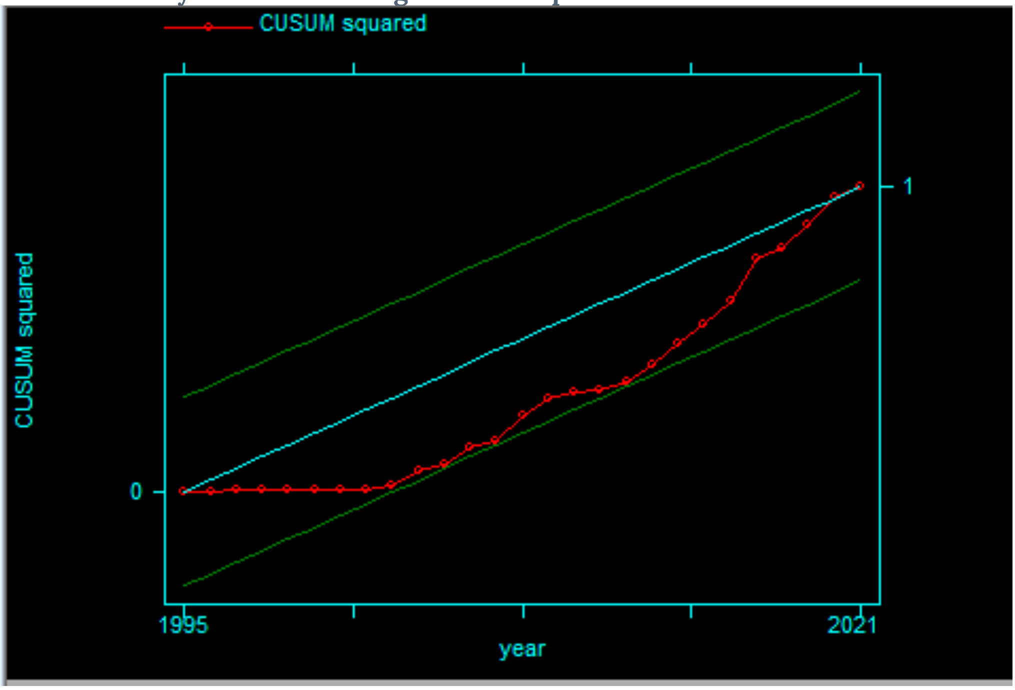
Post tests

GVCPagric equation

Table AP1: Heteroscedasticity test results

```
Durbin-
Watson d-statistic(  7,    31) =  2.136823

bgodfrey, lags (1)
Breusch-Godfrey LM test for autocorrelation
---------------------------------------------------------------------------
   lags(p)  |       chi2           df            Prob > chi2
-------------+-------------------------------------------------------------
     1      |      0.504           1             0.4776
---------------------------------------------------------------------------
                  H0: no serial correlation

imtest, white
White's test for Ho: homoskedasticity
          against Ha: unrestricted Heteroskedasticity

        chi2(26)     =    29.72
       Prob > chi2  =    0.2794

Cameron & Trivedi's decomposition of IM-test

---------------------------------------------------
           Source         |     chi2     df     p
---------------------      +----------------------------
  Heteroskedasticity |     29.72     26    0.2794
          Skewness       |    16.93      6     0.0096
          Kurtosis         |     1.10      1     0.5962
---------------------      +----------------------------
            Total           |    46.93     33    0.0549
---------------------------------------------------
```

Model stability test for GVCP agriculture equation



Posts tests for CO2t equation

Dwatson
Durbin-Watson d-statistic(11, 30) = 2.052341
.
.bgodfrey, lags (1)
Breusch-Godfrey LM test for autocorrelation

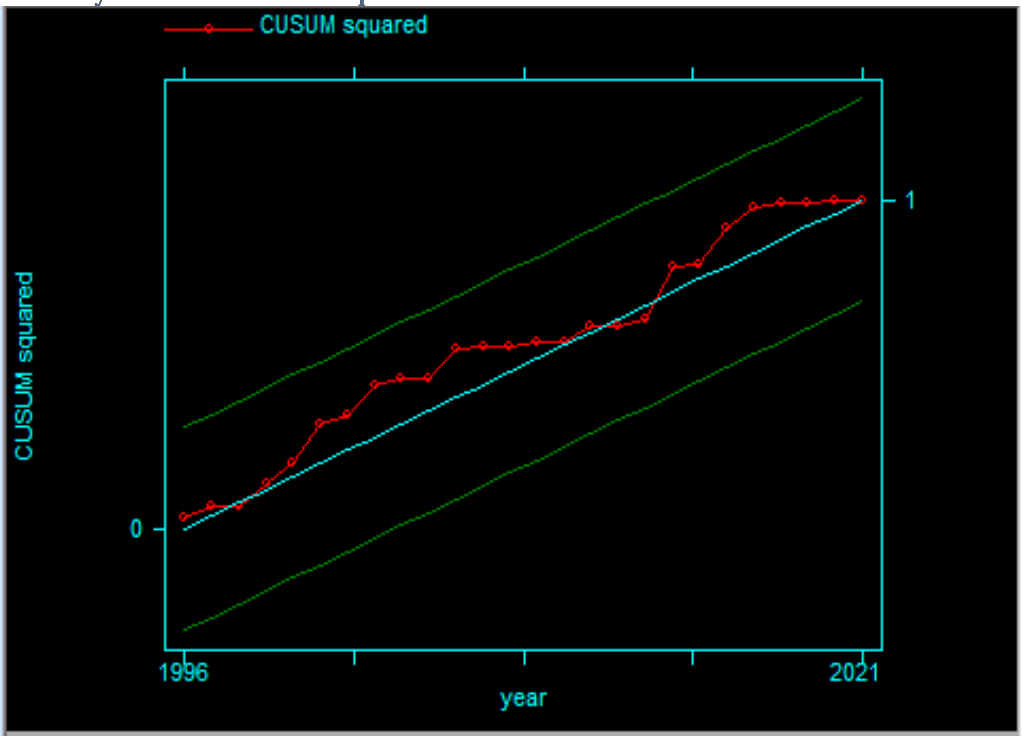
lags(p)	chi2	df	Prob > chi2
1	0.093	1	0.7600

H0: no serial correlation
.
imtest, white
White's test for Ho: homoscedasticity
against Ha: unrestricted heteroscedasticity
chi2(29) = 30.00
Prob > chi2 = 0.4140

Cameron & Trivedi's decomposition of IM-test

Source	chi2	df	p
Heteroskedasticity	30.00	29	0.4140
Skewness	12.53	10	0.2514
Kurtosis	1.33	1	0.2490
Total	43.85	40	0.3114

Stability test for the CO2t equation



The data set

Year	GVCPA	GVCPM	Minpros	POP	CO2t	Climate	CO2
1990	0.062454	0.13672	1.229287	2.68096	12.86154	0	44660
1991	0.048115	0.106114	6.556822	2.576033	8.862876	1	43430
1992	0.038269	0.118732	7.009879	2.509119	12.20994	1	44860
1993	0.048364	0.096536	5.66061	1.431392	11.81764	0	39120
1994	0.048195	0.078055	5.961453	0.588137	11.27577	1	39190
1995	0.052637	0.090275	3.694206	1.239656	14.38038	1	39040
1996	0.058571	0.075185	3.990079	1.660946	14.74048	0	43160
1997	0.083559	0.077516	3.10029	1.634689	15.99402	0	41810
1998	0.077148	0.077853	0.804858	1.623404	15.56535	0	43730
1999	0.07175	0.07876	0.7036	1.44504	20.31149	0	46630
2000	0.094895	0.06524	0.801847	1.003969	14.44695	0	43270
2001	0.055023	0.090062	0.564823	0.642663	13.48563	0	44160
2002	0.083328	0.306103	1.320306	0.616567	13.72549	1	39960
2003	0.106797	0.208363	1.215036	0.75796	13.98601	1	37290
2004	0.164764	0.202989	2.064641	0.701856	12.74817	1	37810
2005	0.118247	0.161235	1.945654	0.523851	12.85297	1	38290
2006	0.16059	0.071871	4.45015	0.861223	13.38912	1	36830
2007	0.15869	0.269206	5.529277	0.969119	12.78586	1	37670
2008	0.282782	0.219074	2.405775	0.798207	13.69128	1	35870
2009	0.333221	0.309992	0.912793	1.026265	15.04178	0	37730
2010	0.070254	0.341777	2.284566	1.25365	13.00108	1	41190
2011	0.076154	0.290856	3.025829	1.438339	20.59621	0	43950
2012	0.062661	0.363021	1.961655	1.822309	22.55245	0	43190
2013	0.042037	0.307122	1.511742	2.163267	24.40476	1	42510
2014	0.035547	0.283786	1.484881	2.191391	22.28024	1	39100
2015	0.029737	0.264275	0.804563	2.136294	24.7191	1	42140
2016	0.023442	0.253518	0.903846	2.081806	25.79546	1	39040
2017	0.019906	0.314254	1.712349	2.04362	25.82301	1	39100
2018	0.014633	0.136526	3.09237	2.020537	26.28782	1	41910
2019	0.015901	0.253154	2.72964	1.989253	26.69415	1	41770
2020	0.013698	0.352954	3.882433	2.031112	26.72301	1	42031
2021	0.018155	0.384759	3.9	2.045715	26.98782	1	42411

Mission

To strengthen local capacity for conducting independent, rigorous inquiry into the problems facing the management of economies in sub-Saharan Africa.

The mission rests on two basic premises: that development is more likely to occur where there is sustained sound management of the economy, and that such management is more likely to happen where there is an active, well-informed group of locally based professional economists to conduct policy-relevant research.

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