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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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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 in agriculture exerts positive pressure on GVCP in agriculture by 0.66% at 1% significance level while, climate change (droughts) and pollution (CO_2 emissions) exert negative pressure on GVCP in agriculture at 5% and 1% level of significance, respectively. This implies that higher returns in the previous period's participation in global value chain positively influence current levels of GVCP in agriculture while droughts and pollution reduce global value chain participation in agriculture. However, GVCP in mining and population growth did not significantly reduce GVCP in agriculture. Moreover, GVCP in mining and population growth increase transport CO_2 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 CO_2 levels at 5% level. This supports the induced investment hypothesis, where increased mining rents facilitate the adoption of cleaner technologies, such as fuel-efficient and environmentally friendly vehicles. 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 as irrigation equipment as well as the removal of other restrictions including opening 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.

Keywords: Global Value Chain Participation, Agriculture, Mining, Environmental Pollution, Zimbabwe

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.), jobs (Ndubuisi and Owusu) and volatility (Dalheimer et al.). Gains associated with value chain trade are not symmetrically distributed and, to some extent, are a mixed blessing for the environment (Ali et al.). 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; Bataka). However, participation in global value chains does appear to lead to positive outcomes (Hua et al.; Fei et al), even when there is significant heterogeneity across income groups. 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 (Montfaucon et al.). 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 GVCP in Zimbabwe's two critical sectors of agriculture and mining at macro level.

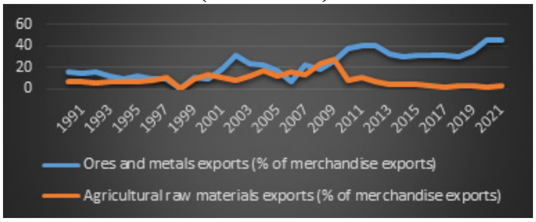
In retrospect, Zimbabwe used to be the bread basket of Africa reflecting its significance in global value chain participation (GVCP) in agricultural products and food in general. However, with climate change as manifested by increased frequency of natural disasters like floods, droughts and cyclones, 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. 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.

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. 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). Underscoring this decrease are elements attributable to a combination of economic and climatic change related factors. 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

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. 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. 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.

Review of Literature

The Conceptual Framework and the Relevant Zimbabwe Legal Framework

We build our conceptual framework and variables linkage from the cobweb theory (Moore and Smith; Working), and empirical work by (Bean; Gouel; Glöser-Chahoud et al.; Chaudhry and Miranda). 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 the Communal Land Act of 1983 and the Mines and Minerals Act Chapter 21:05. The former 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. There are significant and relevant studies by (Ali et al.; Ali and Gniniguè), established that, there is high correlation between environmental pollution and GVC's participation where GVCPs increases environmental pollution while digitalization reduces CO_2 emissions. These studies also established that emissions are associated with international trade, and of concern is that environmental impacts of international trade are borne upstream by African countries while value creation takes place downstream.

Moreover, (Montmasson-Chair) conducted a study on mining value chains and green growth in South Africa, 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). The (OECD) study 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. Thus shifting mining to a more sustainable path can potentially improve environmental performance in existing linkages as well as develop new ones.

However, a study by (Bennett et al.) conducted for Zimbabwe beef value chains using Life Cycle Assessment (LCA), found 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. While that by (Yasmeen et al.) conducted for 39 countries for the period 1995-2009, established a nonlinear relationship between the value-added trade and eight air pollution indicators. The study by (Wang et al.) conducted on selected a study on developing countries for the

(1995-2009) on global value chains, technological progress, and environmental pollution found that there is a threshold in value chain development that influences environmental quality. Suggesting that GVCs may be environmentally friendly to a certain level but not entirely neutral.

Given these conflicting findings on GVCPs and environmental pollution, 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.

Empirical Methods

Data and Measurements

The study employed secondary annual data from 1990 to 2021 sourced from the World Bank databases and Global Carbon Project (GCP) for CO_2 emissions. Detailed study variables and their measurements follows accordingly.

Sectoral Global Value Chain Participation Estimation for Zimbabwe

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

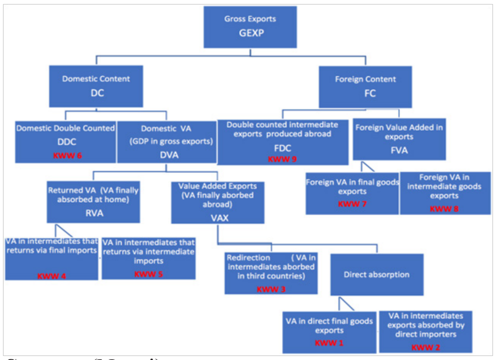
$$GVC_{participation} = (FVA_{it} / TE_t) + (DVX_{it} + TE_t)$$

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.).

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), both forward and backward participation will be considered for the agriculture sector and mining sector. For this study, both Global value chain in agriculture (gvcpa) and Global value chain in mining (gvcpm) is given by $(FVA_{it} / TE_t) + (DVX_{it} + TE_t)$

The estimation of GVC participation variables follows the (Borin and Mancini (BM)) refinement of the (Koopman, Wang and Wei (KKW)) 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)

Pollution Measure

To examine the extent to which GVCPs contributes to the level of transport environmental pollution, transport CO_2 emission (CO_2t) was used as a dependant variable as GVCP mining and GVCP agriculture both contribute to CO_2 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.) that the CO_2 emissions (pollution) are strongly associated with international transport along the GVCPs. Transport CO_2 emissions (% of total fuel combustion) refer to CO_2 emissions from the combustion of fuel for all transport activity in Zimbabwe and was obtained from the World Bank data base.

Control Variables

Control variables were informed by literature, with population growth (pop) and mining rent or mining prosperity (minpros) identified by (Ali et al.; Bataka) as key variables in the analysis of the effects of GVCPs on environmental pollution; while climate (climate) and pollution (CO_2) are considered important variables in determining GVCP in agriculture, hence their inclusion also in this study. Climate is included as a Dummy variable (1=climate change, 0 otherwise) and Climate change is defined as the period when drought is experienced. The data for climate was obtained from SADRI Drought Resilience Profile for Zimbabwe and the variable proxy was guided by data availability as data of other better proxies such as temperature and precipitation was unavailable. Pollution (CO_2) emissions are a summation of annual agriculture methane emission (CO_2 equiv), agric nitrous oxides emission (CO_2 equiv) and greenhouse gas emissions (CO_2 equivalent) obtained from the World Bank data base.

Econometric Model

To analyse the effects of GVCPs in mining (gvcpm) on GVCP in agriculture (gvcpa), we used an empirical model borrowed from (Ali et al.; Pata; Malik et al.; Adom and Bekoe; Bosah et al.) and is presented as Equation 1 as follows:

$$\ln gvcpa_t = \sigma_0 + \sigma_1 \ln gvcpm_t + \sigma_2 \ln CO_{2\,t} + \sigma_3 climate_t + \sigma_4 \ln pop + \varepsilon_t \qquad (1)$$

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.; Danish et al.). CO_2, 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 CO_2 emission (CO_2t) was used as a dependent variable since GVCP mining and GVCP agriculture both contribute to CO_2 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 CO_2 emission and the model (2) was specified as follows:

$$\ln CO_2t_{\,t} = \sigma_0 + \sigma_1 \ln gvcpm_t + \sigma_2 \ln gvcpa_t + \sigma_3 \ln pop_t + \sigma_4 \ln popminpros_t + \varepsilon_t \qquad (2)$$

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

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).

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

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
ln gvcpa	32	-2.840522	.8109307	-4.290469	-1.09895
ln gvcpm	32	-1.775747	.607279	-2.729682	-.9551373
ln minpros	32	.7610276	.7296964	-.5712429	1.94732
ln pop	32	.3104732	.489921	-.6465487	.986175
ln CO_2	32	10.61978	.0674161	10.48766	10.75
Climate	32	.65625	.4825587	0	1
ln CO_2t	32	2.81132	.321623	2.181871	3.295386
ln popminpros	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

Overall, no problem of multicollinearity was observed among the variables to be used in both the gvcpa and the CO_2t 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 CO_2t 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), CO_2, population (pop), CO_2t 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 (Pesaran et al.) was performed for the two equations and the results showed that there is cointegration in the CO_2t equation only; therefore, the need to estimate both the short-run and long-run relationships for CO_2t 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 CO_2t equation at 1% significance level. Thus, a discussion of results then follows in the subsequent section.

Discussion of Results

The short-run ARDL analysis of global value chain participation in agriculture (gvcpa) reveals significant results, particularly in Table 3, column (1). Past values of gvcpa are crucial, showing a 1% increase in previous gvcpa leads to a 0.66% rise in the current period's gvcpa, highlighting the role of past earnings in motivating agricultural production. This aligns with the cobweb cycle concept, where prior earnings influence current output (Chaudhry and Miranda; Glöser-Chahoud et al.). Additionally, climate change and pollution are significant factors affecting gvcpa, with a 1% rise in agricultural pollution causing a 3.52% decline in gvcpa, and drought leading to a 0.42% decrease. Conversely, GVCP in mining and population growth do not significantly impact gvcpa, contradicting the hypothesis of a trade-off between mining and agriculture participation. Overall, the findings emphasize that climate change and environmental pollution are critical influences on gvcpa in Zimbabwe, suggesting the need for policies that enhance irrigation, borehole drilling, dam construction, and sustainable farming practices that are environmentally friendly to boost agricultural participation in global value chains.

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 CO_2 emissions.

Table 3 Regression Results

Independent Regressors	GVCP Agriculture / gvcpa (1990–2021)	CO_2t Emission (Transport CO_2 Emissions) Short-Run Estimates (1990–2021)	CO_2t Emission (Transport CO_2 Emissions) Long-Run Estimates (1990–2021)
	(1)	(2)	(3)
gvcpa (-1)	0.66*** (0.09)		
Gvcpm	−0.09 (0.11)	082** (0.04)	0.16** (0.06)
CO_2	-3.52*** (1.23)		
Climate	-0.42** (0.16)		
Pop	-0.03 (0.22)	0.30*** (0.07)	0.62*** (0.18)
Pop(-1)	-0.24 (0.22)		
Popminpros		-0.06 (0.06)	0.29** (0.10)
Gvcpa		0.06 (0.05)	-0.12 (0.07)
CO_2t(-1)		0.27* (0.13)	
ECT		-0.48*** (0.11)	
C	36.6*** (13.09)	1.33*** (0.29)	1.33*** (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

Source: Authors' own calculation

The ARDL-ECM estimation for the transport CO_2 emissions (CO_2t) equation revealed both short-run and long-run relationships between the independent variables and the dependent variable. The short-run coefficients, presented in Table 3 column (2), highlight the significance of the error correction term (ECT (-1)), which was negative and significant, confirming the robustness of the model. This means the variables had a significant influence on environmental pollution with a speed of adjustment of 0.48%.

The analysis demonstrated that Global value chain participation (GVCP) in mining and population significantly increase transport CO_2 emissions in Zimbabwe at 5% and 1% levels of significance, respectively. This is attributable to the transportation demands of mining activities, including moving ores and workers, as well as the economic and transport demands associated with population growth (Akcil and Koldas). A 1% increase in GVCP mining was found to increase transport CO_2 emissions by 0.08% in the short run and 0.16% in the long run, while a 1% increase in population raised transport CO_2 emissions by 0.30% in the short run and 0.62% in the long run. These findings align with previous studies by (Ali and Giniguè; Bataka), that link global value chain activities, particularly in mining, to environmental pollution under globalization dynamics (Ahmed et al.). The null hypothesis that GVCP does not influence transport pollution in Zimbabwe is, therefore, rejected, and the study concludes that mining activities are not environmentally neutral.

Interestingly, the long-run results showed that the interaction between population and mining prosperity (popminpros) reduces CO_2 emissions by 0.29% for a unit increase in population and mining rents, significant at the 5% level. This supports the induced investment hypothesis, where increased mining rents facilitate the adoption of cleaner technologies, such as fuel-efficient and environmentally friendly vehicles (Bataka; Fei et al.; Chen et al.). On the other hand, GVCP in agriculture was found to have no significant impact on transport CO_2 emissions, consistent with earlier study by (Bennett et al.), suggesting that Zimbabwe's agricultural value chains, such as beef production, have relatively low greenhouse gas emissions compared to external benchmarks. As a result, the study concludes that agricultural value chains have minimal negative impacts on the environment, human health and resource depletion.

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 econometric 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 (this include seed, fertilizer, and mechanization such as tractors). This can also be complemented by removing export taxes on agriculture exports 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. A further study can be done on emission levels of agriculture and mining equipment so as to aid in the adoption and use of smart methods in production processes.

Suggested Areas for Further Research

The analysis of the interlinkages between Zimbabwe's two critical sectors of mining and agriculture is still scanty which leaves significant gaps which could be filled in future studies. One critical area is the interplay between the aforementioned sectors and public finance policies especially national budget allocations. There is need to analyse the impact of national budget allocations, disbursements, and utilization on the two sectors and how these variables have evolved over time. National budgets play a critical role in revealing government policy priorities. Other studies could focus more on specific agricultural outputs such as the impact on cereals, fruits, and other inputs such as labour. The impact of the recently signed African Continental Free Trade Agreement (AfCFTA) on the two critical sectors is another are of potential research.

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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
CO_2	-0.817	0.8140	-5.471***	0.0000	Stationary 1st difference
CO_2t	-1.097	0.7163	-5.968***	0.0000	Stationary 1st difference
Pop	-1.590	0.4884	-7.274***	0.0000	Stationary 1st difference
Minipros	-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 CO_2t Equation

Test Statistic	Value	K
F-statistic	6.282	4
Critical Value Bonds		
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

	ln gvcpa	ln gvcpm	ln minpros	ln Co_2	climate
ln gvcpa	1.0000				
ln gvcpm	-0.1768	1.0000			
ln minpros	-0.1360	-0.0870	1.0000		
ln Co_2	0.4208	-0.2188	-0.1597	1.0000	
Climate	-0.2661	0.3952	0.3286	-0.4820	1.0000

Table A4: Correlation Matrix for CO_2t Equation Variables

	ln Co_2t	ln gvcpm	ln gvcpa	ln minpros	ln pop
ln Co_2t	1.0000				
ln gvcpm	0.5156	1.0000			
ln gvcpa	-0.6351	-0.1768	1.0000		
ln minpros	-0.2619	-0.0870	-0.1360	1.0000	
ln pop	0.5021	0.1730	-0.6396	0.1154	1.0000

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

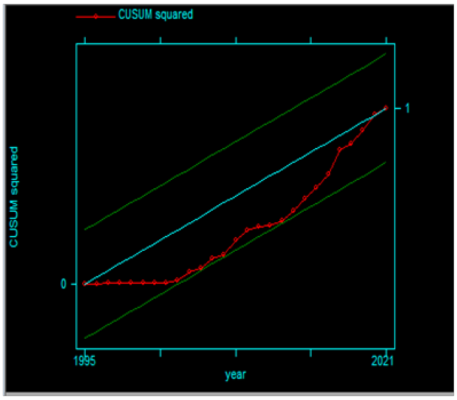
imtest, white
White's test for Ho: homoskedasticity
against Ha: unrestricted Heteroskedasticity

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

Post-tests: GVCPagric equation



Model stability test for GVCPagriculture 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

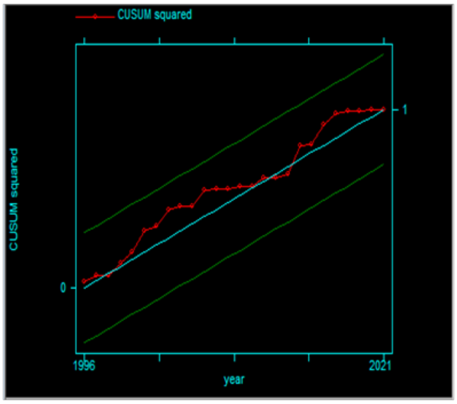
H0: no serial correlation
imtest, white
White's test for Ho: homoscedasticity
against Ha: unrestricted heteroscedasticity
chi2(29) = 30.00

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

Posts tests for CO_2t equation



Stability test for the CO2t equation

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