THE IMPACT OF TRADE LIBERALISATION ON MINING SECTOR TOTAL FACTOR PRODUCTIVITY: EVIDENCE FROM DEVELOPING COUNTRIES

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Abstract

While the paradox of plenty is given much weight on raging debates on resource endowment and growth path of the Southern Africa Development Community (SADC) countries. The study seeks to establish the effect of trade liberalisation on mining total factor productivity. The study employed panel data of selected seven countries from the SADC for the period 1990–2017. The countries in the sample include Botswana, South Africa, Tanzania, Namibia, Zimbabwe, the Democratic Republic of the Congo (DRC), and Zambia, and were chosen based on data availability. Hicks-Moorsteen productivity index was applied to generate the total factor productivity change. A panel auto regressive distributed lag model (PARDL) and pooled mean group (PMG) are the estimation techniques used. The inquiry is crucial to SADC because mining production is a source of foreign exchange that directly contributes to economic growth. However, with open economies of SADC study expects the easy flow and diffusion of technology to aid productivity in the mining sector (Griffith, Redding, & Van Reenen, 2014). Results indicate a positive and statistically significant long-run relationship between trade openness and total factor productivity change in the mining sector. The study recommends progressive trade openness in the mining sector, human capital development, research and development to augment technology transfer.

Keywords: Panel Auto-Regressive Distributed Lag, Pooled Mean Group, Trade Liberalisation, Total Factor Productivity Change, Hicks-Moorsteen Index

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1. INTRODUCTION

This research is founded on several debates going on in Africa, as well as the Southern African Development Community (SADC), especially the SADC Industrialisation Strategy and Road Map 2015–2063, and the Sustainable Development Goals (Gandure, 2013), the African Continental Free Trade Area (AfCFTA), which seek to enforce transition of SADC countries from commodity-dependent growth path to industrialised economies using their regional resource endowments. Also, the African Mining

Vision (AMV) whose mandate is the development and management of Africa's mineral resources, and has a foundational bearing on this study. The Extractive Industries Transparency Initiatives obligates member countries to disclose key steps in the governance of mineral resources (EITI, 2019). SADC is well-endowed with mineral resources, it harbors the world's largest mineral reserves of platinum, gold, diamonds, chromite, manganese, and vanadium (UN. ECA & African Union, 2008). However, a puzzling phenomenon exists that resource-rich countries continue to experience low per capita income. Many African countries like Angola, Nigeria, Sudan, the Democratic Republic of the Congo (DRC), South Africa, Zimbabwe, and Zambia are rich in diamonds, gold, platinum, among other minerals. In contrast, most East Asian economies like Japan, Korea, Taiwan, Singapore, and Hong Kong have achieved better per capita incomes despite being rocky islands with nothing exportable in natural resources (Frankel, 2010). Is it poor productivity in the mining sector and natural resources production that retard progress in industrialisation? Mining gross value addition as a percentage of GDP in SADC averages at 13.2% (African Development Bank, 2019) which presents the massive potential of this sector and its ability to contribute significantly to the economic activities given an abundant mineral resource base.

The mechanism by which trade liberalization is transmitted into success in the mining sector productivity has been left out in most studies. Recent studies confirm that trade liberalisation has been undeniably influenced by the spectacular growth in the mining industry (Awolusi, 2014; Siyakiya, 2017). Trade fosters economic growth by generating long-run gains that are engaging with the rest of the world, which would mean the ability to access the bigger markets and also new technology transfer and hence increased efficiency in production systems.

The research is motivated by the need to establish the link that exists between trade liberalisation and mining productivity in a panel set-up structure of selected countries from SADC. Instead of confirming the resource curse hypothesis, this study moved away from linking composite GDP per capita with natural resources and cascades to the actual mining total factor productivity. The region lags in terms of mining productivity gains from trading, in fact, there are productivity losses in the mining sector and minimal gains in productivity, as total factor productivity change has been trending below one, and only goes above one on an average 0.05 percent (Hick-Moorsteen index calculations, SADC, 2017). However, with the open economies of SADC, we expect the easy flow of technology to aid value-added productivity in the mining sector which has never been the case in SADC.

In the new millennium, most of the SADC countries have passed different policies at the country level for them to complement the debates awash in Africa. Botswana's parliament passed a new Mines and Minerals Act aiming to provide an economic environment that favours investment in the mineral industry and which allows companies to be globally competitive (Botswana Investment & Trade Centre, 2018). On the other hand, the South African government and Chamber of Mines agreed to the security of tenure to attract foreign investors and black empowerment (Feris, 2013). In Zimbabwe, the Zimbabwe Agenda for Sustainable Socio-Economic Transformation (ZIM ASSET), tops all debates centering on value addition and beneficiation in all sectors, inclusive of the mining sector. Nevertheless, the research excludes the mining of oil, mainly because in the sample (Botswana, DRC, South Africa, Zimbabwe, Zambia, Namibia, Tanzania), there is insignificant oil mining. The research contributes to new knowledge horizons by linking trade liberalization and total factor productivity to a specific sector (mining) in SADC. Most empirical work on trade openness and total factor productivity linked to the manufacturing sector and agricultural sector, as well as the service sector, has been given fair attention as evident in the literature review.

The research proceeds as follows. Section 2 reviews the relevant literature on total factor productivity and trade liberalisation. Section 3 analyses the methodology that has been used to conduct empirical research. Section 4 presents the results of the study. Section 5 presents a discussion of the research findings and lastly, Section 6 provides conclusion.

2. LITERATURE REVIEW

This section examines the literature on trade openness and total factor productivity growth in two main steps: the theoretical literature and empirical literature. Theories that underpin productivity were identified as exogenous growth and endogenous growth theories. Currently, there is no theory that directly links trade liberalization and productivity and hence, the research reviews trade liberalisation and productivity separately.

The study starts with productivity growth theories, that is the exogenous and endogenous theories and then trace theories of international trade where analysis covers the classical, neoclassical, and the new trade theories and the traditional trade theories. Productivity and growth are best explained by the neoclassical and the new growth theories, which allude that capital accumulation drives productivity but eventually, it succumbs to diminishing returns to a factor, and therefore long-run productivity growth is an exogenous technical progress phenomenon. On the other hand, new growth models concur that long-run productivity growth is attained either by avoiding diminishing returns to scale or by adopting technical progress internally (Stiroh, 2001).

Solow's growth model predicts that for any economy that increases its capital-labour ratio (equipment per worker) and savings, the economy will have a higher output per worker, however, diminishing returns to scale may set in via capital deepening. Besides, capital accumulation also has more impact on labour productivity in developing countries than in developed. Hence, the theory predicts that, in an open economy setting, capital should be seen flowing from richer countries to poor countries attracted by higher potential returns, thereby accelerating the process of capital accumulation. Again, the theory is known to take technology as a public good meaning every firm or

a nation should equally access the same stock of knowledge freely. This research takes cognisance of Solow's growth accounting, also known as "Solow's residual ideology", which measures changes in the amount of capital and labour that occur in an economy over time. However, changes in technology are not observable and that is total factor productivity, which the current study is interested in, particularly in the mining sector.

The prominent theorists behind the endogenous model include Romer (1994), Lucas (1988), Rebelo (1991), Mankiw, Romer, and Weil (1992), Prescott (1997), and others. The main proposition of the endogenous growth model is that technological progress is treated as an endogenous variable rather than public good as it is in the exogenous model. They also further defined investment, which they broadened from just physical capital accumulation to include investment in knowledge (research and development), human capital formation. The theory integrates well into the present study in that technology and knowledge spillovers are the key means linking international trade and growth. Also, there are increasing returns to scale in production, and is a realistic production scenario than to assume constant returns to scale as in Solow's model. Based on technology transfer spillovers, the role of capital goods imports is a major factor that would boost productivity in the mining sector.

Technology progress is viewed differently in these theories, that is, either endogenously determined or exogenously determined, but they both establish that technology progress is key to the long-run and sustainable growth. We hence acknowledge that Solow's model framework is for the closed economies but endogenous growth models include a positive growth effect of trade that is induced by the innovation incentives, technology transfer. Savings and capital accumulation are important ingredients to grow any economy.

Ricardo (as cited in Eaton & Kortum, 2012) and traditional international trade theorists submit that trade can occur amongst countries if there is a comparative advantage; that is countries would trade among themselves if they have a lower opportunity cost of producing some goods than the rest of the world and production cost advantage comes from differences in technologies among participant countries. The principle of comparative advantage tells that outward orientation increases efficiency and promotes specialization in production. It means that exports increase and that relieves pressure on exchange rates and thus increases the key inputs importation to industries. In the case of this study, for instance, inputs into the mining sector would increase and that transforms into increased efficiency and productivity.

Whereas, the new trade theory is a collection of economic models in international trade that addresses the pitfalls of the traditional trade theory by considering the role of increasing returns to scale and the effect of networks which Helpman and Krugman (as cited in Wakasugi, 1997) and others authored in the 1980s–1970s. The new trade theory migrates from the idea that comparative advantage is the only reason behind international trade but rather coined the imperfect competition framework as the new trade theory. It spells out that economies of scale and increasing returns result in imperfect competition. The theory ascertains intra-industry, product differentiation, mobility of factor endowments, transport cost, economic and political factors as more realistic factors that determine international trade. In doing so, increasing returns result in imperfect competition meaning price is greater than marginal cost, and as such the industry gains substantial economies of scale and becomes dominant. Intra-industry trade reflects the economies of scale that firms enjoy rather than comparative advantage and increasing returns to scale forces industries to engage in international trade. The theory integrates perfectly with the current research in that imperfect competition and increasing returns to scale are common features in the mining industry. The study noted that the mining sector of Africa could have been in a better state had it been that the sector was government protected and given domestic subsidy to encourage the creation of capital-intensive industry to gain economies of scale. Hence, the mining sector struggles to develop its industries because they are far from achieving economies of scale enjoyed elsewhere in developed countries.

The survey covered the empirical literature from SADC, Africa, and outside Africa that investigated the link between trade liberalisation and total factor productivity growth. Therefore, recent studies are reviewed in this section.

Cirera, Lederman, Castillejo, Barrachina, and Sanchis-Llopis (2021) examined the impact of international trade on firm-level total factor productivity (TFP) in Brazil. The study scrutinised how trade policy and firms' status impact the TFP dynamics. In this background, the study separated the effects of inputs and output tariffs on firm productivity. The research used data from firms in Brazilian industrial sectors (manufacturing and mining) during 2000–2008. A Cobb-Douglas production technology using Wooldridge (2009) to estimate the input coefficients and TFP residual. Olley and Pakes (1996, OP) and Levinsohn and Petrin's (2003, LP) approaches were jointly used to estimate generalised method of moments. Results indicated that trade liberalisation, that's general fall in the tariffs on both input and output, greatly improves TFP. Additionally, the impact of trade policy on TFP cascades to all firms irrespective of whether they are trading firms or non-trading firms meaning that trade openness puts pressure on all firms whether exposed to trade or not. On the other hand, the research acknowledges that a real effective exchange rate plays a part in determining the competitiveness of exporting firms than non-exporting firms. Appreciation of the currency puts additional competitive pressure on exporting firms to improve productivity and maintain competitiveness in international markets. The empirics inform the current study on factors that may improve productivity at the firm level and that the contagion effect runs in all firms and even non-trading firms.

Elewa and Ezzat (2019) investigated the linkages on trade liberalisation, domestic competition, and total factor productivity with an aim to conclude on how trade openness and induced international competition impact the total factor productivity in the manufacturing sector of both developing and developed countries. The study employed Levinsohn and Petrin's (2003) methodology to compute

the total factor productivity using panel data in generalised least squares model. Key findings from the research are that trade openness enables international competition which forcefully drives away least efficient firms in the manufacturing industry. However, overall productivity increases in sectors exposed to foreign competition. Again, the study concluded that developed countries benefit more than developing countries from higher international competition and they cite that developing countries face several challenges that hinder them from enjoying the benefits of trade openness to their industries.

Haider, Ganaie, and Kamaiah (2011) investigated the causal link between total factor productivity and openness in the Indian economy in panel data from 1970–2011. The study used the autoregressive distributed lag (ARDL) cointegration and error correction approach to ascertain the long-run and short-run relationship that exists between total factor productivity and trade openness coupled with the Granger causality test. Aggregate total factor productivity change was estimated using the popular Tornquivist index and trade openness was measured using nominal openness (trade as a percentage of GDP). The research concluded that there is a positive and significant long-run relationship between trade openness and TFP and that in the short run a unidirectional causality that runs from trade openness to TFP. The study recommended that India should abandon protectionism as that would deter the growth of efficiency in its domestic industries in the long run and that trade openness as a strategy may fail to enhance total factor productivity but can be augmented by factors like human capital and physical capital.

Ahmed, Khan, Mahmood, and Afzal (2017) investigated the impact of trade liberalisation on industrial productivity in Pakistan. The study compared two eras that are the pre-trade liberalisation and post-trade liberalisation in two stages. A Cobb-Douglass production function was used to estimate the output elasticities induced by labour, capital, and raw materials and the study concluded positive output coefficients for both the pre-trade liberalisation and post-trade liberalisation. However, energy affected negatively on productivity in post-liberalisation, and in the pre-liberalisation, energy positively contributed to productivity. In the second stage, TFP was estimated following Levinsohn and Petrin (2003) and then regressed on trade proxies under three different estimations techniques, that is the panel ordinary least squares, random-effects, and fixed-effects models. Of the three models, the Hausman test confirmed the random-effects (RE) model. The major conclusions made by the research were that import duty positively impacts TFP in both eras though insignificantly. Nevertheless, the effective rate of protection as a proxy of trade liberalisation affected the TFP more negatively in post-trade liberalisation than in the pre-trade liberalisation. The policy implications were that protectionism deters TFP and hence reduction in non-tariff and tariff measures would improve TFP. However, the study noted that not only do trade variables contribute to productivity but rather, availability of

energy, quality of raw materials, capital goods (technology advancement), trade-related infrastructure also plays a critical role in improving TFP.

Siyakiya (2017) explored the effect of trade openness and national productivity on the selected panel data for African countries for the period from 1980 to 2014. A pooled ordinary least squares technique was employed and results depicted an overall positive impact of trade openness on manufacturing and service value-added. We noted that the research concentrated on three sectors, thus agriculture value-added, manufacturing value-added, and service value-added. A positive impact of trade openness on the manufacturing and service sectors was established. The research used these variables, namely, labour productivity, gross fixed capital formation as a percentage of GDP, and trade openness, to determine the impact on total value-added. The capital was found to contribute positively to both overall and sectoral value-added but labour had a negative relationship and that was explained by diminishing returns to scale and poor managerial services.

Ebenyi, Nwanosike, Uzoechina, and Ishiwu (2017) examined the impact of trade liberalization on manufacturing value-added in Nigeria's manufacturing sector and major findings from the study identified that the nature of exports has been the same over the 1970–2009 period in Nigeria. However, there is a shift from the export substitution of primary agro-based exports to primary mining industry-based exports like crude oil. The heavy reliance of Nigeria on imported machinery and equipment reflects a weak manufacturing base of the country. Nigeria's manufacturing sector failed to respond positively to export potentials due to the high cost of production in the country that further disadvantaged manufactured output on the international market. An error correction model was used to ascertain the impact of trade liberalization on mining value added in an ARDL test which confirmed a long-run relationship between trade liberation and manufacturing value-added. The major logic to pick from this study is that the manufacturing sector was performing below expectations ever since Nigeria embraced trade openness.

A research paper by Awolusi (2014) investigated the relationship between mineral resource endowment and economic growth in the Southern African economies using a panel of 14 countries in SADC from 1990 to 2014. An ordinary least square and generalized method of moments were used as the estimation techniques. Economic growth was analyzed using real growth in mining, the share of mineral export to total export, real growth in agriculture, real growth in manufacturing, human capital development, population growth, trade openness, growth in FDI, mineral resource endowment, infrastructural development. The findings were that all the above-stated variables were determinants of economic growth and hence the resource curse was concluded to be just a threat. The research informed the current research in that, realizing that a resource curse is just a threat in SADC, hence, furnishing the link that exists among trade expansion, liberalization, and efficiency in mining productivity becomes very justified since the mineral resource is one of the determinants of growing an economy.

Burange, Ranadive, and Karik (2013) investigated the relationship between trade openness and economic growth in Brazil, Russia, India, China, and South Africa (BRICS) case study. The study used the econometric time series analysis in the cointegration and Granger causality framework. Annual time-series data from 1981 to 2012 for all other countries except Russia, which used data that stretched from 1989 to 2012. Trade openness was measured by merchandise exports, merchandise imports service exports, and service imports all as a ratio of GDP. Results of the research confirmed that, amongst the BRICS countries, the export-led hypothesis was supported in Brazil and China whereas the export- and import-led hypothesis was supported in South Africa. The research fits in here to provide evidence in SADC because we noted the hypothesis of export- and import-led growth is endorsed in Republic of South Africa (RSA) and that trade openness was measured by the most commonly used proxies of trade.

Majeed, Ahmed, and Butt (2010) used the endogenous growth model to assess the link between trade liberalization and total factor productivity growth in large-scale manufacturing (LSM) of Pakistan during the period 1971–2007. Total factor productivity growth was measured using the growth accounting technique and then the ARDL modeling approach was applied to measure the relationship between trade liberalization and productivity growth. The estimated coefficients of openness were negative and statistically significant implying that trade liberalization policy was insignificant in explaining the growth rate in TFP in LSM of Pakistan. The study recognized that trade openness alone may fail to kick start productivity in the industries, and hence government support is primary to the process. Several pieces of research found trade openness proxies, e.g., import penetration, trade policies, reduction of tariffs negatively, and statistically significant to explain total factor productivity growth (Cirera et al., 2021; Elewa & Ezzart, 2019; Majeed et al., 2010). These researches also concluded that export orientation and import orientation do have a different impact on TFP and, more often than not, import orientation is positively linked to TFP growth and export orientation is negative and statistically significant. Hence, the present research closes the gap on what obtains in SADC as far as mining total factor productivity and trade liberalization is concerned. Literature generally confirms a positive relationship between total factor productivity growth and trade liberalization in most parts of the world. However, it is important to point out that the literature is biased towards other sectors like export-oriented manufacturing, service, and agriculture, and least is known about the mining sector. The next section presents the methodology of the study.

3. METHODOLOGY

The study employed panel data of selected seven countries from the SADC for the period 1990–2017. The countries in the sample include Botswana, South Africa, Tanzania, Namibia, Zimbabwe, DRC, and Zambia, where the following minerals are also investigated, that is, diamond, copper, gold, and coal production. Out of fifteen countries in SADC, seven countries were chosen based on data availability. In a bid to give an explicit understanding of the connection between trade liberalization and mining total factor productivity change, the study introduced the measurement of total factor productivity using the Hicks-Moorsteen data envelopment TFP index. The index was then used to calculate mining total factor productivity per country-specific according to the sample under investigation. The calculated values of TFP are posted to the main objective of the study as a dependent variable in the estimation of a panel ARDL under the pooled mean group model which seeks to estimate the long-run and the short-run parameters of the model using Stata 14.

The model is entrenched in the strong theoretical production function, from which the disentangled production output that is not directly accounted for by the changes in inputs, that is total factor productivity. The study adopted and modified the ARDL bound test approach to cointegration used by Majeed et al. (2010) in investigating trade liberalization and TFP growth of a large-scale manufacturing sector in Pakistan:

$$\Delta GRTFP_t = \beta_0 + \beta_1 Y + \beta_2 K + \beta_3 L + \beta_4 HDI + \beta_5 OPENNESS + \mu \tag{1}$$

The main distinction the research is making is that the study employed panel ARDL instead of ARDL bound test approach to cointegration because ARDL bound test is only suitable for time series modeling. A generalized method of moments could have been employed, however, the sample has $T > N$ instead of $N > T$. Also, TFP in mining, as the dependent variable, is calculated using the Hicks-Moorsteen index before regressing it on all the trade variables, other indexes, like the Malmquist index, could have been used but it fails to measure productivity under variable returns to scale. Also, the Tornqvist index could be used to compute the total factor productivity, especially on broadly defined inputs. However, the prices of inputs must be known so as to develop costs share weights for each input (Ondrej & Jiri, 2012). The long-run model is transformed into a logarithm function shown as:

$$lnTFPH_{it} = \sum_{j=1}^{p} \varphi_i lnTO_{i,t-j} + \sum_{j=0}^{q} \phi_i lnFDI_{i,t-1} + \sum_{j=0}^{q} \delta_i lnHC_{i,t-1} + \sum_{j=0}^{q} \psi lnHCGAP_{it-1} + \sum_{j=0}^{q} \rho_i lnGOVNC_{it-1} +$$
$$\sum_{j=0}^{q} \sigma_i lnXR_{it-1} + \mu_i + \varepsilon_{it} \tag{2}$$

where:
i = 1, 2...5 cross-sections;
t = 1990, 1991...2017;
μ_i = country-specific error term;
ε_{it} = independent error term that is distributed on i and t;
$\varphi_i, \phi_i, \delta_i, \psi, \rho_i, \sigma_i$ = the long-run coefficients.

The variables in the model are narrated as $TFPH$ — mining total factor productivity change

(dependent variable); TO — trade openness; FDI — net foreign direct investment; $GOVNC$ — government effectiveness index; XR — the real exchange rate; HC — the human capital; $HCGAP$ — a measure of technology transfer via human capital. Correspondingly, the reparametrized short-run panel ARDL model follows:

$$\Delta lnTFPH_{it} = ln\phi_i TFPH_{i,t-1} - \vartheta_i TFPH_{i,t-2} \sum_{j=0}^{p-1} \varphi_i \Delta lnTO_{i,t-j} + \sum_{j=0}^{q-1} \phi_i \Delta FDI_{i,t-1} + \sum_{j=0}^{q-1} \delta_i \Delta lnHC_{it-1} +$$

$$\sum_{j=0}^{q-1} \psi_i \Delta lnHCGAP_{it-1} + \sum_{j=0}^{q-1} \rho_i \Delta lnGOVNC_{it-1} + \sum_{j=0}^{q} \sigma_i lnXR_{it-1} + \mu_i + \varepsilon_{it}$$

(3)

where, ϕ_i — the error correction term, measures the speed of adjustment to long-run equilibrium in case of a disturbance in the system. A zero value would mean no evidence of co-integration, while ϕ_i — expected to be negative and statistically significant under the prior supposition that variables indicate convergence to the long-run equilibrium in case of any shock. $\varphi_i, \phi_i, \delta_i, \psi, \rho_i, \sigma_i$ representing short-run coefficients. The above model estimates total factor productivity change in the mining sector across all seven countries. Data used was sourced from United Nations Trade Statistics, International Labour Organisations (ILO), World Development Indicators (WDI) and United Nations Conference on Trade and Development (UNCTAD), SADC Statistical Yearbooks, World Bank and Quantec.

Estimation procedures include panel unit root tests, correlation analysis. The research used the first-generation panel unit root tests, which assume that individual time series in panels are cross-sectionally independently distributed, and these include Levin-Lin-Chu (LLC) test, Im-Pesaran-Shin and Fisher-type test — augmented Dickey-Fuller test. However, these have been criticized from literature (Barbieri, 2006) for the strong assumption of cross-sectional independence, citing that there have been co-movements among economic variables and assuming cross-sectional independence could be too restrictive. This is followed by lag selection criteria which use an unrestricted model and both Akaike information criterion (AIC), Schwarz Bayesian information criterion (SBIC) to solidly build results. The optimal lags for each country and each variable in the sample were used. The decision on which lag was reached by matching the most common lags across the countries and variables to represent the lag for the entire model using Stata 14.

Two main panel cointegration tests were carried out to ascertain the presence of long-run relationships prevailing in our model. These include the Pedroni (2004) test of cointegration and the Westerlund (2007) test of cointegration. Pooled mean group (PMG) was chosen because the estimator constrains long-run coefficients to be identical but allows short-run coefficients and error variances to differ across groups (Pesaran, Shin, & Smith, 1999). The study justifies the use of PMG mainly because our sample is made up of countries

that are significantly active in the mining industry and that the mining sector contributes significant percentages averaging 10 percent to their GDP (World Bank, 2019). Also, technology across this group is deemed similar given that the technology leading investors from the UK, Canada, USA, Switzerland, China, Bahamas, Australia, Iran, and India in the mining sector are the same in the SADC for instance, Rio Tinto, De Beers, Anglo American, AngloGold Ashanti, BHP Billiton, Glencore International AG, ArcelorMittal (World Economic Forum, 2009). Lastly, diagnostic tests were constructed to check for the reliability and stability of the model.

The study carried out three main diagnostic tests which include heteroscedasticity, serial correlation, and cross-sectional dependence test. For this study, we checked heteroscedasticity using common tests that are the Breusch-Pagan-Godfrey test and the White test. Of the two, the research found that the latter rely on normality assumptions and the other one is sensitive to normality assumptions. The study rejects the null hypothesis (homoscedasticity) if the p-value is less than 0.05. Also, cross-sectional dependence in panel data may arise from the presence of common shocks, unobserved components that ultimately become part of the error De Hoyos and Sarafidis (2006), and an unrestricted likelihood ratio test was used. If the p-value is less than 10%, the study rejects the null hypothesis that there is a cross-sectional independence correlation in the variable and accepts the alternative hypothesis that there exists cross-sectional dependence in the variable. For serial correlation, the Lagrange multiplier (LM) test of Breusch-Pagan, which is based on the average squared pairwise correlation of residuals, was used. The null hypothesis is rejected when the test statistic is larger than the 1-sided 5% critical of the chi-square distribution.

4. RESULTS

Stationarity tests are done using Levin-Lin-Chu and Im-Pesaran-Shin methods. Table 1 summarises unit root test results for our key variables for the PARDL model.

Table 1. LLC and IPS unit root test results

Variable	Time trend and intercept with panel means included			Intercept and no trend with panel means included		
	Test	Statistics	P-value	Statistics	P-value	Order of integration
LOGTFPH	LLC	-11.5431	0.0000*	-13.6495	0.0000*	1(0) Stationary
	IPS	-14.4559	0.0000*	-12.8063	0.0000*	1(0) Stationary
LOGTO	LLC	-2.3078	0.0105*	-2.2289	0.0129*	1(0) Stationary
	IPS	-1.2901	0.0985**	-2.3241	0.0101*	1(0) Stationary
LOGEXGDP	LLC	-3.6752	0.0001*	-3.1964	0.0070*	1(0) Stationary
	IPS	-2.3656	0.0009*	-3.0426	0.0012*	1(0) Stationary
LOGIMGDP	LLC	-2.0806	0.0187*	-2.4988	0.0060*	1(0) Stationary
	IPS	-1.4259	0.0770**	-2.9620	0.0015*	1(0) Stationary
LOGFD	LLC					
	IPS	-5.0778	0.0000*	-6.5104	0.0000*	1(0) Stationary
	FISHER	-5.4986	0.0000*	-7.0081	0.0000*	1(0) Stationary
ΔLOGGVNC	LLC	-13.6004	0.0000*	-14.1486	0.0000*	1(1) Stationary
	IPS	-13.5200	0.0000*	-13.2491	0.0000*	1(1) Stationary
LOGHCLOGGAP	LLC	-3.3769	0.0004*	-4.5504	0.0000*	1(0) Stationary
	IPS	-7.8786	0.0000*	-7.5400	0.0000*	1(0) Stationary
LOGXR	LLC	-4.3623	0.0000*	-12.0262	0.0000*	1(0) Stationary
	IPS	-4.3241	0.0000*	-8.9555	0.0000*	1(0) Stationary
ΔLOGHC	LLC	-3.1691	0.0008*	-3.9004	0.0000*	1(1) Stationary
	IPS	-1.8470	0.0324**	-1.4559	0.0727**	1(1) Stationary

*Notes: *, **, *** denote significance at 1%, 5%, and 10%, respectively.*
Source: Authors' computations using Stata 14.

The results in Table 1 based on Levin Lin and Chu and Im Pesaran and Shin tests confirm mining total factor productivity (*LOGTFPH*), trade openness (*LOGTO*), exports as a percentage of GDP (*LOGEXGDP*), imports as a percentage of GDP (*LOGIMGDP*), foreign direct investment inflow (*LOGFDI*), an exchange rate (*LOGXR*), and technology transfer (*LOGHCLOGAP*) reject the null hypothesis that panels contain unit roots in levels at 1% significance level. However, governance (*LOGGVNC*) and human capital (*LOGHC*) fail to reject the null hypothesis that panels have unit roots in levels but rather got stationary at the first difference at 1% and 5%, respectively. Unit roots results indicate mixed orders of integration, therefore, that gives us a leeway to run panel ARDL rather than traditional panel data models. Table 2 below outlines the summary of correlation coefficients for the data set used in the panel ARDL model.

Table 2. Summary of the correlation test

Variable	LOGTFPH	LOGTO	LOGFDI	LOGHC	LOGHCGGAP	LOGGVNC	LOGXR
LOGTFPH	1	0.0010	-0.0306	0.0060	0.4622	0.0189	0.0064
LOGTO	0.0010	1	0.2182	0.6773	-0.1725	0.3999	-0.3068
LOGFD	-0.0306	0.2182	1	0.1252	0.0253	-0.0135	0.3005
LOGHC	0.0060	0.6773	0.1252	1	-0.2433	0.4459	-0.3617
LOGHCGAP	0.4622	-0.1725	0.0253	-0.2433	1	-0.1329	0.0959
LOGGVNC	0.0189	0.3999	-0.0135	0.4459	-0.1329	1	-0.0876
LOGXR	0.0064	-0.3068	0.3005	-0.3617	0.0959	-0.0876	1

Source: Authors' computations using Stata 14.

Table 2 summarises the correlation statistics that exits on the predictor variables, and there no multicollinearity problems in the PARDL model. The correlation among the independent variables is less than +/-0.8 (Pesaran et al., 1999). The following section presents the optimal lag selection results.

Table 3. Lag section criteria results

Variable	Lag
LOGTFPH	1
LOGTO	0
LOGFD	1
LOGHC	0
LOGHCLOGGAP	2
LOGGVNC	0
LOGXR	0

Source: Authors' computations using Stata 14.

The results in Table 3 indicate the most common lag for each country per variable. The AIC, BIC, and HQIC information criteria were used to automatically estimate the lags for the model using forvalues syntax from Stata. No information criteria statistics are produced by the syntax but rather it posts common lags for each variable. The study constructed the optimum lag for the model simply by taking the mode lag that appears for a variable throughout the seven countries in our sample and of the selected information criteria AIC, BIC, and HQIC they all favour the same lags for our variables. Therefore, the panel ADRL model used ARDL (1 0 1 0 2 0 0) in specifying the PMG–PARDL model, and this was followed by panel cointegration results.

Panel cointegration results in Table 4a (Westerlund test) and Table 4b (Pedroni test) are confirming that Table 4a shows that both panel (Westerlund test — Pt, Pedroni test — Pa) statistics strongly reject the null hypothesis of no

cointegration at 1% and 5%, respectively, whereas group statistics (Gt) reject the null hypothesis of no cointegration at 1% level of significance whilst the group statistics Ga fails to reject the null hypothesis of no cointegration. Overall, statistics indicate a strong error-correcting behaviour in the mining total factor productivity, foreign direct investment, human capital, trade, and governance. Hence, the variables in the research are strongly cointegrated since the majority of statistics are rejecting the null hypothesis of no cointegration. In Table 4b the result confirms that the six statistics, both panel

statistics and group statistics, in absolute terms are greater than 2 and that the group ADF and panel ADF are all significant at 1%. According to Pedroni (2004), if both panel ADF and group ADF are statistically significant they are more reliable in communicating the presence of cointegration in a data set. The study concludes that there exist strong cointegration relationships among the mining total factor productivity, trade openness, foreign direct investment, human capital, and governance in selected SADC countries.

Table 4a. Summary of panel cointegration using Westerlund cointegration test

Statistics	Value	Z-value	P-value
Gt	-5.129	-7.620	0.00***
Ga	-10.983	0.255	0.601
Pt	-12.072	-5.805	0.000***
Pa	-13.695	-1.884	0.030**

*Notes: ***, **, and * imply significance at the 1%, 5%, and 10% levels, respectively. H_0: no cointegration.*
Source: Authors' computations using Stata 14.

Table 4b. Summary of the panel cointegration result using Pedroni test

Test	Statistics	Test statistics
Panel statistics	Panel v-statistic	0.0869
	Panel rho-statistic	-3.195*
	Panel t-statistics	-17.11***
	Panel ADF-statistic	-7.474***
Group statistics	Group rho-statistic	-2.351*
	Group t-statistic	-22.47***
	Group ADF-statistic	-5.579***

*Notes: ***, **, and * imply significance at the 1%, 5%, and 10% levels, respectively. All test statistics are distributed N (0, 1), under a null of no cointegration.*
Source: Authors' computations using Stata 14.

Table 5. Summary of long run-pooled mean group estimation model (1, 0, 1, 0, 2, 0, 0)

Explanatory variable	Coefficient	Standard error	T-statistic	Probability
LOGTO	0.191512	0.0103781	1.85	0.065**
LOGFD	0.0030139	0.0029251	1.03	0.303
LOGHC	0.0577511	0.0400833	1.44	0.150
LOGHCLOGGAP	0.4373903	0.694502	6.30	0.000***
LOGGVNC	0.0235098	0.0069265	3.39	0.001***
LOGXR	0.0049543	0.0022637	2.19	0.029**

*Notes: ***, **, and * imply significance at the 1%, 5%, and 10% levels, respectively. The optimal lag lengths are selected by the AIC, BIC, and HQIC. Estimations are done by using the (xtpmg) routine in Stata 14. Dependent variable: Logtfph (mining total factor productivity change — Hicks-Moorsteen productivity index).*
Source: Authors' computations using Stata 14.

Table 6. Summary of the short-run dynamics of the panel ARDL model

Lagged variables	Model ARDL (1, 0, 1, 0, 2, 0, 0)						
	Botswana	DRC	Namibia	RSA	Tanzania	Zambia	Zimbabwe
ΔLOGTO (-1)	-0.019 (0.0487)	-0.013 (0.0190)	0.227 (0.1104)***	-0.005 (0.0639)	0.059 (0.0496)	-0.052 (0.0508)	-0.062 (0.0254)***
ΔLOGFD (0)	-0.0190 (0.0061)***	-0.0004 (0.0102)	-0.002 (0.0044)	0.002 (0.0049)	-0.022 (0.013)**	0.005 (0.0103)	-0.010 (0.0050)***
ΔLOGHC (0)	1.571 (1.4220)	-7.95 (8.5568)	-3.292 (1.8495)**	-3.831 (1.8027)***	7.164 (2.6963)***	-0.866 (0.6701)	1.768 (1.0547)**
ΔLOGHCLOGGAP (-2)	0.047 (0.0571)	0.478 (0.2326)***	0.019 (0.1458)	0.002 (0.1015)	0.144 (0.1582)	0.122 (0.1031)	0.047 (0.0694)
ΔLOGGVNC (0)	-0.175 (0.1754)	-0.021 (0.0116)**	0.002 (0.1492)	-0.182 (0.2783)	0.005 (0.0706)	-0.027 (0.0440)	-0.043 (0.0167)***
ΔLOGXR (0)	0.133 (0.0694)**	0.043 (0.0232)**	-0.068 (0.0614)	-0.012 (0.060)	-0.207 (0.0897) *	0.022 (0.0355)	-0.004 (0.0040)
ECT (-1)	-1.25 (0.1863)***	-1.06 (0.2054)***	-1.13 (0.1977)***	-1.12 (0.2223)***	-0.97 (0.1929)***	-1.04 (0.2265)***	-1.17 (0.1485)***

*Notes: ***, **, and * imply significance at the 1%, 5%, and 10% levels, respectively. The value inside the parentheses is the corresponding probability value for the t-statistic. Dependent variable: Tfph (mining total factor productivity — Hicks-Moorsteen productivity index).*
Source: Authors' computations using Stata 14.

The section presents post-estimation diagnostic tests to check for reliability and stability of the model that is heteroscedasticity, autocorrelation, and cross-sectional dependency. The results are shown in Table 7.

Table 7. Summary of the heteroscedasticity, autocorrelation, and cross-sectional dependency tests

Test	Summary	Chi-square statistics	Probability	Decision
Heteroscedasticity	H_o: homoscedasticity	LR = 0.23	0.998	Fail to reject H_o
Autocorrelation	H_o: no first-order autocorrelation	F (1, 6) = 0.123	0.733	Fail to reject H_o
Cross-sectional dependency (Pesaran, Breusch, and Pagan tests	H_o: no cross-sectional dependency	(Pes) = 21.7 (LM) = 21	0.0000 0.0000	Reject: H_0 Reject: H_0

Source: Authors' computations from Stata 14 using (xtgls), (xtserial), and (xtcsd) routine, respectively.

5. DISCUSSION

Table 5 indicates that there is a positive and statistically significant relationship between trade openness and mining total factor productivity in selected SADC countries. A 1% change in trade openness will increase productivity in the mining sectors by 0.019% in the long run and this is consistent with our correlation results that confirmed a positive relationship between productivity change in mining and trade openness. The results show that trade openness enhances growth in mining productivity of SADC in the long run and this implies that efforts on regional integration would bear fruits in the long run in the mining sector. Similar results date back from Pavcnik (2003), Alcala and Ciccone (2004), Abuka (2005), Hossain, Kamil, Baten, and Mustafa (2012), and Siyakiya (2017). These researches were carried in different regions (Europe, America, and Africa). The study can confirm that different measures of trade openness were used, including trade orientation measured by the trade balances, imports, and exports relative to purchasing power parity — real openness, changes in tariffs, for example, tariff concessions, export to output ratios, and import to output ratios, and total trade to GDP. The outcome supports the known theoretical link between trade liberalization and productivity. Conclusions from these studies do concur with the present study, that trade openness enhances productivity only differing in that the latter researches were coined to manufacturing and services sector and the present research ventures into the mining sector.

The interaction term (HCGAP) captures the domestic endogenous innovation that is necessary for technical progress and is measured by the technology gap. A 1% increase in the human capital and technology gap measure will result in a 0.44% increase in the TFP in the mining sector. The result is supported by both the theoretical submissions, for instance, the neoclassical, and the endogenous theory that opinionated that social returns to investment in human capital are higher than those on physical capital. We conclude that human capital is a conduit of technology transfer in the long run in the mining sector of the selected SADC countries. Similar researches that also concluded that human capital is a vehicle of technology transfer and that it positively impacts total factor productivity include de la Fuente (2011), Ramos, Suriñach, and Artís (2009), Engelbrecht (1997), Cirera et al. (2021).

The governance in SADC-selected countries has a positive and statistically significant long-run impact on productivity in the mining sector. A 1% improvement in government effectiveness would increase mining total factor productivity by 0.023%. The result confirms the empirical submissions that good governance is associated with both higher productivity growth and level of per capita GDP and that trade flows are higher between rule-based countries than relation-based countries, as also concluded by Fayissa and Nsiah (2013), Li and Samsell (2009), Han, Khan, and Zhuang (2014), and Mustafa and Jamil (2018).

The research concludes a positive long-run relationship between real exchange rate and mining total factor productivity in SADC and also confirms the Balassa-Samuelson theory. A 1% increase in the real exchange rate will result in a 0.005% increase in total factor productivity in the mining sector of SADC at a 1% level of significance. An appreciation also boosts productivity in some sectors and that is documented by De Gregorio and Wolf (1994), Li and Tang (2007), Amadou (2010), Wondemu and Potts (2016). It can be concluded that in the long run, a real exchange rate appreciation complements productivity in the mining sector.

Table 6 provides the summary of the short-run dynamics that exist per country specifics that is the error correction terms and the associated coefficients for each variable and its linkage to the total factor productivity change in the mining sector.

As far as our sample is concerned, all countries have error correction terms that are negative and statistically significant at 1% and 5% levels. This confirms a robust long-run relationship between trade openness (*LOGTO*) and total factor productivity (*LOGTFPH*) in the mining sector of the SADC countries. That implies that a deviation from the long-run following a short-run shock is corrected at a differing speed of adjustment as depicted by each country's speed of adjustment. In this case, Botswana has 125%, DRC (106%), Namibia (113%), Zimbabwe (117%), and RSA (112%), Zambia (104%), and, Tanzania (97%). However, short-run dynamics results are varied at country specifics.

Table 7 shows results on heteroscedasticity, autocorrelation, and cross-sectional dependency, and according to our findings, the model estimated does not suffer from heteroscedasticity, autocorrelation except cross-sectional dependency. The results of Pesaran's test of cross-sectional independence reject the null hypothesis of no cross-sectional dependence meaning there exists cross-sectional dependence in our model and this confirms that the economies under study do depend on one another, especially in the mining sector, as indicated earlier that their technology and mining activities are technically similar as minimum processing is recorded across these countries. Therefore, we can conclude that the model has passed the post-estimation diagnostic tests except for cross-sectional independence.

6. CONCLUSION

The key objective of the study was designed to investigate the impact of trade openness on mining total factor productivity change. The key findings were that there is a long-run relationship between trade openness (merchandise of export and import as a percentage of GDP) and total factor productivity change in the mining sector of the selected SADC countries. For the period under study, it was found that a 1% increase in trade openness would improve total factor productivity change in the mining sector by 0.19%. In other words, there are positive mining productivity gains from the importing and exporting industry of SADC. All our control variables had expected signs and effects on productivity, that is foreign direct investment (*LOGFDI*), real exchange rate (*LOGXR*), human capital (*HC*), human capital and technology gap (*LOGHCGAP*), and governance (*LOGGVNC*). This economically implies that trade openness enhances the flow of technology needed in the mining sectors of SADC. Reflecting on our key findings, trade liberalisation contributes positively to the total factor productivity change in the mining

sectors of the SADC selected countries. Be that as it may, we register our concern on the marginal contribution which is very minimal given that the mining sector of SADC is international trade-oriented. The study does not go without limitations, aggregate mineral productions were used which may mislead our real productivity calculation. Also, minerals are a non-renewable resource so much that in some cases production ceases because of depletion of the mineral ore. Furthermore, productivity in the mining sector may double in the sector mainly because of the boom of the international market price. And can remain very low if commodity prices are not lucrative. The researchers expect further researches in mineral-specific productivity change, for instance, the impact of trade liberalization on total factor productivity change on gold in SADC, this will allow the crafting of mineral-specific policies that may help improve mineral productivity and value addition. At the time of penning this study, data on mineral-specific production inputs were not adequate, and hence in the future that data may soon be available.

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