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Impact of Rainfall and Temperature on Economic Growth in Angola, Botswana, Tanzania and Zimbabwe

Sanderson Abel[1,2]*, Leward Jeke[1]

[1]Nelson Mandela University, Port Elizabeth, South Africa, [2]Botswana University of Agriculture and Natural Resources, Botswana, *Email: abelsza.mwale@gmail.com

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ABSTRACT

Research indicates that temperature and precipitation have a big impact on economic growth due to greenhouse emission, especially in areas that depend heavily on agriculture. While extreme weather events like droughts or extreme heat can have a negative effect on production and impede economic development, optimal precipitation levels typically result in higher crop yields and economic activity. The purpose of this study is to econometrically test the effect of rainfall and temperature on economic growth in Angola, Botswana, Tanzania and Zimbabwe. The study specifically aims to respond to the following queries: Are rainfall and temperature important indicators of economic growth in Angola, Botswana, Tanzania and Zimbabwe? The results of the study established that rainfall has a negative effect in Angola only in the long run among the selected countries. In Botswana, Tanzania and Zimbabwe rainfall has no effect on economic growth in the long run. Whilst in the short run rainfall retains has a negative effect on economic growth in Angola and Botswana but positive relationship in Tanzania. On the other hand, result shows that temperature has positive impact in Angola and Tanzania with a unit increase in temperature increasing economic growth by 0.6088 and 0.6955% in Angola and Tanzania respectively in the long run. In the short run, temperature has been established to have a positive effect in Angola, Tanzania and Zimbabwe, reflecting that temperature rises have a beneficial effect in these countries. The results imply that climate related variables have an implication for economic growth.

Keywords: Temperature, Rainfall, Climate Change, Autoregressive Distributed Lag, Southern African Development Community
JEL Classifications: Q4, Q43, Q54

1. INTRODUCTION

One of the most difficult problems of the twenty-first century is climate change due to greenhouse emissions, which is especially severe in developing nations because of their geographic vulnerability, low incomes, increased reliance on climate-sensitive industries, and limited ability to adapt to the changing climate (Abidoye and Odusola, 2015). Climate change is the long-term variations in the typical weather patterns that have come to characterize local, regional, and global climates on Earth. The phrase is synonymous with a wide variety of observed outcomes resulting from these changes. Over the past 50 years, mean annual temperatures have risen by at least 1.5 times the known global average of 0.65°C, and the frequency of intense rainfall events has increased (Ziervogel et al., 2014).

It is generally anticipated that climate change will hinder economic growth, mainly through disruptions to agriculture, damage to infrastructure from extreme weather events, higher healthcare costs, and possible supply chain disruptions. These factors will result in lower productivity and an overall slowdown in the affected regions, particularly impacting developing nations with limited capacity for adaptation being especially affected. Developing nations are more susceptible to the negative effects of rising sea levels and the impact on water resources, ecosystems, crop production, fisheries, and human health, the poorest nations and people will be the ones who experience the negative effects of climate change first and suffer the most from it (Stern et al., 2006; Tol, 2008; Yohe and Schlesinger, 2002). Many people in less developed nations work in climate-sensitive industries, and there is limited ability to create and carry out adaptation

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plans. However, these nations must pay for the adoption and promotion of various mitigation techniques (Adger, 2006). Notably, future generations will be the only ones to experience the long-term effects of mitigation (Sathaye et al., 2006). Similarly, impoverished communities in these nations are more susceptible to environmental disasters because of their reduced capacity for adaptation (Smith and Wandel, 2006).

Africa is disproportionately affected by climate change and faces disproportionately high expenses for necessary climate adaptation (World Meteorological Organization, 2023). Figures 1 and 2 show the average annual temperature and rainfall respectively in the selected countries. The top three warmest years in the 124-year record occurred in Africa in 2023. The average temperature was 1.23°C higher than the long-term baseline of 1961-1990 and 0.61°C higher than the average of 1991-2020. According to the report, multi-year droughts persisted in northwest Africa in 2023, major floods produced significant losses and damages, temperature increases in Africa are marginally higher than the world average, and African nations continue to incur rising climate change costs.

World Meteorological Organization (2023) further noted that African nations are losing between 2% and 5% of their GDP on average, and several are spending up to 9% of their budgets to combat climate extremes. Over the next 10 years, the cost of adaptation in sub-Saharan Africa is projected to be between \$30 and \$50 billion, or 2-3% of the region's gross domestic product. If proper response measures are not implemented, it is predicted that up to 118 million extremely poor people (living on <USD 1.90/day) in Africa will be vulnerable to drought, floods, and high heat by 2030. The Southern African Development Community (SADC) is equally impacted by the same issues that sub-Saharan Africa is currently confronting (World Meteorological Organization, 2023).

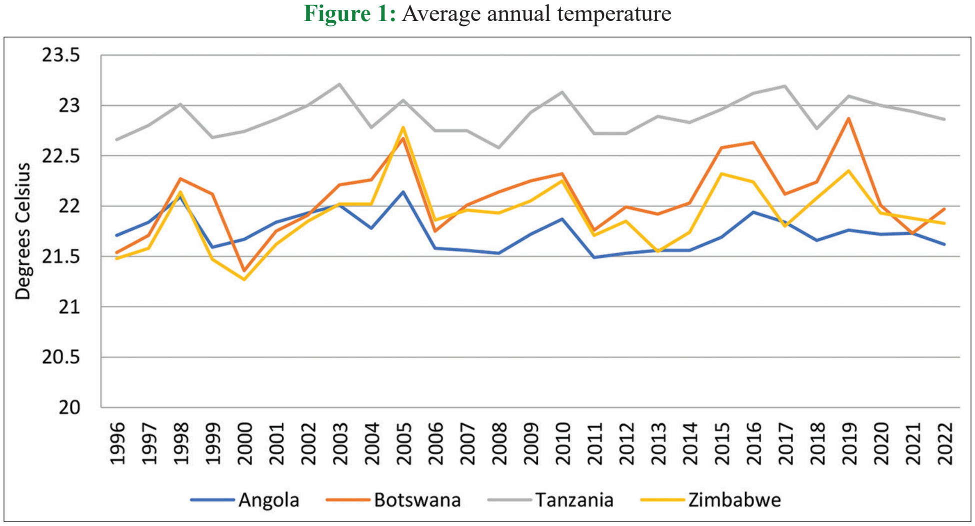
The detrimental impacts of climate change on growth in the Southern African Development Community (SADC) as a whole and on individual nations are not well studied empirically. There is currently no consensus on the extent of this issue's influence on economic growth at the regional and national levels due to the paucity of literature on the continent. The purpose of this study is to quantify how climate change affects selected countries economic growth. The study specifically aims to respond to the following queries: Are rainfall and temperature important indicators economic growth in Angola, Botswana, Tanzania and Zimbabwe?

2. LITERATURE REVIEW

There has been a growth in studies evaluating the effects of climate change on economic growth in various parts of the world (Farajzadeh et al., 2023; Kaushik et al., 2024; Ullah et al., 2024; Abidoye and Odusola 2015; Alagidede et al., 2016). Most of the studies have established that high temperatures harm growth. There are quite variations in the results about the effect of temperature on economic growth with a 1°C rise in temperature leading to a 0.385-0.67% reduction in growth (Kaushik et al., 2024; Abidoye and Odusola, 2015). Scholars have also established that temperatures above 24.9°C considerably impair SSA's economic performance (Alagidede et al., 2016). The consequences of the rise in temperatures and changes in rainfall patterns are hindering the growth projections of the world economy, mostly so in developing countries.

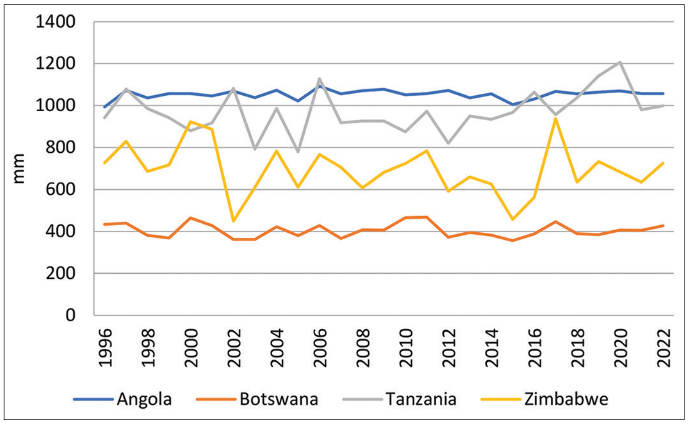
The effect of climate change on economic advancement was assessed by Ullah et al. (2024). The study adopted panel estimation methods, panel-VECM for Granger causality, and fully modified ordinary least squares (FMOLS) and dynamic ordinary least squares (DOLS) for long-term associations. The results point to the long-term benefit of climate change for economic advancement. The study also established a reciprocal relationship between economic growth and climate change. Similarly, a study was undertaken to examine how rainfall and temperature affect economic growth (Kaushik et al., 2024). The study used the panel data regression for the period 1991-2021. It was established that there is a strong inverse link between economic growth and temperature, with a 1°C increase resulting in a 0.385% decline in growth. Additionally, the impact of climate variables varies by income category, according to the study. Adopting a different methodology of the general method of moments (GMM), Farajzadeh et al. (2023) evaluated

Figure 1: Average annual temperature



Source: World Bank Climate Change Portal

Figure 2: Average annual rainfall



Source: World Bank Climate Change Portal

how economic growth is impacted by climate change. The control variables of the study were labor force, capital formation, financial development index, trade openness, and foreign aid. The study established no relationship between climate change and economic growth.

The impact of climate change on sustainable economic growth in Sub-Saharan Africa (SSA) was assessed (Alagidede et al., 2016). The study used temperature and precipitation as climate variables. The study employed the panel cointegration econometric technique to examine the short- and long-term impacts of climate change on growth. According to the study, temperatures above 24.9°C considerably impair SSA's economic performance. The effect of climate change and economic growth for 34 African countries for the period 1961-2009 was evaluated (Abidoye and Odusola, 2015). The study established that a 1% increase in temperature leads to a decline in GDP of 0.67% points. Globally, Dell et al. (2008) investigated how economic activity is affected by climate change. The results show that while increased temperatures have minimal impact on wealthy nations, they significantly slow economic growth in developing nations, and warmer temperatures seem to lower growth rates in developing nations. It was found that rising temperatures have a variety of negative impacts on developing countries, including decreased industrial, agricultural, and aggregate investment output as well as heightened political instability.

Dell et al. (2012) analyzed data from 136 nations between 1950 and 2003 and found three main findings. In the first place, warmer temperatures significantly slow down economic expansion in developing nations. A 1° Celsius increase in temperature over a single year, for example, typically lowers economic growth by 1.3% points. Secondly, it seems that greater temperatures lower growth rates rather than just production levels. Third, increased temperatures affect many other aspects of life, including political stability, industrial production, and agricultural productivity. The influence of climate change on economic growth is not resistant to changes in climate change indicators and samples, according to Bernauer et al. (2010), who used worldwide data from 1950 to 2004. However, there are adverse effects linked to the moving average-based temperature measure for Africa, but only at the 10% level. Additionally, Ali (2012) demonstrates a negative impact on growth using a co-integration study on Ethiopia. In particular, he noted that variations in rainfall intensity and variability have a long-term negative impact on growth.

The general long-term effects of precipitation and temperature on agricultural growth were examined in 32 Sub-Saharan African nations (Talib et al., 2021). Panel estimators with multifactor error structures and augmented autoregressive distributed lag (ARDL) models were employed in the investigation. According to the study, Sub-Saharan Africa's agricultural growth has a negative, long-term link with rising temperatures. A 1° increase in temperature could have a negative effect of up to 4.2-4.7% points on the rate of agricultural growth.

3. METHODOLOGY

Literature on the studies evaluating the relationship between climate change and economic growth reveals that scholars have used different methodologies to establish the relationship (Khurshid et al., 2022; Akram, 2012; Tol, 2024; Bilal and Känzig, 2024). The current study uses the autoregressive distributive lag (ARDL) model (Pesaran et al., 2001). The method has been chosen based on its ease of use when the variables are not integrated of the same order. In other words, the technique can be used when the variables are stationary at different levels, save for orders above one (Shrestha and Bhatta, 2018). The ARDL model is premised on the ordinary least squares method.

The ARDL method is credited with being a smarter method than other methods of similar nature. The method has the following features: It applies to small or finite samples specifically 30 or more observations (Ghatak and Siddiki, 2001). The method can be used even in situations where variables are not stationary at the same level except that the variables are not stationary at levels greater than one. In other words, the method can be used comfortably where a mix of variables is integrated of order one and order zero, not anything above. The method resolves the challenges of serial correlation and indigeneity when modeled with appropriate lags (Pesaran et al., 2001). The ARDL method is useful when estimating the long-run and short-run relationships (Pesaran et al., 2001).

The study specifies the following general model to capture the relationships between economic growth and climate change:

$$Y_t = \alpha_1 + \alpha_2\, CLIM_t + \alpha_3\, LPR_3 + \alpha_4\, GFCF_t + \alpha_5\, TO_t + \alpha_6\, GOV_t + \varepsilon_t \quad (1)$$

Where Y represents economic growth measured by gross domestic product growth rate, CLIM, LPR, GFCF, TO, and GOV are climate change variables, labour force participation rate, gross fixed capital formation, trade openness, and governance indicators.

3.1. Justification of the Variables

The variable climate change (CLIM) will be measured using temperature and precipitation (Alagidede et al., 2016). Rising temperatures are believed to stress crops and impede their growth and development, hence affecting growth Dell et al. (2012). Alterations in precipitation patterns are also linked to climate change since it restricts the amount of water available, and irregular rainfall including more frequent droughts or strong downpours has a substantial effect on crop production which is a growth driver in most African countries Dell et al. (2012).

The Governance indicators or institutional quality (GOV) influence on economic growth has been estimated. Research indicates that ensuring the rule of law and preventing corruption is crucial for promoting economic growth in emerging nations. There isn't any theoretical agreement or reliable empirical data in the literature that would suggest that the relationship between low- and high-income emerging nations is either positive, negative, or non-existent (Fawaz et al., 2021). However, Hassan et al. (2020) pointed out that research has shown that institutional quality is a useful instrument for guaranteeing a nation's sustainability. The extent to which air quality is improved or weakened by institutional quality has not been thoroughly assessed in the literature. The governance indicator is measured using the effectiveness of government index developed by World Development Indicators. All these variables are found on the World Bank data bank as provided in the World Development Indicators.

Fross fixed capital formation (GFCF), which is essentially an investment in new capital goods like infrastructure and machinery is assumd to positively influence growth. Capital formation increases the amount of money in circulation throughout the economy. Capital goods accumulation leads to investment and the creation of additional goods and services, which should increase population income and promote demand. Higher levels of GFCF typically result in higher GDP growth because new capital stock increases an economy's production capacity and productivity (Pasara and Garidzirai, 2020; Makaringe and Khobai, 2018; Saungweme et al., 2019).

Trade openness refers to the degree to which a country's economy is integrated with international trade, essentially measuring how much a country imports and exports relative to its overall economic size, usually calculated by the ratio of a country's total trade (exports plus imports) to its GDP; a higher ratio indicates a more open economy. Trade openness (TO) can result in higher GDP and faster economic development because it increases productivity, gives access to a greater variety of goods and services, and allows for the transfer of technology from trading partners. Trade openness was found to have a positive effect on economic growth (Keho, 2017). Contrary, Malefane and Odhiambo (2018) established that openness can hurt growth in the short- and long-run.

Labour force participation is a measure of the proportion of a country's working-age population that engaged actively in the labour market, either by working or looking for work (Cung and Hung, 2020) a higher labour force participation rate generally has a positive effect on economic growth. This is because more people working translates into more goods and services being produced, which raises GDP.

The estimation technique adopted for this study is the Autoregressive distributed lag model. The ARDL technique estimates $(P+1)^k$ number of regressions to determine the optimal lags for each variable. $P+1$, is the highest number of lags to be used and k is the number of variables in the equation (Shrestha and Chowdhury, 2005)? The model is selected based on the Schwartz-Bayesian Criterion (SBC) that uses the smallest possible lag length and is therefore described as the parsimonious model.

Since the study is mostly interested on understanding the effect of climate change related variable on economic growth one ARDL equation is perceived. The ARDL models are specified in equations 2 and 3. These equations incorporate both short-run and long-run dynamics among the variables.

$$\Delta GDP_t = \beta_0 + \beta_1 GDP_{t-1} + \beta_2 CLIM_{t-1} + \beta_3 LPR_{t-1} + \beta_4 GFCF_{t-1} + \beta_5 TO_{t-1} + \beta_6 GOV_t + \sum_{t=1}^{p}\theta_t \Delta GDP_{t-1} + \sum_{t=1}^{p}\vartheta_t \Delta CLIM_{t-1} + \sum_{t=1}^{p}\mu_t \Delta LPR_{t-1} + \sum_{t=1}^{p}\varphi_t \Delta GFCF_{t-1} + \sum_{t=1}^{p}\omega_t \Delta TO_{t-1} + \sum_{t=1}^{p}\dot{o}_t \Delta GOV_{t-1} \quad (2)$$

Where β_1 to β_6 are long-run parameters and $\theta, \vartheta, \mu, \varphi, \omega$ and ϵ re short run parameters. The null hypothesis of no cointegration is given as $\beta_1 = \beta_2 = \beta_3 = \beta_4 = \beta_5 = \beta_6$ and the alternative hypothesis is $\beta_1 \neq \beta_2 \neq \beta_3 \neq \beta_4 \neq \beta_5 \neq \beta_6$. When the null hypothesis is rejected based on the F-statistic implies there is cointegration. The rejection criterion is premised on the Bounds test. The goodness of fit for the ARDL model were assessed through the stability test provided by the cumulative sum of squares of recursive residuals (CUSUMSQ).

The data for the different variables were sourced from the different World Bank data sets for the period 1996-2022. Temperature and precipitation data were obtained from the World Bank Climate Change portal for development practitioners and policymakers. Governance indicators were obtained from the World Bank's worldwide global indicators. The other variables are labour force participation rate, trade openness, and gross fixed capital formation which were obtained from the Word bank database. The countries of interest for this study are Angola, Botswana, Tanzania and Zimbabwe. These countries are part of the Southern African Development Community (SADC). The choice of these countries was made based on the completeness of data for all the variables under consideration.

4. EMPIRICAL RESULTS

This section presents the econometric results of the study and their interpretation.

The mean, maximum, minimum and the standard deviation of the variables rainfall, temperature, governance index, trade openness, gross fixed capital formation and labour force participation are shown in Table 1. The variation of the data set is minimal, as

Table 1: Descriptive statistics

Statistic	RAIN	TEMP	GOV	TO	GFCF	LPR
Mean	780.63	22.15	−0.574	73.42	23.83	73.46
Median	852.18	22.01	−0.695	76.04	26.19	71.77
Max	1206.24	23.21	0.64	125.78	42.82	89.43
Min	356.58	21.27	−1.55	17.23	2.01	59.86
Standard Deviation	267.65	0.52	0.674	28.51	10.02	9.48

Table 2: Correlation matrix

Variable	Rain	Temp	GOV	TO	GFCF	LPR
Rain	1					
Temp	0.094	1				
GOV	−0.634	0.146	1			
TO	−0.324	−0.614	0.226	1		
GFCF	0.273	0.279	0.319	0.14	1	
LPR	0.602	0.548	−0.345	−0.556	0.411	1

reflected by the low standard deviations of the variables except rainfall which has a higher variability.

The variables under study do not show strong correlation among themselves (Table 2). Gujarati (2007) argued that the problem of multi-collinearity exists if the correlation between independent variables is above 0.8. All the correlation coefficients between the independent variables were <0.8.

Table 3 shows the econometric estimations of the effect of rainfall on economic growth.

Table 3 displays the findings of the rainfall influence on economic growth. Both the short-term and long-term dynamics are displayed in the table. The evidence of a steady long-term association between the variables for each of the four countries is supported by the significant coefficient on the lagged error correction term with the right sign. This coefficient indicates that in Angola, Botswana, Tanzania, and Zimbabwe, a divergence from the long-term equilibrium level of output in 1 year is corrected by 70%, 42%, 60%, and 53% in the subsequent year.

Table 3 shows that rainfall has a negative effect only in Angola in the long run. The results show that 1% increase in rainfall leads to a decline in economic activity of 0.12%. In other the results imply that rainfall has a negative influence on economic growth in Angola in the long run. The results support the study by Brown et al. (2013) who established that that precipitation affects GDP growth, noting that both dry and wet episodes of rainfall lead to a decline in per capita GDP growth rates. As for the other countries, Botswana, Tanzania and Zimbabwe rainfall has no effect on economic growth. A number of studies also has failed to find a robust relationship between the chosen measure of precipitation or water availability and indicators of economic growth (El Khanji and Hudson, 2016; Sadoff et al., 2016). Whilst in the short run rainfall retains a negative effect on economic growth in Angola and Botswana but positive relationship in Tanzania. This implies that an increase in rainfall disturbs the growth momentum in Angola and Botswana while enhancing economic growth in Tanzania in the short term. In Zimbabwe the results show that rainfall has no significant effect on economic growth in both the short and long run.

The results show that trade openness plays a significant role in promoting GDP growth in Angola and Botswana. The coefficients of variable TO (0.3664 and 0.3548) reveals that TO has a significant positive impact on economic growth both in the long run and short run. The result signifies that importance of Angola and Botswana to accelerate trade liberalization to achieve high economic growth. This is supported by a number of prior studies (Leyaro, 2015; Tahir and Khan, 2014). Some studies has established that trade openness has positive effects on economic growth both in the short and long run. Meanwhile the results found that trade openness has detrimental effect on economic growth in Zimbabwe. In other words, increase in the rate of openness reduces the level of economic growth in Zimbabwe. Malefane and Odhiambo (2018) established that openness can hurt growth in the short- and long-run supporting the Zimbabwean case.

Labour force participation rate has a positive effect on economic growth in Angola, Botswana, Tanzania and Zimbabwe. This means that an increase in the population participation in labour force increases economic activity in the country. A higher labour force participation rate generally has a positive effect on economic growth because more people working translates into more goods and services being produced, which raises economic output. The results are in line with Haque et al. (2019).

The gross fixed capital formation has mixed effect on economic growth among the four countries. It has a positive effect on growth in Tanzania, negative effect in Angola and Botswana, and no effect in Zimbabwe. The effect is dependent on the type of investment being attracted to the different countries. The positive results are supported in some studies which established that there is a direct and significant relationship between economic growth and gross fixed capital formation (Gibescu, 2010; Achar et al., 2024). While, Muhammad and Khan (2019) established the adverse effect of gross fixed capital on economic growth. He disclosed that capital significantly and negatively impacts economic growth in Asian host nations.

The effect of governance as measured by the effectiveness of government index has a negative effect in Angola in the long run while having positive effect in the short run. The index has negative effect in Zimbabwe in the short run. This shows that the good governance has positively influenced Angola's economy while adversely impacting on the Zimbabwean economy in the short term. As discussed in the methodology, there isn't any theoretical agreement or reliable empirical data in the literature that would suggest that the relationship between should either positive, negative, or non-existent (Fawaz et al., 2021). However, Hassan et al. (2020) pointed out that research has shown that institutional quality is a useful instrument for guaranteeing a nation's sustainability.

Table 4 displays the results of the effect of temperature on economic growth. The results demonstrate both short-term and long-term dynamics, and the coefficient on the lagged error correction term is significant with the correct sign, confirming the

Table 3: Effect of rainfall on economic growth

Variable	ANGOLA	BOTSWANA	TANZANIA	ZIMBABWE
Dependent variable: GDP				
GDP(−1)	−0.6993 (0.0157)		0.4307 (0.0643)	
RAIN	−0.1281 (0.0030)			
RAIN(−1)	−0.2345 (0.005)		−0.0074 (0.0331)	
RAIN(−2)	−0.1684 (0.004)		−0.0071 (0.0355)	−0.0321 (0.0365)
TO	0.3644 (0.0097)	0.3548 (0.0421)		−0.2145 (0.0698)
TO(−1)		−0.3056 (0.070)		0.1770 (0.0853)
LPR	5.4183 (0.0396)		0.5878 (0.0376)	1.7533 (0.0530)
LPR(−1)	4.3866 (0.0566)			
LPR(−2)		4.1374 (0.0178)		
GFCF	−0.9271 (0.0014)	−2.3105 (0.0030)		0.7847 (0.0519)
GFCF(−1)	−0.4866 (0.0725)			
GFCF(−2)	−0.4669 (0.0347)			
GOV		3.9393 (0.0455)		
GOV(−1)	−6.4905 (0.0563)			
Short run model				
ECM	−0.6999 (0.0000)	−0.4230 (0.0000)	−0.5693 (0.0001)	−0.5347 (0.0003)
D (RAIN)	−0.1272 (0.0012)			
D (RAIN(−1))	0.1684 (0.0001)	−0.05569 (0.0107)	0.0070 (0.0035)	
D (TO)	0.3664 (0.0004)	0.3548 (0.0036)		−0.2145 (0.0510)
D (LPR)		−4.1374 (0.0003)	0.5453 (0.0086)	
D (LPR[−1])	4.3866 (0.0457)			
D (GFCF)	−0.9271 (0.0000)	−2.3105 (0.0001)	0.1348 (0.0151)	
D (GFCF[−1])	0.46692 (0.0012)		−0.1374 (0.0115)	
D (GOV)	3.6362 (0.0620)			−2.602 (0.0147)
D (GOV[−1])	−1.6993 (0.0000)			

Table 4: Effect of temperature on economic growth

Variable	ANGOLA	BOTSWANA	TANZANIA	ZIMBABWE
Dependent variable: GDP				
GDP(−1)	−0.4199 (0.0879)			
TEMP	10.6089 (0.0328)		2.6955 (0.0743)	
TEMP(−2)				17.4499 (0.0104)
TO		0.4399 (0.0157)	0.06983 (0.0546)	−0.2009 (0.0944)
TO(−1)		−0.4095 (0.0214)		
TO(−2)				0.26373 (0.0247)
LPR	6.5833 (0.0166)		0.66198 (0.0097)	
LPR(−1)	8.3015 (0.0069)			
LPR(−2)		4.2180 (0.0160)		
GFCF	−0.5100 (0.0166)	−2.3352 (0.0038)		
GFCF(−1)	−0.5798 (0.0315)	1.1533 (0.0926)		1.7859 (0.0181)
GFCF(−2)	−0.4005 (0.0404)			
GOV(−1)				−7.3877 (0.0211)
GOV(−2)				5.2373 (0.0275)
Error correction model				
ECM	−0.4199 (0.0000)	−0.9127 (0.0000)	−0.6621 (0.0005)	−0.5988 (0.0002)
D (TEMP)	0.6088 (0.0017)		0.6955 (0.0100)	0.3909 (0.0084)
D (TEMP[−1])				−0.1449 (0.0006)
D (TRADE)		0.4399 (0.0005)		−0.2009 (0.0137)
D (TRADE[−1])				−0.2637 (0.0038)
D (LPR)	6.5830 (0.0002)		0.6620 (0.0015)	
D (LPR[−1])				
D (GFCF)	−0.51002 (0.0002)	−2.3352 (0.0001)		0.55320 (0.0442)
D (GFCF[−1])	0.4005 (0.0093)			
D (GOV)				
D (GOV[−1])				−5.7237 (0.0006)

evidence of a stable long-term relationship among the variables for each of the four countries. According to this coefficient, in Angola, Botswana, Tanzania, and Zimbabwe, a deviation from the long-term equilibrium level of output in 1 year is corrected by 42%, 91%, 66%, and 60% over the subsequent year.

Table 4 shows that temperature has positive impact in Angola and Tanzania. The results mean that a unit increase in temperature increase in economic growth by 0.6088 and 0.6955% in Angola and Tanzania respectively in the long run. This means in the long run; temperature increase has a growth enhancing effect in Angola and Tanzania. The results are partially supported by Khurshid et al. (2022) who established that increases and decreases in mean temperature are expected to favourably benefit Pakistan's economic growth. The argument on why increase in temperature enhance growth is provided (Colacito et al., 2018). They argue that positive impact of the rise in temperature on GDP growth is due to its variance from region to region. Higher temperatures in colder regions or during colder seasons may have a positive effect on economic activity because the extreme cold can be just as difficult to perform as extreme heat. Botswana and Zimbabwe show that there is no relationship between temperature and economic growth. This is supported by prior studies (Kalkuhl and Wenz, 2020; Greßer et al., 2021). Kalkuhl and Wenz (2020) did not find evidence for temperature effects on permanent growth rates except on the productivity level. Greßer et al. (2021) studied the relationship between average temperatures and per capita income but found no evidence that both variables are related in a statistically meaningful way. Temperature has also been established to have a positive effect in Angola, Tanzania and Zimbabwe in the short run. Reflecting that temperature rises has a beneficial effect in these countries.

The other results are pretty almost the same as presented in Table 1. The variation is minimum among all the variables (trade openness, governance index, gross fixed capital formation, and labour force participation rate) does not change much hence are discussed above. These variables influence differently economic growth in Angola, Botswana, Tanzania and Zimbabwe.

5. CONCLUSION

The effect of climate change on economic growth remains controversial issue. Literature provides different results on the effect of temperature and rainfall on economic growth. The current study sought to also evaluate how temperature and rainfall impact economic growth in Angola, Botswana, Tanzania and Zimbabwe. Like other studies before, the results have revealed that temperature and rainfall impact countries differently in both the short and long run. Specifically, the study demonstrated that, out of the chosen nations, rainfall only has a detrimental long-term impact in Angola. Rainfall has little long-term impact on economic growth in Botswana, Tanzania, or Zimbabwe. Rainfall retention has a short-term negative impact on economic growth in Botswana and Angola, but a positive link in Tanzania. The other drivers of economic growth, fixed capital formation, labour force participation rate, trade openness, and governance index influences growth with different magnitude and signs dependent on the different country contexts. The crafting of pro-growth policies should ensure that the different country dynamics are taken into consideration. The weakness of the current study is the short-term data series hence studies should be done with longer periods. Panel data studies for the whole SADC would help to understand climate change effects for the whole region.

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