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Can Southern African Countries Weather El Niño Phenomena?

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Abstract

The primary objective of this paper is to analyze the effects of one extreme weather phenomenon – El Niño – on the economic development of the 14 countries in the Southern African Development Community (SADC). Using a panel data set covering the 1973-2005 periods, the results of a fixed effects econometric model indicate that certain measures of El Niño events are associated with a small, but statistically significant, reduction in economic growth. An additional finding is that certain SADC countries are more vulnerable than others to El Niño events. As a second objective, this paper explores various adaptive policies to mitigate the effects of El Niño events. The research suggests that an established international public good is a promising policy intervention – providing information on long-term weather forecasts. However, the success of this intervention depends on time-consuming and costly implementation because it involves reaching out and educating small-scale farmers.

Introduction

Economic disaster caused by weather is not a new phenomenon, but the regularity of extreme climate cycles in the last 35 years has raised serious questions about how developing countries can better cope with these events. For example, the executive summary of the Stern Review noted that global warming, which causes sudden shifts in regional weather patterns, threatens the economic well being of millions of people. Stern (2006) estimated that the costs of extreme weather conditions could reduce world annual GDP by 0.5-1.0 percent by 2050. While El Niño phenomena existed long before global warming was considered an issue, some scientists (discussed subsequently) hypothesize that there is a link between the two, where global warming could cause more frequent and more intense El Niño events.

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This paper's primary objective is to focus on one extreme weather phenomenon – El Niño – and its effects on the economic development of one vulnerable region – the 14 countries in the Southern African Development Community (SADC).[i] A secondary objective is to explore various adaptive policies to mitigate the effects of El Niño events

The next section on this paper provides a brief background on El Niño. The third section quantifies the relationship between El Niño phenomena and economic growth. The fourth section addresses the obvious question of what could be done before and during an El Niño occurrence, by discussing various policies options to help people adapt to the El Niño induced weather change. The final section presents a summary and conclusions.

Background on El Niño

As far back as the late 1800s, Peruvian fishermen noticed changes in their fish catch every few years around December (Christmas time) along with unusually warm sea water (Glantz, 2001). The warmer waters reduced the fish population, especially anchoveta, which reduced the food for fish eating birds, whose carcasses washed up on the beaches. These birds' droppings, called "guano," contained rich amounts of nitrogen and phosphorus and became an important Peruvian export between 1840 and 1880 that fertilized farms in other parts of the world. The fisherman ironically named the phenomenon El Niño, which is the Spanish phrase for "the Christ Child" because the gift was a reduction in available supplies of fish and guano. La Niña which produces the opposite climatic effect is Spanish for "the little girl."

The El Niño-Southern Oscillation (ENSO) is a joint global ocean-atmosphere phenomenon. Its atmospheric change was first noted by Sir Gilbert Thomas Walker in 1923 (Katz, 2002). Shifting trade winds caused atmospheric pressure to oscillate between the eastern Pacific (sinking air) and the western Pacific (rising air). These oscillations can be measured by fluctuations in the air pressure difference between Tahiti and Darwin. This occurrence combined with warmer than normal sea surface temperatures of the tropical Eastern Pacific Ocean produced the ENSO. The link between the two weather phenomena was first suggested tenuously by Bjerknes (1969). While no elements of his

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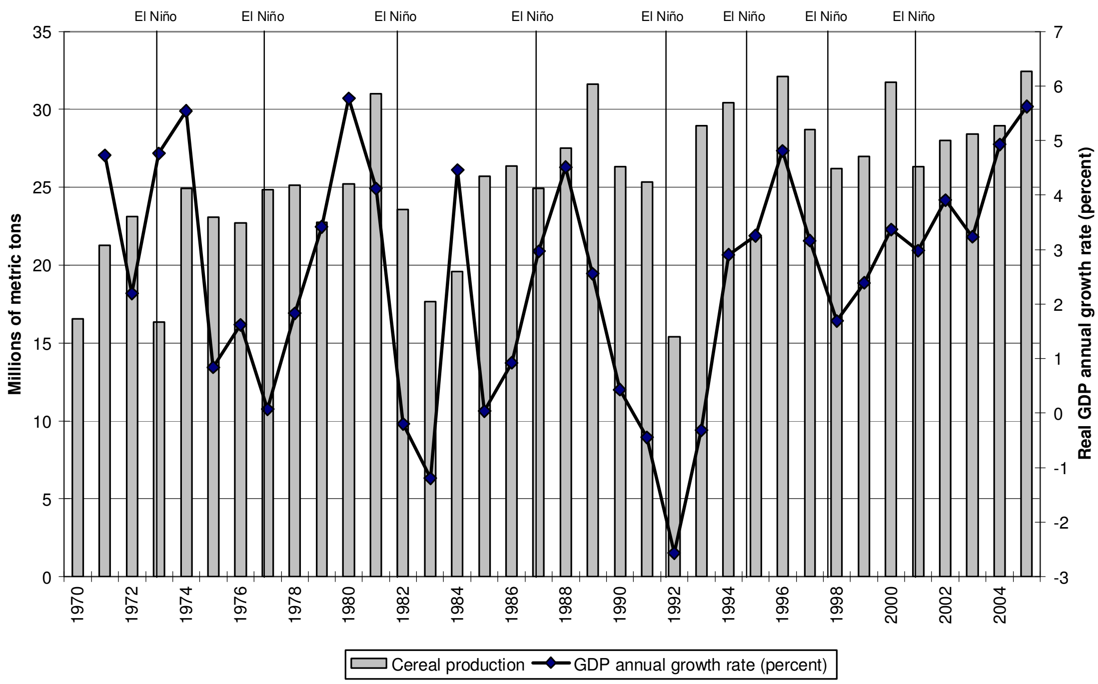
synthesis were entirely new, he integrated them into a conceptual framework supported by plausible dynamic and thermodynamic reasoning, which further research has shown to be basically correct (Philander, 1990). The El Niño weather effects typically persist for 9-12 months and reoccur every 2 to 7 years.

Figure 1 - Cereal Production and Real GDP Growth in Southern Africa, 1970-2005



Sources: World Bank – World Development Indicators, authors' calculations, and the Climate Prediction Center, National Oceanic and Atmospheric Administration (www.cpc.noaa.gov)

Although there may be some regularity to the El Niño and La Niña phenomena with predictable consequences, the frequency of the former has increased in recent years. This has challenged researchers to ask whether there is a connection between global warming and El Niño events. Timmermann et al. (1999) employed a Global Climate Model (GCM) which showed that higher greenhouse-gas concentrations were associated with more frequent El Niño-like conditions. Sun (2000) developed a theoretical framework whereby the tropics rid itself of excessive heat through the El Niño

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phenomena. While not the only variable in the model, an important variable is the difference between the western Pacific sea surface temperature (T_w) and the deep ocean temperature (T_c). When $T^* = (T_w - T_c)$ is sufficiently large, the coupled equatorial ocean-atmosphere finds itself in a thermally forced oscillatory state. The model shows that the larger T*, the greater the magnitude of El Niño. At least in the near future, global warming can contribute to increases in T* and thus to the magnitude of El Niño events.

The effects of El Niño phenomena on the climate of the southern hemisphere are deep and profound. ENSO has its signatures in the Pacific, Atlantic, and Indian Oceans producing adverse weather conditions especially for countries in South America, Asia, and Africa. For SADC countries, El Niño's impact on climate produces wetter than normal conditions during the long rainy season from March to May and drier than normal conditions from December to February, especially in Zambia, Zimbabwe, Mozambique and Botswana. According to World Development Indicators (WDI), six of the 14 SADC countries are highly dependent on farming with agriculture value added greater than 20 percent of GDP. Because of their heavy reliance on basic industries, such as agriculture and fisheries, climate change in these vulnerable countries can have a negative effect on their economic growth, employment, and foreign exchange earnings. As Mendelsohn, Dinar, and Williams (2006) have shown, poor countries are more vulnerable to climate change than rich countries, primarily due to their location in warmer low-latitude regions.

Relationship between El Niño phenomena and economic growth

A visual depiction of the effect of El Niño phenomena on the economies of the SADC is shown in Figure 1, which overlays El Niño events on cereal production and economic growth (real GDP). During the period 1970 to 2005, eight El Niño events occurred. In seven of those eight occurrences, cereal production dropped, especially in 1992 from some 25 million metric tons to some 15 million metric tons. Economic growth in the region fell from the growth of the previous year during five of the eight El Niño events.[ii] The simple average annual growth rate over the 1970-2005 period was 2.5 percent; removing the El Niño years increased the average annual growth rate to 2.9 percent; considering only the average annual growth rate for the eight El Niño years

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lowered the growth rate to 1.4 percent.[iii] But El Niño events are not the only factor in reduced growth.

A more rigorous quantification of how El Niño events affect economic growth requires an econometric model. The literature on economic growth (see, for example, Barro, 1991, Mankiw, Romer, and Weil 1992, Sachs and Warner, 1997, and Temple, 1999), provides various models. This paper follows Mankiw, Romer, and Wei's contribution, using a production function approach that relates output to capital, labor, and other inputs. Let

$$Y(t) = K(t)^{\alpha}(A(t)L(t))^{1-\alpha} \text{ and } 0 < \alpha < 1 \tag{1}$$

where $Y(t)$ = GDP over time, $K(t)$ = a measure of capital, $L(t)$= labor, and $A(t)$ = a measure of the level of technology. The next step is to rewrite the production function in per capita terms using labor rather than population as the denominator.

$$y(t) = A(t)^{1-\alpha} k(t)^{\alpha} \tag{2}$$

where $y(t) = Y(t) / L(t)$, $K(t) = K(t) / L(t)$, and A is divided into two components: one for exogenous technological progress, $A_1(t)$, and the other for the state of the economy (including policy variables and climate measurements), $A_2(t)$. Assuming as Mankiw, Romer, and Weil (1992), that L grows at a rate n, $A_1(t)$ grows at a rate g, and k growth depends on savings (s) and depreciation (δ), a system of equations can be written

$$\dot{k}(t) = s(t)y(t) - (n(t) + g + \delta)k(ty) \tag{3}$$

$$L(t) = L(0)e^{nt} \tag{4}$$

$$A(t) = A_1(t)A_2(t) \tag{5}$$

$$A_1(t) = A(0)e^{gt} \tag{6}$$

$$\text{Ln } A_2(t) = \rho_o + \Sigma_j \ \rho_j \ln X_j \tag{7}$$

This system of equations can be solved for the steady state growth path

$$k^*(t) = A(t)[s(t) / (n + g + \delta)]^{1/(1-\alpha)} \tag{8}$$

which implies that saving is positively related to k* and labor (population) growth negatively related to k*. By substituting (8) back into the production function (2), the steady state path is obtained

$$y^*(t) = A(t)\, s(t)^{\alpha/(1-\alpha)}\, (n + g + \delta)]^{-\alpha/(1-\alpha)} \tag{9}$$

If all countries were in their steady state, equation (9) would be appropriate, but it does not seem likely that the SADC countries are on their long-run steady-state growth paths. Instead, we assume that they are in some dynamic transition which can be implemented with a Taylor Approximation, after writing (9) in efficiency units (i.e., dividing both sides by A(t)), and taking logs.

$$\begin{aligned} \ln y(t) - \ln y(t_0) &= -\beta \ln y(t_0) + \beta \ln A(t) + \beta(\alpha/(1-\alpha)\ln s(t) \\ &- \beta(\alpha/(1-\alpha)\ln(n+g+\delta) + (1-\beta)(\ln A(t) - \ln A(t_0)). \end{aligned} \tag{10}$$

Next substitute the state of the economy variables, X_j, for $A(t)$ and $A(t_0)$, combine all constants into one term, and let the coefficient $\gamma = \beta(\alpha/(1-\alpha))$. This produces the growth path to a steady state assuming conditional convergence.

$$\Delta \ln y(t) = -\beta \ln y(t_0) + (\gamma_1) \ln s(t) + (\gamma_2) \ln X_j(t) \qquad + (\gamma_3)(t-t_0) + (\gamma_0)] \tag{11}$$

The state of the economy variables, X_j, include a measure of human capital, the degree of openness, measures of the agricultural sector, and measures of El Niño activity. In previous studies, the human capital variable, the degree of openness, produced significant results, as well as exports, which is not used here (Dimkpah, 2002). Because this paper is focusing on how El Niño events affect economic growth, two measures of the agriculture sector are included – cereal production (in kilograms per hectare) and a more general index of crop production; as well as measures of El Niño activity.

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Climatologists who track El Niño activity have developed various ways to measure these events. The two most common are the southern oscillation index (SOI) and the standardized southern oscillation index; a third, more recently developed measure, is the multivariate ENSO index (MEI).[iv] Other studies that have focused more generally on climate and economic growth have used temperature or precipitation rates (Tol, 2009).

The regressions were estimated on a panel data set of the 14 SADC countries over the period 1973-2005. First OLS regressions were run on the pooled data without taking into account any fixed or random effects. The pooled regressions (not shown here, but available from the authors upon request) produced R^2s in the range of 0.13, indicating that other variables, perhaps something specific to a country, were omitted. Next a fixed effects model was employed, which takes into account in a general manner country-specific differences. Table 1 present the results of the fixed effects model. While the R^2 is low for each regression, it has doubled from the pooled OLS regressions. The F statistic provides support for a fixed effects model by rejecting the null hypothesis that all the country dummy variables are zero. Tests for random effects, where the differences among countries are captured in the error term were also undertaken. The Hausman specification test (not shown here, but available from the authors upon request), which compares random effects versus fixed effects models, produced results indicating that a fixed effects model is more appropriate than a random effects model.

Turning to the coefficient estimates, the lagged GDP variable is negative as the model hypothesizes and significant and the investment (share of capital) share is also always significant.

The model hypothesizes that population growth is negatively related to economic growth, but the coefficient on population growth while always negative is not always statistically significant. Both cereal production and the more general crop production index are significant and positively related to economic growth, although the magnitude is relatively small.

The two most common measures of El Niño events – the SOI and the standardized SOI – are negative during El Niño and positive during La Niña, so the sign on these coefficients is positive as expected, and the t-statistic indicates the coefficients

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are significantly different from zero. For the MEI, El Niño events are positive and La Niña events are negative, so the coefficient sign is negative as expected, but not statistically significant. While the coefficients show that the region's economic growth is reduced by a small amount, a question can be raised regarding the individual countries in the SADC. Did El Niño events affect countries differently, i.e. are some SADC countries more vulnerable than others?

The results obtained from fixed effects model identify, in a relative manner, which countries are more vulnerable. Consider the coefficients on the country specific dummy variables in Table 1, where the intercept term is Zimbabwe and the dummy variables are deviations from the Zimbabwe intercept. The country with the highest negative coefficient and thus the most vulnerable relative to Zimbabwe is the Democratic Republic of the Congo; the least vulnerable countries are Botswana, Mauritius, and South Africa.

Policies to mitigate the adverse effects of El Niño

To a certain extent, some of the SADC countries are at the mercy of El Niño phenomena, but an adaptive strategy to reduce the adverse effects of El Niño phenomena is certainly possible. Beg et al. (2002) argued that policy makers who are concerned with sustainable development should integrate climate variability into their development strategies. Climate variability places a new emphasis on various environmental policies, such as those related to energy efficiency and land use. In their view a policy framework should be adopted following a process that first considers long-term ecological issues, then formulates targets, and finally formulates the specific policies. Bosetti, et al. (2004) also argue that long-term goals are important, but point out that short-term targets should be flexible, given the degree of uncertainty associated with climate change, which would include El Niño events. They contend that present policies should not set in place an irreversible policy direction that would restrict future policy options, which is also sound advice in designing many public policies outside of climate change.

In formulating the specific policies, Beg, et al. (2002) argues, on the one hand, that cost-benefit analysis (CBA) could provide support for a given set of policies, since

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Table 1: Coefficient Estimates from Various El Niño Measures.

Dependent Variable Output Growth	Δlny	Fixed Country Effects	Fixed Country Effects	Fixed Country Effects	Fixed Country Effects	Fixed Country Effects	Fixed Country Effects
Constant		0.392 (3.66)	0.391 (3.65)	0.405 (3.76)	0.320 (3.16)	0.319 (3.15)	0.327 (3.21)
Ln Lagged GDP	$y_{(t-1)}$	-0.049 (-4.90)	-0.049 (-4.89)	-0.050 (-5.04)	-0.042 (4.56)	-0.042 (-4.56)	-0.043 (-4.65)
Ln Capital Share	s	0.023 (3.45)	0.023 (3.45)	0.024 (3.59)	0.025 (3.18)	0.025 (3.81)	0.026 (3.96)
Ln Openness	OP	-0.028 (1.81)	-0.027 (-1.80)	-0.029 (-1.87)	-0.033 (-2.20)	-0.033 (-2.19)	-0.033 (-2.24)
Human Capital Index	HKI	0.003 (0.59)	0.005 (0.61)	0.001 (0.23)	0.004 (0.99)	0.005 (1.01)	0.003 (0.63)
Population Growth	ΔlnP	-0.907 (-2.34)	-0.910 (-2.35)	-0.883 (-2.26)	-0.629 (-1.62)	-0.632 (-1.63)	-0.599 (-1.53)
Cereal Production	CP	0.0001 (2.71)	0.0001 (2.70)	0.0001 (2.88)			
Agriculture Production Index	API				0.0007 (4.50)	0.0007 (4.49)	0.0007 (4.56)
ENSO Index	IX_1	0.003 (2.54)			0.003 (2.57)		
ENSO Standardized Index	IX_2		0.005 (2.56)			0.005 (2.60)	
Multivariate ENSO Index	IX_3			-0.002 (-1.17)			-0.002 (-1.08)
Country Specific Dummies:							
Angola		0.062 (1.94)	0.063 (1.96)	0.052 (1.64)	0.060 (1.90)	0.060 (1.92)	0.050 (1.59)
Botswana		0.168 (6.74)	0.167 (6.73)	0.171 (6.83)	0.136 (6.12)	0.136 (6.11)	0.137 (6.14)
Congo Dem. Rep		-0.092 (-2.42)	-0.091 (-2.40)	-0.101 (-2.65)	-0.111 (-2.95)	-0.110 (-2.93)	-0.119 (-3.17)
Lesotho		0.034 (1.61)	0.034 (1.60)	0.034 (1.58)	0.036 (1.72)	0.036 (1.71)	0.035 (1.68)
Madagascar		-0.020 (-0.72)	-0.019 (-0.70)	-0.027 (-0.98)	-0.008 (-0.33)	-0.008 (-0.31)	-0.014 (-0.56)
Malawi		-0.018 (-0.65)	-0.018 (-0.63)	-0.026 (-0.94)	0.005 (0.20)	0.005 (0.21)	-0.002 (-0.70)
Mauritius		0.087 (3.41)	0.087 (3.39)	0.089 (3.47)	0.106 (4.36)	0.105 (4.35)	0.109 (4.49)
Mozambique		0.019 (0.62)	0.193 (0.64)	0.011 (0.36)	0.026 (0.90)	0.027 (0.91)	0.019 (0.64)
Namibia		0.096 (4.76)	0.095 (4.75)	0.099 (4.92)	0.017 (4.01)	0.071 (4.01)	0.074 (4.11)
South Africa		0.102 (4.72)	0.102 (4.71)	0.105 (4.86)	0.094 (4.44)	0.094 (4.43)	0.097 (4.56)
Swaziland		0.103 (4.23)	0.102 (4.22)	0.104 (4.26)	0.096 (4.09)	0.096 (4.08)	0.097 (4.10)
Tanzania		-0.003 (-0.18)	-0.003 (-0.17)	-0.006 (-0.33)	-0.005 (-0.27)	-0.005 (-0.26)	-0.007 (-0.40)
Zambia		-0.015 (-0.98)	-0.014 (-0.97)	-0.017 (-1.16)	-0.014 (-1.00)	-0.014 (-0.99)	-0.017 (-1.16)
R2		0.26	0.26	0.25	0.28	0.28	0.28
F		6.09*	6.09*	6.16*	5.80*	5.79*	5.79*

(The t-values are in parentheses; and the * indicates a 95 percent confidence level for the F statistic.)

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CBA is well known and widely accepted. They also note, on the other hand, that CBA has drawbacks because it cannot fully quantify environmental and social impacts; nevertheless Butt, McCarl, & Kergna (2006) have quantified the benefits for certain adaptation policies in Mali. Pierce (1998) also advocates using CBA, even though uncertainties exist.

One specific policy designed to mitigate the effects of El Niño in SADC countries is providing information on long-term weather forecasts. Scientists now understand El Niño teleconnections better, which allows them to provide seasonal climate forecasts for various locations around the world. The availability of sound data is essential for effective management of El Niño related risks (Benson and Clay, 2004a). Provision of such information is in effect an international public good – no one country can be excluded from the information once it is disseminated and there is no rivalry in consumption of such information (the extent to which one country consumes the information does not reduce the extent to which another country can consume it). However, like most public goods, there are problems in valuation of the good and in determining how the cost of producing the good will be shared. Nevertheless, by the late 1990s a formal process emerged to disseminate long-lead weather forecasts through the Southern African Regional Climate Outlook Forum (SARCOF), funded by the Drought Monitoring Centre for Southern Africa, the International Research Institute for Climate Prediction, and other regional and international organizations.

The value of this international public good flows to both public sector policy makers and private individuals. Public sector managers can adjust their level of preparedness and their management of the food system, while those in the agriculture sector can engage in private risk management. Unfortunately, as Benson and Clay note, private risk management actions have only been taken by some commercial farmers. Small-scale farmers lack the capacity to make adjustments such as changing crops, changing seed variety, or changing traditional planting practices. It has been suggested that an Extension Service type effort on weather-related risks would be needed to disseminate information to the small-scale farmers. SADC countries have National Early Warning Units (NEWUs) and a Drought Monitoring Centre as part of a regional disaster

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mitigation strategy (Garanganga, 2003). However, gaps still exist in disseminating credible information to small-scale farmers, many who do not understand the meaning of terms such as "average" or "probability" (Archer, et al., 2007). Unfortunately, small-scale farmers may ascribe a high degree of uncertainty to the weather forecast and thus fail to act on the information decisively. Agrawala and van Aalst (2005) have identified an "uncertainty trough" where the information is not communicated in a credible manner to small-scale farmers.

Applying this time-intensive policy of careful interactive communication to all SADC countries would require a considerable amount of scarce resources, some of which should be allocated to poverty alleviation and basic needs (Kulindawa, 1998). However, the fixed effects model indicates where such a policy, along with other adaptive policies, could be concentrated in order to maximize the marginal impact of policy intervention. The research previously discussed suggests implementing a pilot project in the Democratic Republic of the Congo before the next El Niño event could provide significant marginal benefits for those countries, if it were well-planned and well-executed. This proposal does not negate the public good aspect of information provision to all countries in the region, but it would increase what Archer, et al. (2007) call outreach and application resources to the most vulnerable. The lessons learned from this type of pilot project then can be applied (in hopefully a more cost-effective manner) to an expanded climate prediction policy initiative for all SADC countries.

Summary and conclusions

The main purpose of this study was to examine the effects of El Niño phenomena on the 14 countries in the Southern Africa Development Community (SADC). Economic growth was generally less robust in years that El Niño occurred. The simple average annual growth rate over the 1970-2005 period with the El Niño years excluded was 2.9 percent; while the average annual growth rate during the El Niño years was only 1.4 percent. A fixed effects econometric model indicated a reduction in economic growth due to El Niño events for two of three measures of El Niño activity.

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Also, this paper discussed adaptive policy options to mitigate the effects of El Niño occurrences. Various policies are available; however, there is a gap between the articulation of a policy and its implementation. Several constraints or restrictions exist (e.g., the uncertainty trough, timely information, and credit availability) that prevent small-scale farmers from taking full advantage of the policies intended effects. It is suggested that a pilot project to improve the credibility of communication be implemented in one (or more) of the most vulnerable countries identified by the model. The lessons learned from a pilot project then could be applied (in a cost effective manner) to other SADC countries.

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Notes:

[i] The 14 countries are: Angola, Botswana, Congo – Democratic Republic, Lesotho, Madagascar, Malawi, Mauritius, Mozambique, Namibia, South Africa, Swaziland, Tanzania, Zambia, and Zimbabwe.

[ii] The same pattern emerged when real GDP per capita annual growth was considered.

[iii] The 0.4 percent difference between the average annual growth rate with the El Niño years removed and all years is not statistically significant, but the difference between 2.9 and 1.4 percent is statistically significant, using a one-tailed test.

[iv] The SOI is an index of sea level pressure anomalies between Darwin, Australia and Tahiti; the standardized SOI smoothes out variations in local wind conditions by taking 5-month running averages; the multivariate ENSO index is calculated using Principal Components on several variables: sea level pressure, sea surface temperature, surface air temperature, surface wind, and total cloudiness fraction of the sky (Wolter and Timlin, 1993 and 1998). These data were obtained from the National Oceanic & Atmospheric Administration (www.cpc.ncep.noaa.gov/data/indices and www.cdc.noa.gov/people.klaus.wolter/MEI/).