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20 October 2016

Online at <https://mpra.ub.uni-muenchen.de/74671/>

MPRA Paper No. 74671, posted 22 Oct 2016 07:52 UTC

# **NONLINEAR RELATIONSHIP BETWEEN EXCHANGE RATE VOLATILITY AND ECONOMIC GROWTH: A SOUTH AFRICAN PERSPECTIVE**

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**ABSTRACT:** In this paper, we challenge the traditional assumption of a linear relationship between exchange rate volatility and economic growth in South Africa. By using data collected from 1970 to 2016 applied to a smooth transition regression (STR) model, we are able to prove that the exchange rate-economic growth correlation is indeed nonlinear within the sampled time period. In particular, we find that regime switching behaviour is facilitated by government size in which exchange rate volatility positively and significantly influences economic growth when growth in government spending is below 6 percent. Above this 6 percent threshold, volatility exerts an insignificant effect on economic growth. In light of the adoption of a free floating exchange rate regime by the Reserve Bank, our results emphasize the importance of the role which fiscal authorities play on the extent to which exchange rate movements affect economic growth.

**Keywords:** Exchange rates; economic growth, smooth transition regression (STR) model; thresholds; nonlinearity; volatility; South Africa; monetary policy; fiscal policy.

**JEL Classification Code:** C01; C21; C52; E52; F31; O40.

## **1 Introduction**

Recent concerns about the monetary system in South Africa can be largely attributed to wide exchange rate fluctuations in the domestic currency with the recent sharp depreciation in the exchange rate of the South African Rand (ZAR) having raised questions as to the stability and efficiency of the current floating exchange regime. In January 2016, the ZAR was trading at an all-time low of R17.91 per US dollar and this was a 160 percentage, 5-year depreciation from its previous exchange rate value of R6.90 per dollar in June 2011. Before this period South Africa last experienced such large depreciation in her currency between 1994 and 2001, when the ZAR depreciated by 180 percent from R3.56 per dollar to R10.50 per dollar. These random fluctuations in the domestic exchange rate are of great concern seeing that financial systems in developing economies have been toppled on the basis of failed exchange regimes with Latin American and Asian countries providing classical examples of such. Further mounting on to these concerns is the fact that the much unstable South African Rand is the most traded African currency and is the currency of the Common Monetary Area (CMA) between South Africa, Swaziland, Lesotho and Namibia. Since the first multiracial elections in 1994, the South African Reserve Bank (SARB) has been floating the exchange rate in foreign exchange markets. This has caused the exchange rates to be very volatile which, in turn, is a threat to the growth of international trade and macroeconomic stability because of the presence of hedging facilities that would be employed to protect individuals against exchange rate risk (Nyahokwe and Ncwadi, 2013).

Instead of fixing or pegging the domestic exchange rate on other major currencies, the SARB is currently using inflation targets of 3 to 6 percent as the core of domestic monetary policy and has been doing so since 2002. The decision for the SARB to adopt the inflation targeting framework came about as a recommendation of the World Bank and the International Monetary Fund (IMF) who advised on monetary authorities adopting a combination of inflation targets and floating exchange rates. This was due to the perception of a monetary policy “trilemma” whereby monetary policy in open economies are unable to simultaneously attain capital mobility, a fixed exchange rate and independent monetary policy and can only achieve two of the three stated goals at a given time (Phiri, 2016). Of recent, a number of academics have argued against the use of floating exchange rate regimes by claiming that such a policy stance allows too much flexibility and discretion in policymaking and this, in turn, has caused excessive exchange rate volatility and poor macroeconomic performance (Katusiime et. al.

(2016) and Alagidede and Ibrahim (2016)). So far, most empirical works on the volatility of the Rand have been concentrated on its effects on trade flows and sectoral employment (Buh and Amusi (2003), Sekantsi (2011), Ekanayake et. al. (2012), Azaikpono et. al. (2005), Todani and Munyama (2005), Nyahokwe and Ncwadi (2013), Ishimwe and Ngalawa (2015) and Chamunorwa and Choga (2015)). Surprisingly, there appears to be very little empirical evidence documenting the effects of the exchange rate volatility on overall economic growth with the study of Sibanda et. al. (2013) being the only available study on the subject matter up-to-date. And even so, the study presented by Sibanda et. al. (2013) could be considered as being limited in scope on account of the linear estimation techniques employed by the authors at arriving at their empirical conclusions.

Of recent, there have been major speculations that most macroeconomic variables, such as exchange rates and economic growth, may be nonlinear and that any estimations of these time series variables should take nonlinearity into account in order to avoid producing spurious regression analysis (Cuestas and Mourelle, 2011). Despite such advocacy for nonlinearity within time series variables, there still exists a scarce amount of empirical studies which have investigated a nonlinear relationship between exchange rate volatility and economic growth, with the works of Aghion et. al. (2009), Ndambendia and Alhayky (2011), Vieira et. al. (2013) and Alagidede and Ibrahim (2016) being the few exceptional case studies. Nevertheless, these nonlinear studies hold the intuition that exchange rates may affect economic growth differently depending on whether the economy is below or above some estimated threshold. Under such a scenario, policymakers do not behave in a monotonous manner but take decisions with regards/respect to the state in which the economy is. Ideally, policymakers would desire to keep the economy at the threshold point or value which is responsible for regime switching behaviour as this considered the optimal rate at which exchange rates maximize economic growth gains or similarly minimize growth losses. In our study, we contribute to the academic paradigm by estimating such a threshold for South Africa using a smooth transition regression (STR) model applied to annual data collected for the period of 1970 to 2015. We choose the STR model as our methodological base because compared to other nonlinear econometric models, the STR conducts its transition between regimes in smooth as opposed to abrupt manner. This feature makes the model theoretically appealing since this smooth transition is consistent with the fact that economic agents do not conduct their behaviour simultaneously and in the same direction (Phiri, 2016). Moreover, the STR model encompasses other nonlinear

models like the threshold autoregressive (TAR) and Markov Switching (MS) models and this makes it more superior to these other competing models.

The remainder of the paper is organized as follows. In the next section we provided an overview of exchange rate regimes and economic growth developments in South Africa. In the third section of the paper, we provide a review of previous literature pertaining to the subject matter. In the fourth section of the paper we present the methodology used in our study, whereas the data and empirical results are presented in the fifth section of the paper. Main conclusions and policy implications are drawn in the sixth section of the paper.

## **2 An overview of exchange rate regimes and economic growth developments in South Africa**

### ***2.1 An overview of exchange rate regimes in South Africa***

The historical collapse of the Bretton Woods system in 1971 initially led the South African Reserve Bank (SARB) to peg the Rand against the dollar in 1971. The rand-dollar attachment was sustained until June 1974 when the Reserve Bank decided to adopt an independently managed floating currency with a fixed rand-dollar exchange rate which would vary every few weeks. However, in June 1975, the ‘dual exchange rate system’ was terminated and a stable dollar attachment was established and sustained until 1978. And then in 1979, the securities rand was changed into the financial rand which was used by non-South African residents to gain quoted and non-quoted shares in South Africa companies and the Reserve Bank began to develop the South African foreign exchange market as means of making it free from any intervention. However, following the recommendations of the De Cock Commission in 1979, flexibility in the domestic foreign exchange market was pursued by reuniting the exchange rate regime to a managed float and thus discontinued the use of the financial rand (Aron et. al., 1997).

From 1985 to 1994, the SARB adopted a dual exchange rate system which comprised of a managed floating commercial currency and the free float financial rand. In light of heightened domestic unrest and political tensions in the 1980’s, it was during this period that domestic currency began to tremendously devalue against the US dollar. In response, monetary authorities began accessing the debt markets which then increased foreign investor’s interest

and confidence in the South African economy and ultimately resulted in an appreciation in the financial rand and a decline in the financial rand discount. Following the historical democratic elections of 1994, the Reserve Bank terminated the dual exchange rate system to that of a unified currency in March 1995 and this floating exchange rate regime has been the status quo of exchange rate policy in South Africa up-to-date.

## ***2.2 Exchange rate and economic growth developments in South Africa:1994-2016***

Prior to the democratic elections of 1994, the South African economy experienced negative growth averages of -0.7 percent between 1989 and 1993 due to various economic hardships experienced throughout the 1980's such as political instability, high inflation, increasing disinvestment, debt standstill and a 'brain drain' of human capital. Therefore in 1994, the newly democratically elected government inherited an economic system characterized by declining economic growth, low employment growth and high levels of income inequality (Chamunorwa and Choga, 2015). As a remedy, fiscal authorities initially implemented the Reconstruction and Development Programme (RDP) and its offspring the Growth Employment and Redistribution (GEAR) policy as macroeconomic strategies aimed at correcting the social imbalances inherited from the previous Apartheid rule. These macroeconomic strategies emphasized the need for a competitive exchange rate as the backbone for an export-oriented growth path with accompanied employment opportunities in the manufacturing sector. In order to ensure export-competitiveness, the Reserve Bank decided to float the Rand under a unitary exchange rate system in which domestic currency is determined by forces of demand and supply in the foreign exchange market with minimal intervention by monetary authorities.

Subsequent to adopting a flexible exchange regime in 1994, the Rand began to depreciate against the currencies of major trading partners as a direct result of increased trade liberalization. According to Laubscher (2014), following the termination of trade barriers, the amount of exports, as well as imports increased by 65% from the period of 1991 to 1998 therefore enhancing the country's ability compete on a global platform. This was also accompanied with slowly improving economic growth rates even though this came at a cost of an increasingly volatile exchange rate. In 1997, the collapse of the Thai Baht sparked the Asian financial crisis which resonated throughout the Asian continent and then to financial markets in the rest of the world. This was the Rand's first major external shock under the floating regime

and the currency fluctuated wildly between 1998 and 2001. Before the crisis in January 1997 the Rand was trading at R4.71 per dollar whereas by February 2001 it had depreciated by 69 percentage to R7.98 per dollar. Even though the Rand stabilized in 2003, volatility levels never returned to their moderate averages experienced before the 1997 financial crisis. Nevertheless, economic growth picked up immediately after the Asian contagion averaging 3.92 percent between 1999 until 2006.

From 2006 to 2012, the South African government introduced three consecutive macroeconomic programmes which were intended to foster economic growth and minimize poverty as well as income inequality. The first was the Accelerated and Shared Growth Initiative for South Africa (ASGISA) programme which was formed with the specific mandate of halving poverty and unemployment as well as achieving a 6 percent economic growth rate by 2014. However, following the global recessionary period of 2009, when economic growth rates sunk as low as -3.27 percent, it was clear that government would not reach its objectives. Furthermore, exchange rate volatility had also increased during this period as capital flows decreased, the Johannesburg Stock Exchange (JSE) market declined and ultimately Rand depreciated by approximately 65 percent against US dollar from R6.90 per dollar in January 2008 to R11.40 per dollar in September 2008. Following these developments, the second economic programme (i.e. new growth path (NGP)) was the introduced in 2010 with set objectives of creating 5 million employment opportunities and reducing unemployment to 10 percent by 2020. In differing from the ASGISA programme, the NGP is more labour focused programme which uses job creation and employment opportunities as a basis for fostering growth within the economy. The third programme, the national development plan (NDP), was introduced in 2012 with the objective of eliminating poverty by 2030. Specific targets for the NDP include an elimination of households living below R418 per person for a month as well as reducing the Gini coefficient rating from 0.7 to 0.6 by 2030. However, subsequent to global recession period of 2009, economic growth picked up for first two years averaging 3.09 percent but has been on a downward trend averaging 1.48 percent between 2012 and 2016. These figures coincide with the currency devaluation of the rand from R8.48 per dollar to R13.93 per dollar over the same time period.

### **3 Literature Review**

Over the last couple of decades, an increasing amount of research effort has been dedicated towards studying the relationship between exchange rate volatility and economic growth. So far, the accumulated empirical evidence gathered on the subject matter can be best described as been inconclusive. On one hand, the studies of Cottani et. al. (1990), Dollar (1992), Bosworth et. al. (1996), Schnabl (2009), Musyoki et. al. (2012), Dickson (2012), Sanginabadi and Heidari (2012) and Adewuyi and Akpokodje (2013) all find a negative effect of exchange rate volatility on economic growth. These findings are consistent with the dynamics found in conventional growth theory which speculates that exchange rate volatility depresses economic growth by reducing international trade, discouraging investment and compounding the problems people face in insuring their human capital in incomplete asset markets (Obstfeld and Rogoff, 1995). On the other hand, there are other studies which find a positive (e.g. Ghosh et. al. (1997), Mahmood and Ali (2011), Danmola (2013) and Katusiime et. al. (2016)) or an insignificant effect of exchange rate volatility on economic growth (e.g. Ghura and Grennes (1993), Bleaney and Greenaway (2001)). The argument for a positive relationship between exchange rate volatility and economic growth is that developed financial systems provide hedging facilities against any adverse effects of volatile exchange rate fluctuations. Generally speaking, there are two academic rationales for the conflicting results presented in the review of these previous studies. Firstly, the conflicting results are probably caused by differences in country-specific characteristics, differences in time spans and differences in methodologies employed by the various authors. Secondly, these reviewed studies have ignored probable nonlinearities existing in the volatility-growth relationship by employing linear econometric frameworks in their empirical analyses.

Of recent, there has emerged a number of empirical studies which are indicative of a nonlinear relationship between exchange rate volatility and economic growth. For instance, Vieira et. al. (2013) find that for 82 advanced and emerging countries high exchange rate volatility positively affects economic growth whereas low exchange rate volatility negatively affects growth. In a separate study conducted for 83 developed and developing countries, Aghion et. al. (2009) find a negative relationship between exchange rate volatility and economic growth in countries with financially underdeveloped markets whereby this relationship turns positive for financially developed economies. The implication from the study is that financial development provides hedging facilities against exchange rate risk whereas such hedging opportunities do not exist in undeveloped financial markets. Moreover, Ndambendia and Alhayky (2011) find a nonlinear relationship between exchange rate volatility and economic



growth in 15 sub-Saharan countries. The authors particularly find a negative volatility-growth relationship when the ratio of domestic credit to GDP is below a threshold of 57 percent, whereas above this threshold the relationship becomes positive. Once again, the implication from this study is that the development of financial infrastructure in developing countries will provide hedging opportunities against exchange rate risk. Lastly, Alagidede and Ibrahim (2016) establish that for the Ghanaian economy, low levels of exchange rate volatility either insignificantly or positively affects economic growth whereas at higher levels, exchange rate volatility adversely affects economic growth. These results imply that the use of a floating exchange rate regime by Ghanaian monetary authorities could prove to be costly to economic growth especially since the floating of currency makes the exchange rate vulnerable to high fluctuations.

## **4 Methodology**

### **4.1 Growth equation**

Within the theoretical paradigm, academics are yet to be in consensus on a single theory of exchange rate determination. According to Musyoki et. al. (2012) and Sibanda et. al. (2013), there are at least five competing theories of exchange rate determination and these theories are i) the elasticity approach to exchange rate determination; ii) the monetary approach to exchange rate determination iii) the portfolio balance approach to exchange rate determination iv) the purchasing power theory of exchange rate determination, and v) the modern theory which explains the short-run exchange rate volatility and its tendency to overshoot in the long-run. However, from an economic growth perspective, it should be noted that exchange rates did not feature as a growth determinant in the neoclassical and endogenous dynamics models as these growth frameworks did not have any role for the open economy (Dickson, 2012). On one hand, the neoclassical model posits that steady-state growth is an outcome of exogenous technical progress, whereas on the other hand, endogenous growth theory hypothesizes on steady-state growth being generated endogenously through external capital accumulation, human capital development and technological innovation (Katusiime et. al., 2016). Nevertheless, these growth models are typically augmented with a variable representing exchange rate volatility as a proxy for the external sector which is related to economic growth through foreign trade and balance of payments (Alagidede and Ibrahim, 2016). Typically, such a growth equation would be specified as follows:

$$gdp_t = \alpha_0 + \alpha_1 Z_t + \alpha_2 vol_t + \varepsilon_t \quad (1)$$

Where  $gdp_t$  is economic growth,  $Z_t$  is a vector of growth determinants variables,  $vol_t$  is a measure of exchange rate volatility and  $\varepsilon_t$  is a well-behaved error correction term. In our study, we employ a similar growth regression model which is augmented with exchange rate volatility. To be more specific, we draw from the theoretical predictions of the model of Kandill and Mirzaie (2002) which shows a combination of demand and supply channels which depict that real output growth on movements in the exchange rate, money supply and government spending. Bahmani-Oskooee and Kandil (2010) as well as Sanginabadi and Heidari (2012) employ reduced form-regressions of Kandil and Mirzaie (2002) theoretical predictions. Their estimation equation is given as:

$$gdp_t = \alpha_0 + \alpha_1 Ln M_t + \alpha_2 Ln G_t + \alpha_3 Ln ER_t + \varepsilon_t \quad (2)$$

Where  $Ln$  is the natural logarithm of the variables,  $\alpha_i$  are the long-run regression coefficients,  $gdp_t$  is real output,  $M_t$  is money supply which proxies monetary policy,  $G_t$  is government spending which proxies fiscal policy and  $ER_t$  is the exchange rate. According to conventional growth theory as well as the empirical confirmations of Levine and Renelt (1992) and Salai-I-Martin (1997), investment is one of the most important drivers or determinants of economic growth. Bearing this in mind, we add the investment variable as a growth determinant to the growth regression (2) which results in the following empirical estimation model regression:

$$gdp_t = \alpha_0 + \alpha_1 Ln M_t + \alpha_2 Ln G_t + \alpha_3 Ln Inv_t + \alpha_4 Ln vol_t + \varepsilon_t \quad (3)$$

Where  $Inv_t$  is the investment variable and the exchange rate,  $ER_t$ , is now proxied by the exchange rate volatility variable,  $vol_t$ . As dictated by the standard literature, different proxies have been used as a measure of exchange rate volatility and this issue of choice of volatility measure for our study is particularly addressed in the next sub-section.

## 4.2 *Measuring exchange rate volatility*

A number of statistical approaches have been proposed in the literature in extracting a measure of exchange rate volatility. For instance, the studies of Kenen and Rodrick (1986), Lastrapes and Koray (1990), Chowdury (1993), Arize et. al. (2003), Mushyoki et. al. (2012), Khosa et. al. (2015), Panda and Mohanty (2015) and Serenis and Tsounis (2015) have all successfully used the moving standard deviation of the exchange rate time series to proxy exchange rate volatility. The conventional standard deviation formula is represented as follows:

$$sd = \left[ \left( \frac{1}{n} \right) \sum_{i=1}^n (ER_t - ER_{t-1})^2 \right]^{\frac{1}{2}} \quad (4)$$

Where ER is the exchange rate and t is a time subscript. Chowdury (1993) highlights that the standard deviation method of extracting exchange volatility captures the temporary variation in the absolute magnitude of changes in real exchange rates and therefore exchange rate risk, over time. However, the standard deviation method has been criticized for falsely assuming that the empirical distribution is a normal one and for also failing to capture the potential effects of high and low peak of the exchange rate which leads to the inability to distinguish between predictable and unpredictable elements in the exchange rate process (Takaendes et. al., 2006). For this reason, an increasing number of authors such as Rapach and Strauss (2008), Dickson (2012), Abdulla (2012), Pelinescu (2014), Pilbeam and Langeland (2015), Katusiime et. al. (2016), Alagidede and Ibrahim (2016) and Bahmani-Oskooee et. al. (2016) have all relied on the generalized (GARCH) model of Bollerslev (1986) as a framework for measuring exchange rate volatility. This model is seen as a superior alternative to the standard deviation method because it is more parsimonious and thus circumvents the problem of overfitting. Furthermore, unlike other measures of exchange rate volatility which risk ignoring information on the stochastic process by which exchange rates are generated, the GARCH model captures the time-varying conditional variance as a parameter generated from a time series model of the conditional mean and variance of the growth rate, and thus is very useful in describing volatility clustering (Chowdury, 2005). By design, the GARCH model assigns weights that decline exponentially to past observations in the data and therefore more recent shocks exert more impact on the model. Our estimated GARCH (1,1) is based on an autoregressive (AR) model of the real effective exchange rate (REER) of order 1 and is specified as follows:

$$REER_t = \Psi_0 + \Psi_1 REER_{t-1} + e_t \quad (5)$$

$$e_t/\Omega_{t-1} \sim iid(0, \sigma_t^2) \quad (6)$$

$$\sigma_t^2 = \omega + \alpha(L)\sigma_{t-k}^2 + \beta(L)\eta_t^2 \quad (7)$$

Where  $\Omega_t$  is an information set;  $\sigma_t^2$  is the conditional variance which is modelled as a weighted average of past squared deviations which gradually declines but never reaches zero;  $\alpha(L)$  and  $\beta(L)$  are polynomials of lag operators and  $\eta$  is known as the innovation. Alternatively, the GARCH model can be expressed as:

$$\sigma_t^2 = \omega + \sum_{i=1}^q \alpha_i \sigma_{t-i}^2 + \sum_{j=1}^p \beta_j \eta_{t-j}^2 \quad (8)$$

And following equation (6), our empirical GARCH (1,1) is specified as:

$$\sigma_t^2 = \omega + \alpha_1 \sigma_{t-1}^2 + \beta_1 \eta_0 \quad (9)$$

The estimated conditional variance ( $\sigma_t^2$ ) from equation (9) is used as the second proxy measure of exchange rate volatility. Furthermore, the autoregressive root which governs the persistence of volatility shocks is derived as the sum of the parameter coefficients  $\alpha + \beta$  and if this sum is greater or equal to unity then the series exhibits explosive behaviour.

### 4.3 STR regression framework

As previously mentioned, the econometric model that we use to estimate our growth regression (3) is the STR model which is specified as:

$$y_t = \beta_0' z_t + \beta_1' z_t G(z_t; \gamma, c) + \varepsilon_t \quad (10)$$

$$e_t \sim iid(0, \sigma_t^2) \quad (11)$$

$$G(z_t; \gamma, c) = [1 + \exp(-\gamma(z_t - c_k))]^{-1} \quad , 0 < G < 1 \quad (12)$$

Where  $y_t$  is a scalar;  $\beta'_0$  and  $\beta'_1$  are parameter vectors;  $z_t$  represents the vector of explanatory variables; and  $\varepsilon_t$  is a well-behaved error term. The transition function  $G(z_t; \gamma, c)$  assumes the logistic function represented in equation (12) and consists of a transition or threshold variable,  $z_t$ , a transition parameter,  $\gamma$ , and a threshold parameter,  $c$ . Moreover, we restrict the STR model to the cases for  $k=1$  and  $k=2$  which yield the LSTR-1 and LSTR-2 regressions, respectively. Terasvirta (1994) suggests a modelling cycle which includes tests for linearity, estimation procedure and model evaluation techniques. The linearity tests included testing candidate transition variables and selecting the variable which produces the strongest rejection rate. Conventionally, testing for linearity would be achieved by testing the null hypothesis of  $H_0: \gamma = 0$  or  $H_0': \beta_1 = 0$  in regression (10). However, the linearity tests are complicated by the nuisance variable under the null hypothesis and this violates asymptotic distribution theory. To circumvent this problem, Luukkonen et.al. (1998) suggest a testing procedure which involves replacing the transition function  $G(z_t; \gamma, c)$  by its first order Taylor expansion around  $\gamma = 0$ . The Taylor auxiliary function is specified as follows:

$$y_t = \mu_t + \beta_0'^* x_t + \beta_1'^* x_t z_t + \beta_2'^* x_t z_t^2 + \beta_3'^* x_t z_t^3 + \varepsilon_t^* \quad (13)$$

Where the parameter vectors  $\beta_1^*$ ,  $\beta_2^*$ ,  $\beta_3^*$  are multiples of  $\gamma$  and  $\varepsilon_t^* = \varepsilon_t + R_3 \beta_1' x_t$ , with  $R_3$  being the remnant portion of the Taylor expansion. Hereafter, the null hypothesis of linearity may be tested as:

$$H_0^*: \beta_3^* = \beta_2^* = \beta_1^* = 0 \quad (14)$$

And this null hypothesis can be tested by a LM test statistic which will not violate asymptotic distribution theory. Once the null hypothesis of linearity is rejected, the econometrician can proceed to select between a LSTR-1 or LSTR-2 regression specification by making use of the following sequence of hypotheses tests:

$$H_{03}^*: \beta_3^* = 0 \quad (14)$$

$$H_{02}^*: \beta_2^* = 0 | \beta_3^* = 0 \quad (15)$$

$$H_{01}^*: \beta_1^* = 0 | \beta_3^* = \beta_2^* = 0 \quad (16)$$

The decision rule for selecting either a LSTR-1 or LSTR-2 model is thus as follows. Select a LSTR-2 specification if  $H_{02}^*$  has the strongest rejection, otherwise, we select the LSTR-1 specification. Subsequent to selecting an appropriate LSTR model, Terasvirta (1994) recommends the estimation of the parameters  $\gamma$  and  $c$ . In our study, these parameters are estimated using a form of the Newton-Raphson algorithm to maximize the conditional maximum likelihood function. This involves minimizing the following objective function:

$$\psi^* = \min_{\psi} \sum_{t=1}^T (y_t - G(z_t, y_t; \psi))^2 \quad (18)$$

Once the true values of  $\gamma$  and  $c$  are obtained then, one can proceed to estimate the remaining model parameters  $\beta'_0$  and  $\beta'_1$ . As a final step in the modelling process, we evaluate the estimated LSTR regression by testing for no remaining nonlinearity, no autocorrelation, no ARCH effects and normal distribution.

## 5 Data and empirical results

### 5.1 Data description

The data used to carry out our empirical analysis has been retrieved from the South African Reserve Bank (SARB), the World development Indicators (WDI) from the World Bank and the Federal Reserve Economic Data (FRED) online databases. The empirical analysis employs annual time series data for South Africa and has been collected from 1970 until 2015. The dataset consists of growth in gross domestic product ( $GDP_t$ ), growth in M3 money supply ( $M_t$ ), growth in government expenditure ( $G_t$ ) and the nominal exchange rate to the US dollar ( $NER_t$ ). In line with Musyoki et. al. (2012) and Alagidede and Ibrahim (2016), we compute the real effective exchange rate ( $REER_t$ ) as:

$$REER = NER \times P^{usa} / prsa \quad (18)$$

Where  $P^{usa}$  is the US price index and  $P^{rsa}$  is the South African consumer price index. Using this definition of real exchange rate we proceed to extract the exchange rate volatility proxies from the moving-standard deviation model ( $SD_t$ ) and from the GARCH model ( $VOL_t$ ). The estimates for the GARCH model are given in Table 1 below and whereas the plots for the  $SD_t$  and  $VOL_t$  are given in Figure 1 and 2, respectively.

Table 1: GARCH (1,1) estimates of exchange rate volatility

	estimate	standard error	t-value	p-value
AR equation				
$\Psi_1$	0.05	0.01	3.64	0.00***
variance equation				
$\omega$	0.01	0.00	3.79	0.00***
$\alpha_{t-1}$	0.15	0.03	5.80	0.00***
$\beta_{t-1}$	0.81	0.03	24.14	0.00***

Notes: '\*\*\*', '\*\*' and '\*' represent 1%, 5% and 10% significance levels, respectively.

As can be observed from Table 1, the coefficients parameters  $\alpha$  and  $\beta$  are both positive and they are significant at all critical levels. Moreover, the parameter coefficients satisfy the condition  $\alpha + \beta < 1$ , which implies that the process is not explosive. However, since the sum of coefficients are close to unity ( $\alpha + \beta = 0.96$ ), then this implies that shocks to the time series die rather slowly. All-in-all, our regression estimates reported in Table 1 confirm significant GARCH effects in the time series data.

Figure 1: Moving standard deviation measure of exchange rate volatility

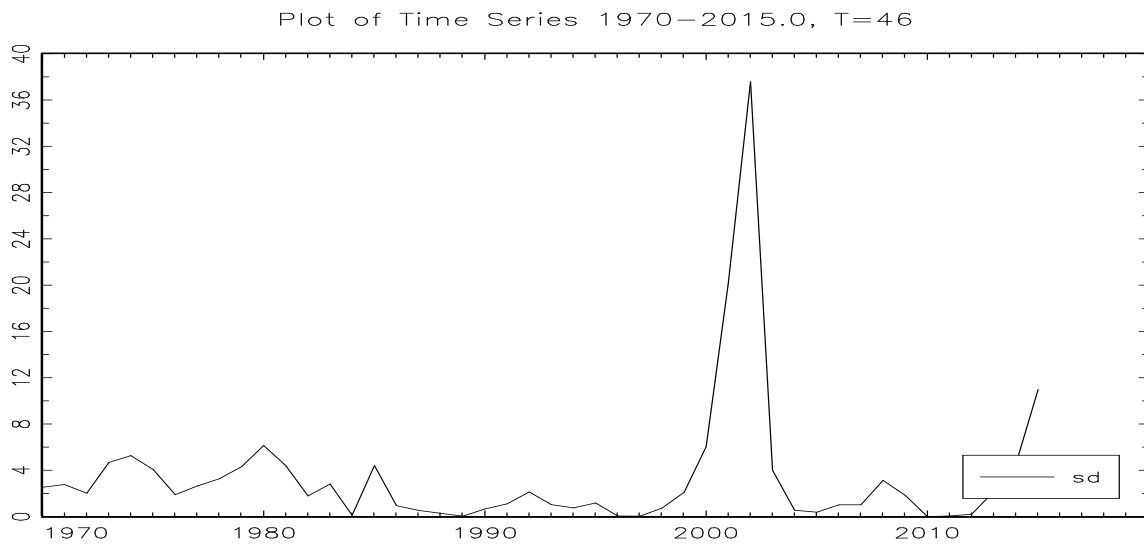
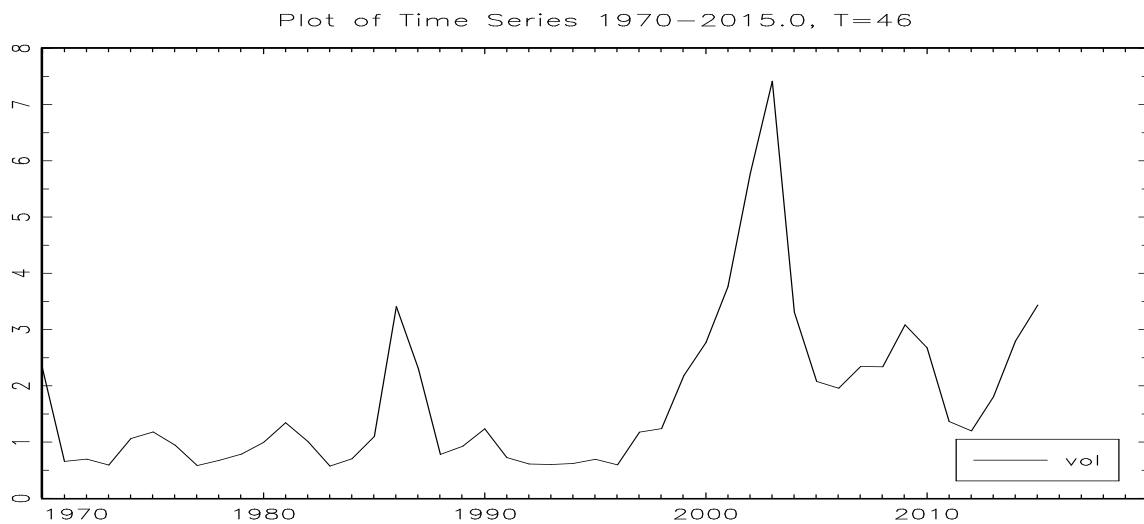


Figure 2: GARCH (1,1) representation of exchange rate volatility



## 5.2 Unit root test results

As a preliminary step before estimating our empirical STR, we firstly examine the integration properties of the individual time series variables. This is important because a precondition for the estimation of STR models requires that all variables included in the regression are levels stationary. However, conventional unit root tests such as the ADF and PP tests have been criticized on their inability to distinguish between a unit root and a near-unit root process as well as been unable to significantly account for structural breaks. In order to circumvent the short-comings of the traditional unit root tests, we supplement these unit root



tests with the so-called ‘second-generation’ tests of Elliot et. al. (1996) and Zivot and Andrews (1992) to determine whether the time series have deterministic trends or not. The unit root tests are performed i) with a drift and ii) with a trend, and results of this empirical exercise are given in Table 2.

Table 2: Unit root test results

time series	test statistic	levels		first differences		Decision
		drift	trend	drift	trend	
Ln GDP <sub>t</sub>	ADF	-4.54***	-4.48***	-7.08***	-6.98***	I(0)
	PP	-4.66***	-4.59***	-9.22***	-9.09***	I(0)
	DF-GLS	-1.77*	-2.26	-3.89***	-4.87***	I(0)
	ZA	-5.29**	-4.83**	-7.36***	-6.98***	I(0)
Ln M <sub>t</sub>	ADF	-4.50***	-5.09***	-7.16***	-7.07***	I(0)
	PP	-4.02***	-4.26***	-7.60***	-7.54***	I(0)
	DF-GLS	-2.10**	-2.56	-5.04***	-4.84***	I(0)
	ZA	-6.40***	-5.84***	-7.31***	-7.13***	I(0)
Ln G <sub>t</sub>	ADF	3.81***	-3.91**	-7.42***	-7.29***	I(0)
	PP	-4.91***	-5.11***	-12.76***	-12.57***	I(0)
	DF-GLS	-0.64	-1.35	-4.14***	-3.88***	I(1)
	ZA	-5.86***	-4.52***	-7.99***	-7.30***	I(0)
Ln INV <sub>t</sub>	ADF	-4.99***	-5.04***	-6.67***	-6.59***	I(0)
	PP	-3.64***	-3.62**	-5.92***	-5.83***	I(0)
	DF-GLS	-1.75*	-2.27	-3.82***	-4.24***	I(0)
	ZA	-5.81***	-5.47***	-6.93***	-6.59***	I(0)
Ln SD <sub>t</sub>	ADF	-4.03***	-4.01***	-5.98***	-5.91***	I(0)
	PP	-3.79***	-3.77**	-7.36***	-7.26***	I(0)
	DF-GLS	-2.98***	-3.04*	-4.01**	-3.94***	I(0)
	ZA	-4.69*	-4.02	-7.26***	-6.03***	I(0)
Ln VOL <sub>t</sub>	ADF	-2.97**	-3.65**	-5.62***	-5.56***	I(0)
	PP	-2.48	-3.24*	-5.75***	-5.66***	I(0)
	DF-GLS	-1.90*	-2.36	-2.55**	-3.76**	I(0)
	ZA	-4.84**	-3.71	-7.00***	-5.64***	I(0)

Significance levels are given as follows: ‘\*\*\*’, ‘\*\*’ and ‘\*’ represent the 1 percent, 5percent and 10 percent significance levels respectively.

In referring to the unit root test results reported in Table 2, we firstly note that the ADF test statistics, whether performed with a drift or a trend, manage to reject the null hypothesis of a unit root for all the time series variables at a significance level of at least 5 percent. For the PP test statistics, the unit root null hypothesis is rejected for all the time series variables at a 10 percent critical level only when the test is performed with a trend. When a drift is included, we

observe that PP tests can only reject the unit root hypothesis for the  $VOL_t$  variable in its first difference. Concerning the ZA test statistics, the null hypothesis of a unit root is rejected at a 5 percent level of significance for all the time series variables when a drift is included in the test whereas when a trend is included for the  $SD_t$  and  $VOL_t$  variables, the unit root null is only reject in their first differences. In lastly turning to the results for the DF-GLS statistics, we note that when a drift is included the unit root null hypothesis is reject for all the variables at a 10 percent significance level in their levels with the exception of the  $G_t$  time series where the unit root null is reject in the first differences. On the other hand when a trend is included in the DF-GLS test, the null hypothesis of a unit root is only rejected for all the time series variables in their first differences with the exception of the  $SD_t$  variable whereby the unit root hypothesis is rejected in its levels at a 10 percent significance level. In deriving general conclusions from our unit root tests, we deduce that the test statistics point to all the time series being stationary in their levels and this sufficient evidence to model and estimate our STR regressions without fear of obtaining spurious results.

### ***5.3 STR regression analysis***

Having provided evidence of stationarity in the time series, we proceed to model and estimate our empirical STR regressions. It should be noted that the empirical analysis is performed on two empirical models, the first, with exchange rate volatility being proxied by  $SD_t$  variable, and a second, with exchange rate volatility being proxied by the  $VOL_t$  variable. To begin our empirical analysis, we test for STR nonlinearities within the two empirical models. To recall, we do so by performing the F-tests for nonlinearity for each possible transition variable candidate in each empirical model and the variable associated with the strongest rejection (i.e. the smallest p-value) is selected as the transition variable. Besides identifying the appropriate transition variable these tests serve to also determine whether we a LSTR-1 or LSTR-2 model is an appropriate specification for the chosen transition variable. Note that the decision rules for selecting either a LSTR-1 or LSTR-2 model has been discussed in a previous section of the paper. The results of the tests for linearity are reported below in Table 4.

Table 4: Tests for linearity

model type	transition variable	test statistics				decision
		F	F4	F3	F2	
	Ln $M_t$	0.4434	0.1215	0.4409	0.9978	Linear
SD <sub>t</sub>	Ln $G_t$	0.4480	0.2372	0.3248	0.8629	Linear#
Model	Ln $Inv_t$	0.3031	0.0733	0.6624	0.6930	Linear
	Ln $SD_t$	0.1770	0.8524	0.0199	0.4544	Linear
	Ln $M_t$	0.4983	0.1705	0.5043	0.9154	Linear
VOL <sub>t</sub>	Ln $G_t$	0.0410	0.0402	0.1512	0.3616	LSTR(1)#
model	Ln $Inv_t$	0.2241	0.2089	0.3175	0.3324	Linear
	Ln VOL <sub>t</sub>	0.5195	0.6005	0.4342	0.3089	Linear

Note: The F-tests for nonlinearity are performed for each possible candidate of the transition variable and the variable with the strongest test rejection (i.e. the smallest p-value) is tagged with symbol #.

Judging from the test results reported for the SD<sub>t</sub> model, we observe that none of the transition variables can reject the notion of linearity and hence we cannot proceed to perform empirical estimates of the STR regression for SD<sub>t</sub> model. However, in turning to the F-statistics reported for the VOL<sub>t</sub> model, we find that when government spending,  $G_t$ , is the transition variable, only then are we able to reject the null hypothesis of linearity. In focusing on the remaining F-statistics associated with the  $G_t$  transition variable, we further observe that F4 statistic produces a p-value of 0.04 and this of smaller value compared to the p-value of 0.15 obtained for the F3 statistic. We therefore conclude on a LSTR-1 regression being the most appropriate model for modelling and estimating nonlinearities within the VOL<sub>t</sub> model. Thus for the chosen model, we further carry out tests of no remaining linearity and the results are reported in Table 5 below. As can be observed from Table 5, the p-value of 0.0431 associated with the F statistic highly rejects the hypothesis of no additive nonlinearity. We thus conclude that there is no evidence of any remaining linearity.

Table 5: Tests of no remaining nonlinearity

F-statistics	p-value
F	4.3106e-02
F4	7.4704e-01
F3	4.6116e-01
F2	1.1494e-02

Having validated the presence nonlinearities and further finding no evidence of remaining nonlinearity in the  $VOL_t$  model with government spending being the transition variable, we proceed to estimate the LSTR-1 regression model. The model parameter estimates, the threshold estimate as well as the transition function estimate are reported in Table 6. The corresponding graph of the transition function for the estimate LSTR-1 model is plotted in Figure 3. As can be observed from Table 6, we obtained a threshold estimate of 0.06 with a relative low smoothing parameter 2.80. This implies that there are two states of the model economy depending upon whether the growth in government spending is above or below the 6 percent threshold level. Furthermore, judging from the estimate on the smoothing parameter, we note that transition from one regime to another is rather abrupt and this is confirmed by the sharp turn in the plot of the transition function in Figure 3.

In the lower regime of the model, we firstly note that the coefficient estimate on the exchange rate volatility variable is positive and significant. Note that this result is consistent with that obtained in the previous studies of Ghosh et. al. (1997), Mahmood and Ali (2011), Danmola (2013) and Katusiime et. al. (2016). We also obtain a positive and significant coefficient estimate on the investment variable, a result which is consistent with predictions of conventional growth theory. However, for the government spending variable, we obtain a negative and insignificant estimate whereas for the money supply variable, we obtain a positive and insignificant estimate. Notably these insignificant coefficient estimates are in coherences with those found in Bahmani-Oskooee and Kandil (2010) and Sanginabadi and Heidari (2012). Moreover, these results are particularly consistent with the intuition of a diluted relationship between money supply and economic growth in South Africa since the 1980's (Phiri, 2016) whereas the insignificant relationship between government size and economic growth at low levels of government spending has been previously hypothesized by Asimakopoulos and Karavias (2016). In particular, Asimakopoulos and Karavias (2016) argue that if government

spending is small then economic growth is very limited due to difficulties in the provision of public goods.

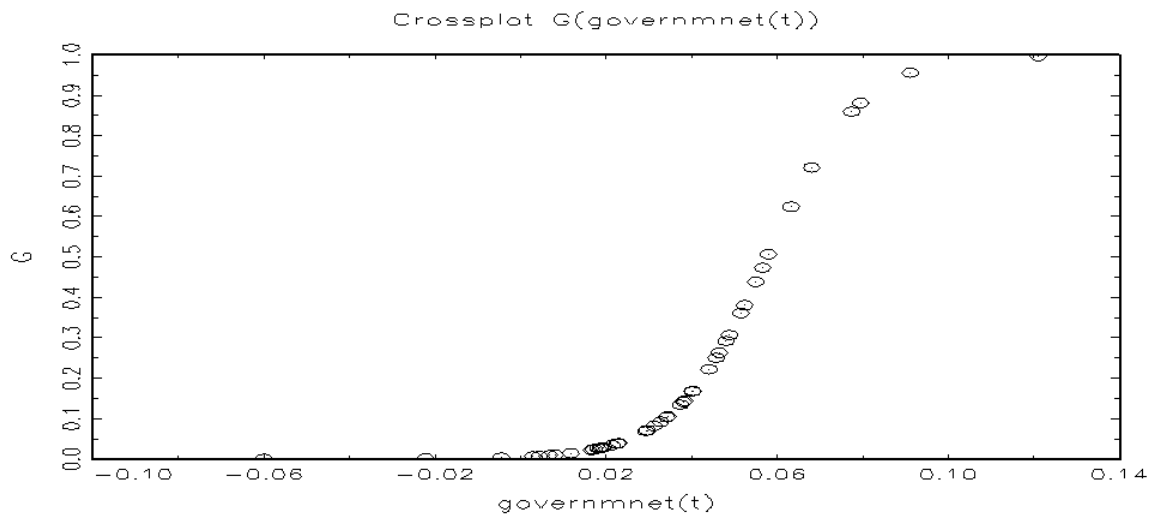
In turning to our parameter estimates for the upper regime of the LSTR-1 model, we collectively note insignificant coefficient estimates for all variables including investment and exchange rate volatility. These results highlight a number of interesting phenomenon. Firstly, these results validate the notion of regime switching behaviour in the relationship between exchange rate volatility and economic growth. This revealing is consistent with that presented in the works of Aghion et. al. (2009), Ndambendia and Alhayky (2011), Vieira et. al. (2013) and Alagidede and Ibrahim (2016), albeit using different estimation techniques and transition variables. Secondly, the finding of an insignificant effect of investment on economic growth at high levels of government spending in South Africa has been iterated in the study of Biza et. al. (2015) who notes that high levels of public spending crowd out the positive effects of investment in South Africa. Lastly, we note regime switching behaviour between government spending and economic growth where at low levels of public spending there is a negative relationship between the two variables and this relationship turns insignificant at higher levels. This notion of a nonlinear relationship between government size and economic growth has been theorized by Bird (1972) and recently empirically proven for the case of South Africa in study of Phiri (2016).

Table 6: STR regression estimates

variable	estimate	standard deviation	t-stat	p-value
linear part				
constant	0.00	0.01	-0.21	0.83
Ln $M_t$	0.05	0.05	1.03	0.31
Ln $G_t$	-0.07	0.19	-0.38	0.70
Ln $Inv_t$	0.18	0.04	4.18	0.00***
Ln $VOL_t$	0.65	0.36	1.80	0.08*
nonlinear part				
constant	0.09	0.07	1.23	0.23
Ln $M_t$	0.13	0.15	0.91	0.37
Ln $G_t$	-0.82	0.52	-1.59	0.12
Ln $Inv_t$	0.09	0.13	0.72	0.47
Ln $VOL_t$	-2.06	1.38	-1.49	0.15
$\gamma$	2.80	2.53	1.10	0.28
c	0.06	0.01	4.03	0.00***
$R^2$	0.71			
$\sigma^2$	0.00			
$\sigma$	0.01			

Notes: '\*\*\*', '\*\*' and '\*' represent 1%, 5% and 10% significance levels, respectively.

Figure 3: Transition for estimated LSTR-1 model



As a final step in our empirical procedure we conducted diagnostic tests on the residuals obtained from the estimated LSTR-1 model. In particular we perform tests of autocorrelation, tests for autoregressive conditional heteroscedasticity (ARCH) and tests for normality effects. The diagnostic tests results are recorded in Table 7 below. The p-values associated with the tests statistics from the performed diagnostic tests imply that we cannot reject the null hypothesis of no autocorrelation, no ARCH effects and normal distribution. We therefore conclude that our estimated LSTR-1 regression satisfies the condition of a normal estimated regression model.

Table 7: Diagnostic test results

tests	null hypothesis	t-statistic	p-value
LM	no autocorrelation	0.68	0.61
ARCH	no ARCH effects	7.19	0.52
JB	normal distribution	0.97	0.61

## 6 Conclusion

Up-to-date, there has been much empirical research on the effects of exchange rate volatility on trade performance and sectoral employment in South Africa with little emphasis being placed on the relationship between exchange rate volatility and economic growth. On an international platform, the empirical investigation to the exchange rate volatility-economic

growth relationship has been dominated by linear frameworks. In our study, we sought to deviate from this norm by investigating nonlinearities in this relationship using the STR model applied to a reduced-form estimation equation derived from Kandill and Mirzaie (2002) theoretically model and using annual data collected between 1970 and 2016 to estimate the model regression parameters. We favour the STR econometric model for empirical purposes primarily on the basis that the transition variable which dictates regime switching behaviour is endogenously determined within the model as opposed to being arbitrarily chosen as has been done in previous studies. Another advantage provided by the STR model in comparison to other competing nonlinear econometric models, is that the transition between regimes is conducted in a smooth as opposed to abrupt manner which is theoretically consistent with the fact that economic agents within the economy do not behave simultaneously and in the same direction. Our estimation results prove that regime switching behaviour is dictated by the growth in government spending and the model economy is split into two regimes depending on whether the growth in government spending is above or below the 6 percent threshold level. In particular, we find that below this threshold, exchange rate volatility positively affects economic growth whereas above this rate, the volatility-growth co-relationship turns insignificant.

There are a number of important policy implications which can be drawn from our empirical findings. For one, the fact that the change in the growth of government spending is responsible for regime switching behaviour in the model, emphasizes the importance in which the growth of government size is related to the effects that exchange rate volatility exerts on economic growth. So far, much emphasis has been placed on monetary authorities in assuming responsibility for the adverse effects which exchange rate volatility exerts on the economy. However, in light of the fact of the Reserve Bank having chosen to free-float domestic currency such that exchange rates are determined by forces of demand and supply in the foreign exchange market, then there is very little that the Central Bank can do to independently influence exchange rate behaviour if such goals are not on par with the inflation-targeting goals. Moreover, based on the findings of our empirical study, fiscal policy in the form of public spending levels could be used as an avenue to influence the effect which exchange rate volatility exerts on economic growth. In particular, fiscal authorities are urged to ensure that the growth in public spending should not exceed the threshold of 6 percent per annum in the interest of promoting economic growth. As a natural development to this study, future



empirical works could investigate the effects of government size on exchange rate behaviour in South Africa.

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