Nonlinear impact of inflation on economic growth in South Africa: A smooth transition regression (STR) analysis

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NONLINEAR IMPACT OF INFLATION ON ECONOMIC GROWTH IN SOUTH AFRICA: A SMOOTH TRANSITION REGRESSION (STR) ANALYSIS

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ABSTRACT: In this paper, we challenge the notion of a monotonic relationship between inflation and economic growth in South Africa. In particular, we establish threshold effects in the inflation-growth relationship using a smooth transition regression (STR) model which is applied on data collected between 1994:Q1 and 2016:Q2. Our empirical results confirm a threshold of 5.4 percent in which the effects of inflation on economic growth are positive below this threshold whereas inflation exerts adverse effect on economic growth at inflation levels above this level. In a nutshell, our study offers support in favour of the optimal level of inflation lying between the current 3-6 percent inflation target and more specifically suggests that the monetary authorities should slightly lower the upper level of this target to about 5.4 percent as a means creating a more conducive financial environment for promoting higher economic growth.

Keywords: Inflation; Economic growth; Thresholds; Smooth transition regressions (STR); South Africa Reserve Bank.

JEL Classification Code: C22; C32; C52; E31; E52; O40.

1 Introduction

In February 2002, the South African Reserve Bank (SARB) reached a milestone in monetary policy conduct by becoming the first African Central Bank to adopt an inflation targeting regime with predetermined inflation targets of between 3 to 6 percent forming the backbone of monetary policy conduct in the country. This policy objective is re-enforced by the constitution act of 1996 (Act No. 108) and is further enforced by the SARB Act No. 90 of 1989. The attainment of a low and stable inflation rate is viewed as worthy macroeconomic objective for SARB because of the associated adverse effects which inflation is believed to exert on the macroeconomy. For instance, high inflation can interfere with the price signalling mechanism resulting in a misallocation of resources (Hodge, 2009). Furthermore, inflation can reduce a country's international competitiveness by making exports expensive, hence impacting the balance of payments (Gokal and Hanif, 2004). Inflation can also interact with the tax system to distort borrowing and lending decisions within the economy (Papepetrou, 2001). However, the most damaging effects of inflation are those associated with unanticipated inflation which makes it difficult for policymakers to make long-term economic decisions (Briault, 1995).

Despite the efforts made by the SARB in ensuring a relative low inflation environment, some economists and other structuralists groups such as COSATU, have counter-argued that the inflation targeting regime places too much emphasis on price stability, which by doing so hampers potential economic growth. In a much earlier study, Weeks (1999), demonstrates that stringent monetary policies undertaking by the SARB are inappropriate for the attainment of maximum possible economic growth. This implies that economic growth could be higher and unemployment lower, under policies tolerating moderately higher inflation rates. Nell (2000) also identifies high interest rates as the reason to why strictly conducted monetary policy is unsuitable for improved economic growth as well as for wealth distribution. Epstein (2003) notes that fundamental processes such as openness, political instability and tax policy play a larger role in promoting economic growth in developing countries as opposed to price stability. Further contributing to these arguments is the structuralist viewpoint, that inflation helps to 'grease the wheels of the macroeconomy' hence implying that not all levels of inflation are harmful towards economic growth.

Traditionally, both empirical and theoretical conventional revelations have typically vouched for a negative yet linear relationship between inflation and economic growth, hence supporting the intuition that inflation is detrimental to economic growth and that a low and stable inflation rate is necessary for the attainment of higher economic growth. However, this statement in itself gives rise to another critical question; how low should policymakers keep the inflation rate at inflation? Ideally, policymakers would choose an inflation rate that maximizes growth output gains or similarly minimizes output losses. Recent academic literature has exploited this phenomenon by speculating on a nonlinear relationship between inflation and economic growth, in which inflation positively or insignificantly affects economic growth up to a certain threshold, of which above this threshold, inflation begins to exert an adverse effect on economic activity (Phiri, 2010). In reference to the South Africa as an inflation-targeting country, empirical estimates of inflation thresholds can be used to evaluate the effectiveness of the targeted inflation range of 3 to 6 percent. If the estimated inflation threshold is found to lie outside the SARB's 3 to 6 percent target, then the target may be deemed as being inappropriate. Conversely, if the estimated inflation threshold is found to lie within the Reserve Bank's inflation target, then the SARB's target is an inappropriate one.

At present, there exists a handful of studies which have estimated inflation threshold points for South African data. On one hand, are the panel studies of Sarel (1996), Ghosh and Phillips (1998), Khan and Senhadji (2001), Drukker et. al. (2005), Mi (2006) and Kremer et. al. (2013) which include South Africa in their panel set and obtain threshold estimates of 8 percent, 2.5 percent, 11 percent, 19 percent, 14 percent and 17 percent, respectively. Notably these panel studies generalize their estimates for different countries with varying economic situations thus rendering these panel threshold estimates as being biased and therefore unreliable. On the other hand, there also exists a separate cluster of studies which estimates inflation thresholds for the South African economy as a singular country. Inclusive of these studies are the works of Phiri (2010), Leshoro (2012), Morar (2012) and Adusei (2012) who obtain thresholds of 8 percent, 4 percent, 9.5 percent and 7 percent, respectively. One major concern with these studies is that they all employ outdated empirical techniques at arriving at their threshold estimates. Moreover these empirical results contradict factual data which tends to show that inflation rates above 7 percent are accompanied with dismal economic growth rates, more prominently for the post-inflation targeting period.

Our paper thus makes use of a smooth transition regression (STR) econometric model to estimate threshold effects in the inflation-growth relationship for quarterly data collected for the post-inflation targeting era i.e. 2001:Q1 to 2016:Q4. To the best of our knowledge, this study becomes the first to use this framework to estimate inflation thresholds for South Africa as a singular country. We have chosen the STR model as preferential choice of empirical framework because of it's superiority over other competing nonlinear econometric model. For instance, STR models conduct their transition between regression regimes in a smooth manner thus rendering the model as being more theoretically appealing in comparison to other threshold models which impose abrupt change in the regime coefficients (Phiri, 2015). Moreover, the STR model is designed in a manner which encompasses other nonlinear econometric models such as the threshold autoregressive (TAR) model and the Markov-Switching (MS) models.

Against this background, we organize the remainder of the paper as follows. In the following section, we provide an overview of inflation targeting as a policy conduct by the SARB. In the third section of the paper, the literature review of the study is provided. In the fourth section of the paper, the empirical model used in the paper is presented. The fifth section of the paper we present the empirical analysis whereas the study is concluded in the sixth section of the paper.

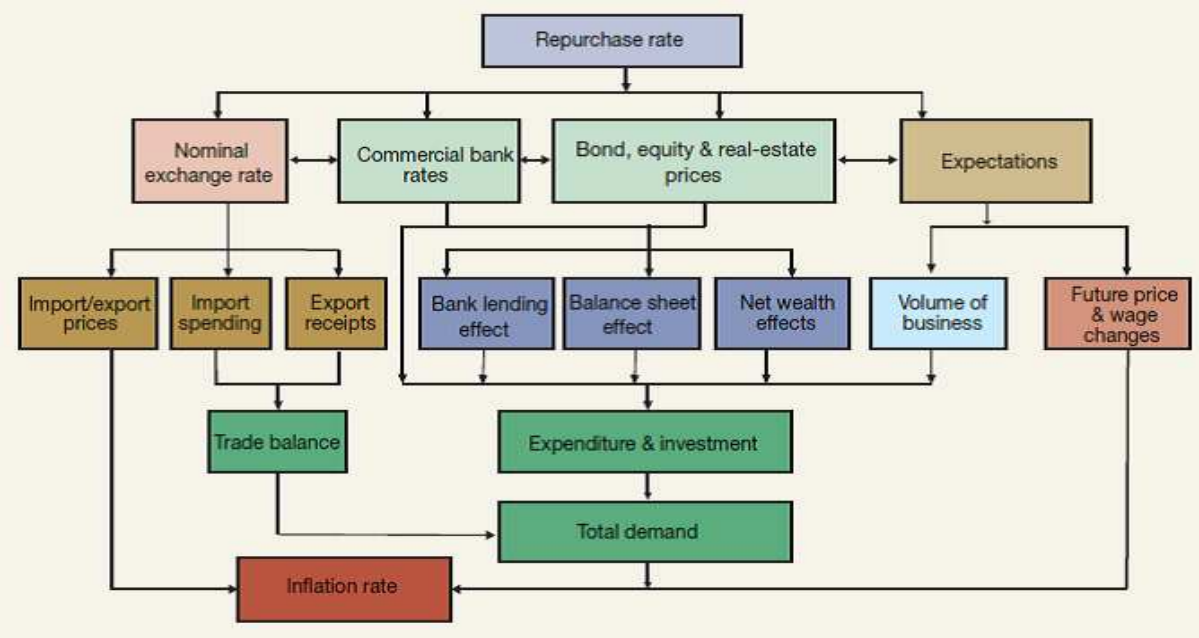
2 The South African Reserve Bank (SARB) and inflation targeting

The SARB Africa formally introduced inflation targeting as a form of monetary policy conduct in February 2000, after announcing the intention to adopt the framework in August 1999. Prior to adopting the inflation-targeting framework, the Bank had adopted a number of frameworks inclusive of liquid-asset based system, cost of cash reserves based system with monetary targeting, as well as a repurchase agreement (repo) system with both monetary targeting and informal inflation targeting (Phiri, 2016). Under the formal inflation targeting regime, the Reserve Bank announces an explicit inflation target and manipulates the repurchase or 'repo' rate as a means of keeping inflation within it's designated target. Initially the inflation target was set a 3 to 6 percent in 2002 and then temporarily change to a target of 3 to 5 percent in 2005, and then changed back to 3 to 6 percent in 2006 and the target has remained so since then. From 2002 until 2009, the SARB had targeted the CPIX inflation index which is a measure of the consumer price index (CPI) less mortgage interest costs. However, following

the global financial crisis of 2008 and the resulting global recession period of 2009, the Reserve Bank resorted to targeting the CPI index and is still currently targeting this particular index.

The decision making process under the inflation targeting regime is undertaken by the monetary policy committee (MPC) which currently constitutes of six members namely; the Reserve Bank governor, the three deputy Reserve Bank Governors, the adviser to the Reserve Bank governor and head of the research and statistics division at the SARB. Each member of the committee has a vote to set the repo rate at a level which is felt will be consistent with meeting the set inflation target. The decisions of the MPC in setting the repo is influenced by a wide range of economic and financial indicators as well as by projected forecasts of inflation over a forward-looking period of 24 months. The decision rules for the committee are as follows. If actual inflation is above it's target then interest rates are raised in order to lower inflation to within the 3 to 6 percent target. If inflation is below it's target then interest rates are lowered in order to keep inflation within its target. And if actual inflation is within it's target the interest rates will be left unchanged. The mechanism through with the repo rate works itself to the inflation rate is demonstrated by the monetary transmission mechanism depicted in Figure 1. The final decision of the MPC to either lower, rise or leave interest rates unchanged is then communicated to the general public through press conferences, releases of a quarterly bulletins and various monetary policy forums delivered to an invited audience.

Figure 1: monetary policy transmission mechanism (source: SARB)



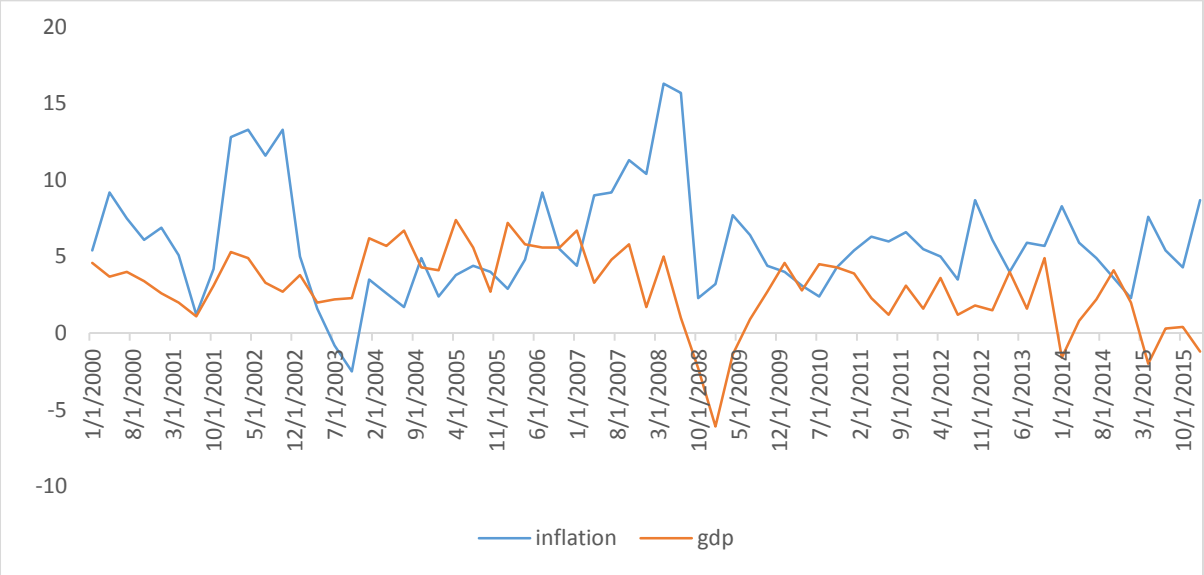
3 Inflation and growth developments under the IT regime

Movements in inflation and economic growth in South Africa for the post-inflation targeting era have been mainly influenced by external shocks to the economy. Subsequent to adopting the inflation targeting regime, inflation in South Africa was above the target range of 3-6 percent in 2002 following the repercussions of the 9/11 terrorist attacks in the United States and this was accompanied by a slowdown in GDP performance. However, inflation fell sharply to negative figures in late 2003 following the official implementation of the inflation targeting regime in the previous year and GDP growth also began to steadily improve. Throughout the period of 2003 to 2005, actual inflation remained below the set inflation target range averaging 2.6 percent with GDP growth averaging 4.4 percent during this period. In 2006, inflation began to rise although remaining within it's target averaging 5.6 percent and this was accompanied by improving economic growth performance with averages of 6.05 percent for GDP growth. This improvement in economic growth can be attributed to a positive budget surplus experienced during the fiscal year of 2006/07. However, declining economic growth performance of 3 percent experienced during the second quarter of 2007 was mainly due to poor domestic investment climate and South Africa's poor export performance as well as strong import demand following increases in domestic demand. The annual inflation rate also increased to 9 percent in 2007.

However, the worst was to come following the bankruptcy of the Lehman brothers and the subsequent global financial crisis in late 2007 and these external shocks caused the domestic inflation rate to increase to averages of over 11.2 percent in early 2008. As a result of the financial crisis, the world experienced a recessionary period in 2009 in which GDP growth reached a historic low annul average of -1.8 percent even though at this time inflation had subsided to averages of 8 percent. Further aggravating higher inflation and falling economic growth rates were increase in oil prices, soaring food prices and a declining domestic currency. Between the fiscal years of 2008/2009 and 2009/2010, the government implemented a fiscal stimulus packages which saw economic growth improve and sharp hikes in the repo rate in late 2009 lowered inflation rates to within the set target. Since 2010, inflation has more-or-less been kept within it's 3-6 percent target averaging 5.34 percent between 2010 and 2015 whilst economic growth has been on a downward trend, averaging 2.1 percent under the same

time period. Poor economic growth performance over the last 5 years is attributed to a slowdown in China's economy and sharp deterioration in domestic exchange rates in late 2015. Figure 1 provides a graphical depiction of the CPI inflation and GDP growth developments since 2000.

Figure 2: CPI inflation and GDP growth: 2000-2015



4 Literature Review

A majority of growth models which predicted the effects of inflation on economic growth arose in the post-great depression era. Mundell (1963) and Tobin (1965) were among the first to provide insightful theoretical revelations into the relationship between inflation and economic growth. In their models inflation encourages people to accumulate greater wealth through increased saving, thus driving down the real interest rate and ultimately increasing capital accumulation. A number of early empirical papers provided support for this claim of a positive inflation-growth correlation including the study of Krogh (1967) for South Africa. The next development in the theoretical literature come about as a courtesy of Sidrauski's (1967) superneutrality hypothesis which depicts that an increase in inflation does not affect steady-state level of capital accumulation and neither affects real variables such as output growth. However, the superneutrality hypothesis is contradictory to the epic rise in inflation accompanied with low economic growth rates as experienced in the early 1970's throughout to the early 1980's. Hereafter, endogenous growth models began to replace these previous neoclassical models in accounting for the inflation-growth correlation. These models generally

depict a negative relationship between the variables through various welfare costs of inflation on steady-state output (i.e. Stockman (1981), Greenwood and Huffman (1987)), Lucas and Stokey (1987), McCallum and Goodfriend (1987) and Cooley and Hansen (1989).

However, in the early 1990's empirical researchers turned their attention towards capturing possible convexities in the inflation-growth relationship. Fischer (1993) as well as Bruno and Easterly (1996) were among the first to explore the possibility of nonlinearity in the inflation-growth correlation for a panel of developing and developed countries. These authors used spline (continuous piecewise) regressions to demonstrate that the adverse effects of inflation on growth intensify the higher one moves up the inflation band ranges of '0-15 percent', '15-40 percent' and '40 percent and above'. In a different study, Ghosh and Phillips (1998) establish a kink in the inflation-growth relationship at 2.5 percent inflation, were inflation is positively correlated with growth below these levels and negatively so above this threshold. One major shortcoming of these preceding studies is that the 'inflation threshold' values are picked by judgement rather than through an empirical search which made it difficult to pinpoint an exact inflexion point at which the effects of inflation on economic growth switch. The study of Sarel (1996) become the first to circumvent this problem by estimating an optimal inflation level of 8 percent of which above this level, inflation adversely affects economic activity. The econometric assumption underlying Sarel's (1996) empirical model is that observed data of inflation, economic growth and other growth determinants can be segregated into two regimes; one regime capturing the dynamics of the data below a predetermined inflation threshold whilst the second regime analyses it's effect above the threshold (Phiri, 2010). The inflation threshold is selected as the inflation rate associated with estimated growth regression that produces the highest explanatory power. The empirical strategy developed in Sarel's (1996) study has been used extensively in the literature and is the current mode of investigation used in previous studies estimating inflation thresholds for the South African economy (see Phiri (2010), Leshoro (2012), Morar (2012) and Adusei (2012)).

Khan and Senhadji (2001) improved on the methodology used in Sarel's (1996) paper by making use of the more empirically refined threshold autoregressive (TAR) model of Hansen (2000). Furthermore the authors segregated their data into two panels, one for industrialized economies and on for developing countries. The authors estimate inflation thresholds of 2 percent for industrialized economies whereas the inflation thresholds of 11-12 percent are found for developing countries. These results imply that inflation thresholds in

developing countries is higher than in industrialized economies hence insinuating that developing countries can withstand higher levels of inflation. Other authors which have used similar TAR models in estimating inflation thresholds for a panel of countries containing South African data include the works of Drukker et. al. (2005), Mi (2006) and Kremer et. al. (2013), Bick (2010) just to give examples. And even more recently, many authors have dedicated research efforts towards examining the inflation thresholds within the context of a smooth transition (STR) model framework of Luukkonen et. al. (1988). STR models are preferred over their TAR counterparts due to smooth transition between regressions regimes, a feature which is considered to be more theoretically appealing compared to other nonlinear econometric models. Panel studies which have include South African data in their analysis include the works of Jude (2010), Lopez-Villavicencio and Mignon (2011), Seleteng et. al. (2013) and Ibarra and Trupkin (2016). Nevertheless, these various panel studies obtain a variety of conflicting inflation threshold estimates hence warranting the subject matter open to further deliberation. Moreover, previous studies which have investigated inflation thresholds for South Africa as an individual country have not gone beyond using the empirical strategy of Sarel (1996) which is considered to be outdated in light of more sophisticated econometric models such as the STR model.

5 Methodology

In line with the former studies of Lopez-Villavicencio and Mignon (2011), Seleteng et. al. (2013) and Ibarra and Trupkin (2016), our current study makes use of the STR model to estimate inflation thresholds for South African data. In it's basic representative form the baseline STR model can be specified as:

$$y_t = \varphi' z_t + \Phi' z_t G(\gamma, c, s_t) + \mu_t \qquad (1)$$

Where y_t is a scalar; z_t represents the vector of explanatory growth variables; φ' and Φ' are the parameter vectors of the linear and nonlinear part of the STR regression, respectively and μ_t is a well behaved error terms with properties $N(0, h^2_t)$. The transition function $G(\gamma, c, s_t)$ is bounded between zero and unity and determines whether the economy is in the 'high regime', the 'low regime' or is transitioning between the two. In particular, when $G(\gamma, c, s_t) = 0$, then equation (1) reduces to a linear model; whereas when $G(\gamma, c, s_t) = 1$, equation (1) transforms

into a two regime TAR model with abrupt regime-switching behaviour. When $0 < G(\gamma, c, s_t) < 1$, then the model is a weighted average of the 'low regime' and the 'high regime'. The variable s_t is the transition variable; the variable γ measures the smoothness of transition between the regimes and c represents the threshold parameter that measures the location of the transition function. In our study we specify the transition function in the following logistic form:

$$G(\gamma, c, s_t) = 1 + \exp\{-\gamma \prod_{k=1}^{K}(s_t - c)\}^{-1} \quad (2)$$

Which yields the logistic smooth transition regression (LSTR) model. Furthermore the LSTR model can be assume two functional forms, the first when K=1 which results in the LSTR(1) model and; when K=2 which results in the LSTR(2) model. However, prior to determining whether a LSTR(1) or LSTR(2) model is the most appropriate functional form, one must firstly test for linearity. This can be achieved by imposing the following constraints n equation (1), H_0: $\gamma=0$ or H_0': $\Phi'=0$. And yet it is well known that associated tests are nonstandard since the LSTR regression contains unidentified parameters under the null hypothesis of linearity. As a means of circumventing the identification problem, Luukkonen et. al. (1988) propose a solution to replace the transition function $G(\gamma, c, s_t)$ by third order Taylor approximation expanded around $\gamma=0$ and this results in the following auxiliary function:

$$y_t = \varphi' z_t + \Phi_1'^{*} z_t + \Phi_2'^{*} z_t^2 + \Phi_3'^{*} z_t^3 + \mu_t^* \quad (3)$$

Where the parameters $\Phi_1'^{*}$, $\Phi_2'^{*}$and $\Phi_3'^{*}$are multiples of γ and $\mu_t^* = \mu_t + R_3 \Phi_1'^{*} z_t$, with R_3 being the remnant portion of the Taylor expansion series. The null hypothesis of linearity can now be tested as $H_0'' = \Phi_1'^{*} = \Phi_2'^{*} = \Phi_3'^{*} = 0$. Under this null hypothesis, the LM test statistic is still applicable and has as asymptotic χ^2 distribution with 3(p+1) degrees of freedom. Once linearity is rejected, the next step in the specification process is to select an appropriate transition variable, c_t, and then decided on whether the STR model should be modelled as a LSTR(1) or LSTR(2) regression. Since our study is concerned with examining regime switching behaviour based on inflation thresholds we thus selected the inflation variable as the appropriate transition variable. We thereafter apply the decision rule of Terasvirta (1994) based on the following sequences of tests:

H_{04}: $\Phi_3 = 0$

$H_{03}: \Phi_2 = 0/\Phi_3 = 0$

$H_{02}: \Phi_1 = 0/\Phi_3 = \Phi_2 = 0$

¶

The above hypotheses are tested by F-tests denoted as F4, F3 and F2 respectively. The decision rule for selecting ether LSTR(1) of LSTR(2) model is as follows. We select the LSTR(2) if the F2 statistic has the lowest p-value, otherwise, we select the LSTR(1) model. Once the LSTR(1) or LSTR(2) model is chosen, we then carry out three-dimensional grid search over the values of γ, c and s_t and choose the optimal values as those which minimize the residual sum of squares (RSS). The model is then estimated using the Newton-Raphson algorithm to maximize the conditional maximum likelihood function. Moreover, diagnostic tests are performed over the estimated regression in the form of ARCH tests, tests of no autocorrelation and normality tests.

6 Data and empirical results

6.1 Data and unit root tests

The data used to carry out our empirical analysis consists quarterly series total expenditure by national government and total national government revenue. All data has been retrieved from the South African Reserve Bank (SARB) online database over the period 1960:Q1 to 2016:Q2. The dataset consist of the percentage change in the real gross domestic product at market prices (*gdp*); the percentage change in total consumer prices (π), the gross domestic fixed investment to GDP (*inv_gdp*), the ratio of M2 money aggregate to GDP (*m2_gdp*); the ratio of government expenditure to gdp (*gov_gdp*) and the real effective exchange rate (*REER*). In reference to our empirical STR regression, *gdp* represents the dependent variable whereas the remaining time series variables represent growth explanatory variables and the choice of these time series variables as growth explanatory variables is guided by conventional economic growth theory as elaborated in Levine and Renelt (1992) and Salai-I-Martin (1997). The summary of descriptive statistics for the observed time series variables are provided for in Table 1 below.

Table 1: Descriptive statistics of the time series variables

	gdp	π	inv_gdp	M2_gdp	gov_gdp	REER
Mean	2.95	5.90	18.74	2.89	26.43	-0.24
Median	3.10	5.40	19.20	2.94	26.60	0.40
Maximum	7.40	16.30	25.30	9.29	33.20	13.50
Minimum	-6.10	-2.50	15.00	-0.52	19.90	-14.00
Std. dev.	2.51	3.60	2.46	2.01	2.95	5.06
Skewness	-0.83	0.76	0.18	0.59	-0.05	-0.17
Kurtosis	1.31	0.79	-0.59	0.16	-0.43	0.50
JB	13.61	8.86	1.10	4.11	0.35	1.35
Probability	0.00	0.01	0.58	0.13	0.84	0.51

As a preliminary step before evaluating and estimating our STR model, we firstly examine the integration properties of the individual time series variables. Conventional unit root tests such the ADF and PP unit root tests have come under criticism for of not been able to effective distinguish between a unit root process and a near unit root process. We therefore supplement these conventional unit root tests with so-called second generation unit root tests of Elliot et. al. (1996) as well as the structural-break unit root test of Zivot and Andrews (1992). Each of the time series is tested for unit root using these 4 unit root testing procedures and each test is performed with a drift and with a trend. The empirical results of the unit root tests are reported in Table 2 below.

Table 2: Unit root test results

time series	test statistic	levels		first differences		decision
		drift	trend	drift	trend	
gdp	ADF	-2.95**	-3.46**	-6.92***	-6.88***	I(0)
	PP	-3.92***	-4.45***	-11.48***	-11.49***	I(0)
	DF-GLS	-2.01**	-2.99*	-3.28***	4.06***	I(0)
	ZA	-4.33*	-3.87	-7.67***	-6.90***	I(0)
π	ADF	-2.99*	-4.20***	-4.06***	-7.38***	I(0)
	PP	-4.10***	-4.06**	-8.58***	-8.50***	I(0)
	DF-GLS	3.17***	-3.19**	-1.87*	-3.16**	I(0)
	ZA	-4.71*	-4.24*	-8.40***	-7.83***	I(0)
inv.gdp	ADF	-1.77	-2.05	-4.23***	-4.26***	I(1)
	PP	1.43	-1.62	-4.63***	-4.62***	I(1)
	DF-GLS	-0.91	-1.67	-2.28**	-2.40	I(1)
	ZA	-3.19	-3.42	-7.54***	-4.32*	I(1)
M2_gdp	ADF	-3.52***	-4.49***	-9.39***	-9.39***	I(0)
	PP	-4.83***	-5.47***	-15.51***	-15.61***	I(0)
	DF-GLS	-1.36	-1.52	-1.66*	-3.08**	I(1)
	ZA	-7.02***	-4.55**	-9.97***	-9.79***	I(0)
gov_gdp	ADF	-0.94	-4.66***	-7.95***	-7.92***	I(0)
	PP	-5.61***	-12.90***	-54.09***	-55.89***	I(0)
	DF-GLS	-0.19	-1.04	-0.47	-1.31	I(1)
	ZA	-6.43***	-5.25***	-8.32***	-8.32***	I(0)
REER	ADF	-5.66***	-5.66***	-11.20***	-11.13***	I(0)
	PP	-7.10***	-7.11***	-15.54***	-15.49***	I(0)
	DF-GLS	-3.19***	-3.37**	-1.99**	-3.26**	I(0)
	ZA	-6.67***	-6.14***	-11.36***	-11.72***	I(0)

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

As can be observed from the unit root tests results reported in Table 2, the employed test statistics manage to reject the null hypothesis of a unit root process for almost all the observed time series variables. In particular, we note that all four unit root test statistics (i.e. ADF, PP, DF-GLS and ZA) manage to reject the null hypothesis of a unit root process at a significance level of at least 10 percent for *gdp*, π and *reer* time series variables in their levels regardless of whether the unit root test has been performed with a drift or with a trend. Concerning the *M2_gdp* and the *gov_gdp*, all unit root test statistics, with the exception of the DF-GLS statistic, manage to reject the unit root null hypothesis at a 5 percent level of significance for the time series in their levels. With respect to the *inv_gdp* time series, we note that the null hypothesis of a unit root cannot be rejected for the time series at all levels of

significance. However, in it's first difference, the ADF, PP and ZA statistics manage to reject the unit root hypothesis at a significance level of at least 10 percent. Collectively, we conclude that with the exception of the *inv_gdp* variable, the remaining time series variables can be deemed as being levels stationary or integrated of order I(0). This is important for our empirical analysis since the estimation of the STR model requires that the time series should levels stationary.

6.2 STR regression analysis

In light of finding the time series variables to be levels stationary, we proceed to estimate the STR model of inflation and growth. However, before doing so, we must firstly tests whether the inflation variable is a suitable transition variable and which functional form of the STR model (i.e. LSTR(1) or LSTR(2)) should be applied. To do so, we perform tests of linearity for the inflation variable as well tests of no remaining linearity for the same variable. The results of these tests are reported in Table 2 below.

Table 3: Linearity tests and tests of no remaining nonlinearity

linearity tests		test of no remaining linearity	
F-stat	p-value	F-stat	p-value
F	1.5622e-02	F	7.4216e-01
F4	3.7786e-02	F4	8.8423e-01
F3	9.7957e-01	F3	5.3572e-01
F2	5.7002e-03	F2	3.2848e-01

t-statistics are reported in parentheses. Significance levels are given as follows: '***', '**' and '*' represent the 1 percent, 5percent and 10 percent significance levels respectively.

In referring to the results reported in Table 3, the F-statistic rejects the null hypothesis of linearity and this result offers support that inflation is a suitable transition variable for the STR model. When deciding on which functional form to choose, we find that the p-values associated with the F3 statistic is larger than the p-values of the F4 and F2 statistics. On this basis, the LSTR(1) model is chosen for further empirical purposes. We also note that there is no remaining nonlinearity in our chosen LSTR(1) when inflation is chosen as the transition variable. Given this evidence, we proceed to estimate the LSTR(1) model for the data. The empirical results of this exercise are reported in Table 4 below.

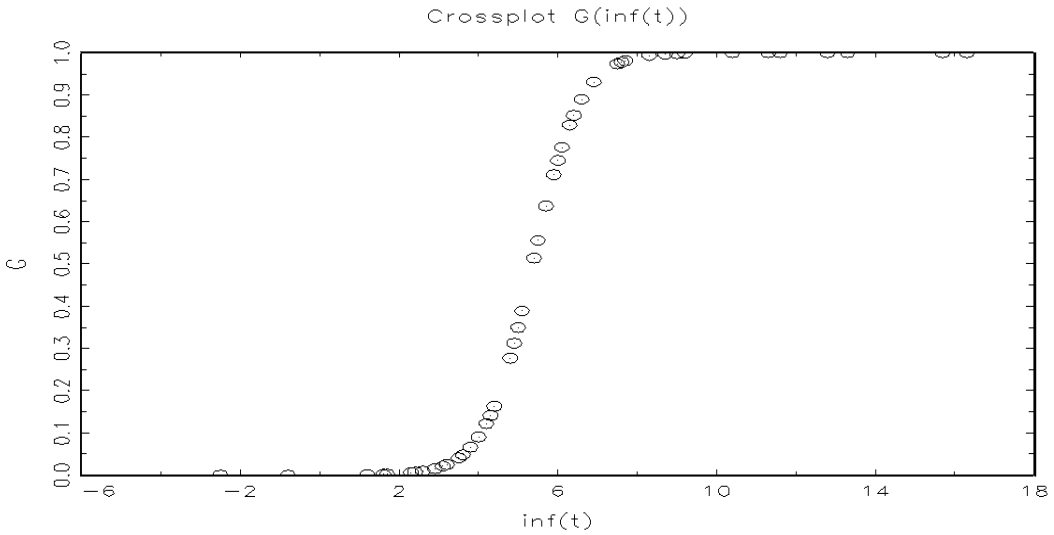
Table 4: STR estimates of inflation-growth model regression

variable	estimate	standard deviation	t-stat	p-value
		linear part		
constant	6.96	4.46	1.56	0.12
π	0.72	0.29	2.50	0.01***
inv_gdp	-0.65	0.22	-3.02	0.00***
M2_gdp	0.47	0.23	2.07	0.04*
gov_gdp	0.19	0.28	2.23	0.02**
REER	0.10	0.10	1.00	0.32
		nonlinear part		
constant	7.66	7.35	1.04	0.30
π	-0.62	0.32	-1.97	0.05*
inv_gdp	0.64	0.28	2.24	0.03**
M2_gdp	-0.26	0.32	-0.82	0.42
gov_gdp	-0.72	0.30	-2.41	0.02**
REER	-0.25	0.13	-1.84	0.07*
γ	6.09	3.64	1.67	0.10
c	5.37	0.53	10.15	0.00***
R^2		0.52		
AIC		1.53		
SSR		3.81		

t-statistics are reported in parentheses. Significance levels are given as follows: '***', '**' and '*' represent the 1 percent, 5percent and 10 percent significance levels respectively.

In referring to the empirical estimates of the STR model as reported in Table 3, we firstly note an inflation threshold estimate of 5.37 percent with a smoothing parameter of 6.09 hence indicating that transition between the lower and upper regime is relatively abrupt and quite rapid. We note that the threshold estimate is relatively comparable with the 4 percent obtained in the study of Leshoro (2012) and yet significantly different from those obtained in the panel studies of Sarel (1996), Khan and Senhadji (2002), Drukker et. al. (2005), Mi (2006) and Kremer et. al. (2013), Bick (2010), Jude (2010), Lopez-Villavicencio and Mignon (2011), Seleteng et. al. (2013) and Ibarra and Trupkin (2016). It is also important to note that this threshold value lies within the 3-6 percent inflation target currently employed by the SARB. This implies that the Reserve Bank's inflation target lies within a range conducive for economic growth. Figure 2 shows the transition function plotted against the inflation rate.

Figure 2: Transition function for the estimated LSTR(1) model



In turning to the coefficient estimates for the growth explanatory variables, we firstly note that estimate on the inflation variable is positive and statistically significant at the 1 percent level in the lower regime whereas this coefficient estimate turns negative and significant at the 5 percent level in the upper regime of the model. This result is in line with the theoretically predictions of Huybens and Smith (1999) and Bose (2002) who hypothesize that inflation positively affects economic growth at low levels and then exerts it's adverse effects at higher levels of inflation. We also observe similar positive coefficients for government spending (*gov_gdp*) and financial deepening (*m2_gdp*) in the lower regime of the model and these estimates are significant at a 1 and 5 percent level, respectively. The signs on these coefficients are line with those predicted by conventional growth theory as iterated in the works of Levine and Renelt (1992) and Salai-I-Martin (1997).

However, contrary to growth theory we find a negative coefficient on the investment variable in the lower regime of the model and this estimate is significant at all levels of significance. Notably, a similar negative coefficient on investment is obtained in the study of Leshoro (2012) and there are two rationale explanations for this finding. Firstly, a greater part of South Africa's investments are not 'Greenfield investments' which would contribute to infrastructure development and job creation but are rather mergers and acquisitions (Fortainer, 2007). Secondly, the current high levels of public spending and budget deficits crowd out the positive effects of investment in the South African economy (Biza et. al., 2015). Nevertheless, in the upper regime of the model, the negative effect of investment on economic growth turns

positive at a 5 percent significance level. This result is an iteration of that found in Epstein (2003) who finds that the low inflation environment may not be conducive for investment in South Africa and a less restrictive monetary policy stance, involving less manipulation of interest rates, may prove to facilitate for a more favourable investment environment. We further note the coefficient on the exchange rate variable is positive albeit insignificant in the lower regime of the model and this turns positive at a 10 percent level of significance in the upper regime of the model. This particular result implies that it would be in the best interest of the Reserve Bank to keep inflation at low levels in light of the adoption of free floating exchange rate regime in which exchange rates are primarily determined by market forces.

In the final phase of our empirical process, the estimated LSTR(1) model was subjected to various diagnostic tests performed on the regression residuals. In particular, the model was tested for autocorrelation, for ARCH effects as well as for normality effects. The results of the diagnostic tests are reported in Table 5 below. Starting with our test for autocorrelation, the LM statistic testing the null hypothesis of no autocorrelation produced a statistic of 3.04 with a p-value of 0.08 hence rejecting the notion of serial correlation amongst the error term of the estimated regression. Concerning the tests for ARCH effects the associated LM test produces a test statistic of 5.44 with an associated p-value of 0.71. Henceforth, the regression residuals are deemed to be free of any ARCH effects. Finally in testing for normality effects, the JB test statistic produces an estimate of 11.96 with an associated p-value of 0.00 hence verifying that the estimated LSTR(1) model regression has a normal distribution.

Table 5: Diagnostic tests results

tests	null hypothesis	t-statistic	p-value
LM	no autocorrelation	3.04	0.08
ARCH	no ARCH effects	5.44	0.71
JB	normal distribution	11.96	0.00

7 Conclusion

Estimating inflation thresholds or the optimal level of inflation which maximizes economic growth or similarly minimizes growth losses is considered a very important empirical exercise for South Africa as an inflation targeting country. Thus far, previous studies

investigating this phenomenon for South Africa have been characterized by two shortcomings. Firstly, some studies have conducted the estimations of inflation thresholds for South Africa using panel data techniques which generalize the threshold estimates for a cluster of countries facing differing economic situations. Secondly, other studies which have used single country analysis have relied on outdated empirical estimation techniques hence putting into question the validity of the obtained empirical estimates. Therefore, in our study, we contribute to the empirical literature by investigating threshold effects in the inflation-growth relationship. In particular we estimated a growth equation using a STR model on quarterly data collected between 2001:Q1 and 2016:Q4. Our empirical results reveal an inflation threshold estimate of 4.8 percent for the data, which incidentally lies within the current 3 to 6 percent inflation target set by the SARB.

Given that the inflation threshold estimate obtained in our study lies within the 3-6 percent target specified by the SARB we commend the Reserve Bank for choosing an inflation target which provides a conducive environment for maximizing economic growth through government expenditure and financial deepening. However, this low inflation environment produces a negative effect of investment on economic growth and this effect only turns positive when inflation is above 4.8 percent. This result implies that around the mid-point of the target, the Reserve Bank faces a trade-off between investment, on one hand, and government expenditure and financial depth, on the other hand. If the Reserve Bank keeps inflation below it's mid-target (i.e. below 4.5 percent) then government creates an environment in which it can increase government expenditure and create more financial depth without harming economic growth. However, this scenario comes at an economic cost of a poor investment environment. Conversely, if the inflation is above it's mid-point of the inflation target, and in specific above 4.8 percent, then the financial environment is conducive for investment but not so for increased government expenditure and increased financial deepening.

In the aftermath of the global recessionary period of 2009, South African fiscal authorities have implemented two main macroeconomic policies (i.e. New Growth Path (NGP) and National Development Plan (NDP)) which require increased future government investment expenditure as means of halving present unemployment rates and closing the poverty gap. Our results imply that this would require the Reserve Bank to keep inflation below the inflation threshold estimate of 4.8 percent. So whilst the inflation threshold estimate lies in between the Reserve Bank's target range it would be more beneficial for the Central Bank to lower the

current target such that the upper margin of the target coincides with the 4.8 percent threshold. By doing so monetary authorities would be targeting an inflation range which would produce a conducive financial environment for fiscal authorities to increase government expenditure as a means if meeting their macroeconomic objectives. Therefore, in differing from a majority of previous studies our empirical results advocate for the effectiveness of the chosen inflation targeting regime and does not suggest the abandoning of the current target range yet it does suggest a slight adjustment of the upper target limit. Moreover, the insignificant effect of the exchange rate variable below the threshold reflects the effectiveness of the Reserve Bank's flexible approach to exchange rate determination as a complimentary policy to the inflation targeting regime.

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