Re-Examining the South African Reserve Bank's Policy Reaction Function Using the NARDL Model

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The 3–6 percent inflation target is a policy rule used by the South African Reserve Bank (SARB) to fulfil its statutory obligation of ensuring a low and stable inflation environment and its policy reaction function assesses how the Reserve Bank responds to deviations of inflation from its target. We rely on nonlinear autoregressive distributive lag (NARDL) models to estimate the asymmetric preferences which the Reserve Bank has to inflation deviations during rising and falling episodes of inflation. Using quarterly data spanning from 2002:q1 to 2021:q4, we estimate the policy reaction functions using 7 disaggregated measures of inflation to capture the heterogeneity in the formation of price expectations. We further segregate our data into two sub-periods, corresponding to the pre-crisis and post-crisis era, as a robustness exercise. Overall, our findings indicate that in the post-crisis era the SARB (i) has become more responsive to inflation, output fluctuations and exchange rates and (ii) has responded more aggressively to rising inflation than falling inflation.

Key Words: Taylor rule, nonlinear policy reaction function, nonlinear autoregressive distributive lag (NARDL) model, survey-based inflation expectations, South Africa
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Introduction

The statutory mandate of the South African Reserve Bank (SARB) is to protect the (purchasing) value of currency in the interest of balanced and sustained economic growth. In 2001, the SARB intensified its commitment to these statutory obligations by abandoning its previous monetary targets/eclectic monetary policy and adopting a fully-fledged inflation targeting (IT) framework hinged on a policy rule of keeping inflation within a 3–6% target range. Essentially, the IT regime is a forward-looking monetary policy framework, in which the Reserve Bank makes econometric projections for future inflation rates at forecast periods of 12 to 24 months in advance. If inflation is expected to exceed its upper target bound of 6 percent, then the central bank raises the repo rate in anticipation of the target breach. This, in effect, does two things. Firstly, this 'cools' the real economy by suppressing demand pressures and consequentially lowering inflation back to its target via various monetary transmission mechanisms (Botha et al. 2017). Secondly, higher interest rates protect the purchasing power of savers and investors by ensuring that the returns gained from financial institutions offset the changes in the prices of goods and services.

Ultimately, the extent to which the Reserve Bank can contain inflation within its target and smooth out business cycle fluctuations is dependent upon the central bank's response to deviations of inflation and output growth from their fundamentals. The policy reaction function, first introduced by Taylor (1993), is traditionally used to gain insight into the behaviour of an independent monetary policymaker whose prime objective is to stabilize inflation around predetermined targets. This 'rules-based' monetary policy approach is considered a 'time-consistent solution' to the dynamic optimization problem faced by monetary authorities in simultaneously stabilizing inflation at low rates and minimizing growth losses (Kydland and Prescott 1977). If the Taylor rule holds, then a central bank can be deemed to have sufficient independence and credibility to respond to positive (negative) inflation deviations from its target without driving the economy to a recession (overheating the economy).

There are some stylized facts observed from the time series plot of repo rate, inflation expectations and the output gap presented in figure 1 which provide insights into the performance of the SARB in keeping inflation within its target using a rules-based policy. We particularly observe that whilst the repo rate appears to positively track both inflation and output gap (i.e. higher (lower) repo movements are synchronized with higher (lower) inflation and output gap), the Reserve Bank has had varying success in keeping inflation within its target. For instance, during the early adoption of the framework, as well as during the build-up to the global financial crisis (GFC), when inflation was generally rising, the SARB missed its target by wide margins. However, subsequent to the post-GFC, which is generally characterized by periods of lowering inflation rates, the Reserve Bank seems to have had more success in containing inflation within its target. This, in turn, implies that the Taylor rule dy-

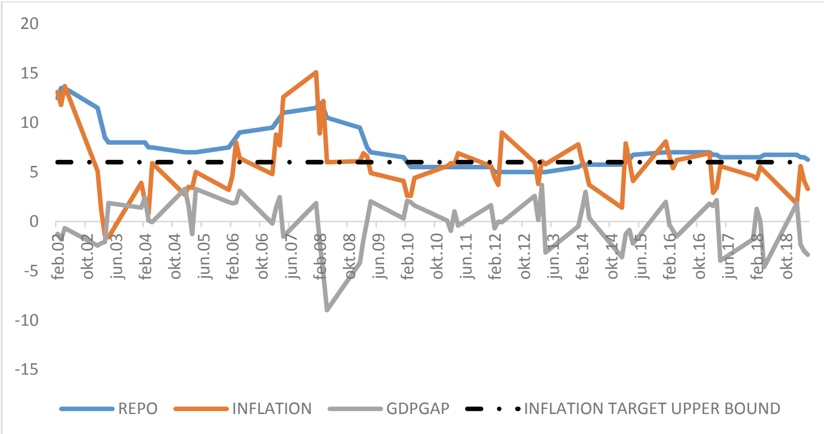

FIGURE 1 Time Series Plot of Repo Rate, Inflation and Output Gap in South Africa The repo rate and inflation rate are specified in percentages whilst the gap variable is the cyclical component of the HP-filter of the GDP growth rate. Data collected from SARB.

namics observed during periods of rising inflation may differ from those existing during periods of falling inflation. Nonetheless, the current studies which have estimated policy reaction functions for the SARB do not take into consideration these dynamics, hence warranting further investigation into the subject (Aron and Muellbauer 2000; Ortiz and Sturzenegger 2007; Ncube and Tshuma 2010; Naraidoo and Gupta 2010; Naraidoo and Raputsoane 2010; 2011; Veller and Ellyne 2011; Klein 2012; Naraidoo and Paya 2012; Kasa and Naraidoo 2013; Baaziz, Labidi, and Lahiani 2013; Bold and Harris 2018).

We contribute to the literature by re-examining the SARB's policy reaction function for the post inflation targeting era of 2002 to 2021 and determining whether the SARB has an asymmetric policy response to rising and falling periods of inflation. This objective is achieved by estimating the Taylor-type reaction function using the nonlinear autoregressive distributive lag (NARDL) model of Shin, Yu, and Greenwood-Nimmo (2014) to decompose inflation into its partial sum processes which separate periods of increasing inflation from periods of falling inflation and hence capture different forms of asymmetric monetary policy preferences. To ensure robustness of our empirical analysis we employ an array of inflation and inflation expectations classifications in constructing the inflation gap variable used in the policy reaction function. We further perform a sensitivity analysis in which we re-estimate our empirical regressions for two sub-samples corresponding to the pre- and post-crisis periods.

Having laid out the foundation of the study, the rest of our paper is structured as follows. The next section presents the literature review and contextualizes our contribution to the literature. The third section outlines the analytical framework. The fourth section presents the empirical data as well as our empirical findings. The fifth section concludes the paper in the form of policy implications and recommendations.

Literature Review and Contribution to the Study

Since its inception, the policy reaction function has undergone numerous modifications ranging from the 'forward-looking' or 'rationale-expectations-based' Taylor rule (Clarida, Gali, and Gertler 1998; 2000; Orphanides 2002) to augmentations with real exchange rates (Svensson 2003; Engel and West 2006; Wilde 2012; Chen, Yao, and Ou 2017), asset prices (Chadha, Sarno, and Valente 2004; Morley and Wei 2012; Finocchiaro and Heideken 2013) and financial conditions (Baxa, Hoorvath, and Vašíček 2013; Nair and Anand 2020; Ahmad 2020), to nonlinear policy reaction functions due to asymmetric policy preferences or asymmetries in monetary-macroeconomic relationships such as the Aggregate Supply or Phillips curve (Orphanides and Wieland 2000; Orphanides and Wilcox 2002; Nobay and Peel 2003; Schaling 2004; Dolado, Pedrero, and Ruge-Murcia 2004; Surico 2007; Cukierman and Muscatelli 2008; Castro 2011; Koustas and Lamarche 2012; Zu and Chen 2017). Notably, many of these modified Taylor policy rules have been estimated exclusively using South African data and this has resulted in a variety of empirical fits of the SARB policy reaction function (Aron and Muellbauer 2000; Klein 2012; Ncube and Tshuma 2010; Naraidoo and Gupta 2010; Naraidoo and Raputsoane 2010; Naraidoo and Paya 2012; Baaziz, Labidi, and Lahiani 2013; Bold and Harris 2018).

Whilst acknowledging the existence of previous studies which validate the Taylor rule for the SARB, we note that the magnitude of the response of the central bank to deviations of inflation from its target varies amongst the different studies. On the one hand, there are the studies of Aron and Muellbauer (2000), Ortiz and Sturzenegger (2007), Klein (2012), Veller and Ellyne (2011) and Bold and Harris (2018) which employ linear frameworks to fit the Taylor rule for the SARB. From this group, the studies of Aron and Muellbauer (2000) and Veller and Ellyne (2011) find a 'less-than-unity' response of the SARB to a percentage change in deviations of inflation from its target, whereas the studies of Ortiz and Sturzenegger (2007), Klein (2012) and Bold and Harris (2018) find a 'greater-than-unity' response to inflation deviations. On the other hand, there exists a separate group of studies which find that nonlinear policy reaction functions are better suited for capturing the SARB policy preferences (Ncube and Tshuma 2010; Naraidoo and Gupta 2010; Naraidoo and Raputsoane 2010; 2011; Naraidoo and Paya 2012; Kasa and Naraidoo 2013; Baaziz, Labidi, and Lahiani 2013). Whereas the studies of Ncube and Tshuma (2010) and Bazziz, Labidi, and Lahiani (2013) find lower responses of the Reserve Bank when inflation is below an estimated inflation of 9%, 6% and 5.6%, respectively, the works of Naraidoo and Raputsoane (2010; 2011), Naraidoo and Paya (2012) and Kasa and Naraidoo (2013) find that the SARB responds to inflation only outside an inflation 'zone area.'

Notwithstanding the empirical developments in the South African literature, the purpose of this paper is not concerned with merely validating the existence of a Taylor rule for the SARB, but we are rather interested in examining whether the Reserve Bank has been able to fulfil its obligation of protecting the country's citizens from the corroding effects of inflation. For this to be proven true, the SARB must be found to adhere to a policy reaction function such that there exists at least a 'one-for-one' co-movement between the policy instrument and inflation during periods of rising inflation. Conversely, during periods of falling inflation the Reserve Bank may lower interest rates but must ensure at most a 'one-for-one' response to the deflation rates so that the purchasing power of money held with financial institutions does not deteriorate over time. Primarily invoked by the lack of consensus concerning the magnitude of coefficient estimates obtained for the SARB policy reaction function, our study reevaluates the empirical evidence and in doing so, contributes to the literature in four ways.

Our first contribution to the current South African literature is the methodological approach used to estimate the policy reaction functions, in which our study makes use of the nonlinear autoregressive (NARDL) model of Shin, Yu, and Greenwood-Nimmo (2014). In the context of estimating the Taylor policy rules, we consider the NARDL framework as superior to other nonlinear econometrics frameworks, such as the threshold autoregressive (TAR), the smooth transition regression (STR) or the Markov-switching models commonly used in previous studies. For instance, the NARDL model is flexible in that it can accommodate a mixture of stationary and first difference time series, unlike other frameworks which require the series to be integrated of the same order. Furthermore, the NARDL framework reduces the chances of regression bias by accommodating the modelling of long-run and short-run asymmetric cointegration relations whilst remaining robust to possible endogeneity arising from the estimated regression. Courtesy of the lag design of the framework, interest rate smoothing and 'backward-looking' dynamics are also endogenously incorporated into the estimation process. Our study uses the NARDL to induce asymmetries into the SARB's policy reaction function by partitioning the inflation gap variable into negative and positive portions, such that we can discern the policymaker's preferences depending on whether inflation is on the rise or inflation is falling. Note that this differs from assumptions underlying the STR framework adopted in the previous South African studies of Ncube and Tshuma (2010), Naraidoo and Gupta (2010), Naraidoo and Raputsoane (2010; 2011), Naraidoo and Paya (2012) and Baaziz, Labidi, and Lahiani (2013), in which the policymakers' preferences differ only when inflation crosses some estimated threshold.

Our second contribution is that we estimate backward Taylor's policy rules for the SARB from a disaggregated perspective, that is, in addition to the aggregated CPI index commonly used in most of the previous South African literature, our study further employs the disaggregated price indexes for goods, on the one hand, and for services on the other. We consider this approach important since the price index used by the SARB, which is constructed based on a plutocratic weighting technique, is criticized for being an unsuitable measurement tool of inflation as it mainly reflects the consumption bundle of the top ten percent of households (Bhorat et al. 2014). As was witnessed during the 2007–2008 subprime crisis, the prices of consumer goods, which are associated with the poorest deciles, increased much more heavily compared to that of services purchased by households in the upper percentiles of the income distribution (Bhorat et al. 2014). Therefore, examining Taylor policy rules strictly using aggregated measures of inflation can be thought of as being biased, since it is possible that monetary policymakers respond differently to the varying items contained within the basket of goods and services used to calculate the aggregated consumer price index.

Our third contribution to the literature concerns our formation of the inflation expectations, which is an important component of the 'forward-looking' policy reaction function. Previous South African studies typically form inflation expectations either using a perfect foresight model with one-period ahead values of the actual inflation (Ncube and Tshuma 2010; Naraidoo and Paya 2012) or by using a simple learning rule of inflation expectations (Naraidoo and Gupta 2010; Naraidoo and Paya 2012). Our study follows the works of Gorter, Jacobs, and Haan (2008), Klein (2012), Bold and Harris (2018) and Kliesen (2019a; 2019b) by making use of survey-based measures of inflation expectations in inducing 'forward-looking' policy reaction functions. As revealed in the studies of Lai (1997), Soderlind (1998) and Kaliva (2008), the use of survey-based inflation forecasts to investigate the relationship between monetary policy instrument and inflation expectations (i.e. the Fisher effect) circumvents the problems of systematic forecasting errors produced from econometric-based forecasts. Moreover, Kabundi, Schaling, and Some (2015), as well as Miyajima and Yetman (2019), have shown how the SARB has anchored the expectations of market participants differently. In our study, we account for the observed heterogeneities in survey-based expectations with respect to estimating nonlinear 'forward-looking' policy reaction functions for the SARB using expectations from different market participants, i.e. the financial sector, business sector and trade unions.

Lastly, our study performs a sensitivity analysis in which we examine whether the 2008 financial crisis has caused a change in the SARB's policy preferences with respect to its responses to inflation and output deviations. Belke and Klose (2011) note that since the financial crisis, the Taylor rule has been criticized as being an inappropriate policy tool for central banks whose policy rates are close to the zero lower bound. However, Gerlach (2011), Klose (2011) and Jung (2018) argue that the rules-based monetary policy must not be entirely dismissed, and Taylor policy rules can still be estimated within the financial crisis but with adjusted coefficients. For instance, Yellen (2012) prescribes modified policy rules with quantitative easing and forward guidance for US monetary authorities. More recently, Ahmad (2020) has proposed that the US policy reaction rule be modified such that policy rates respond 'two-for-one' with inflation deviations. However, for the case of the SARB, whose interest rates are well above the zero lower bound, such policy prescriptions may be unwarranted for the central bank.

Nevertheless, there is still a need to explore whether the coefficients on the Taylor policy rule have been altered by the global financial crisis, and we note that previous South African studies have not endeavoured to estimate policy rules strictly for the post-crisis period. In taking advantage of the fact that the NARDL framework works well with small sample sizes, our sensitivity analysis demonstrates how estimated nonlinear policy reaction for the SARB changes across two sub-sample periods corresponding to the pre-crisis and post-crisis eras. The policy implications of these findings are discussed at the end of this paper.

Analytical Framework

Taylor (1993) proposes the following benchmark central bank policy reaction function:

$$i_t = r^* + \pi_t + f_\pi(\pi_t - \pi^*) + f_y(y_t - y^*). \tag{1}$$

Following Garcia, Restrepo, and Roger (2011), Baaziz, Labidi, and Lahiani (2013) and Caporale et al. (2018), we augment equation (1) with real exchange rates, particularly for emerging economies, i.e.

$$i_t = r^* + \pi_t + f_\pi(\pi_t - \pi^*) + f_y(y_t - y^*) + f_{rer}(rer), \tag{2}$$

where i_t is the Reserve Bank's policy rate, r^* is the equilibrium real interest rate, π_t is the inflation rate, π^* is the targeted rate of inflation, y_t is the actual level of output and y^* is the output trend such that $(\pi_t - \pi^*)$ is the inflation-gap, $(y_t - y^*)$ is the output-gap and *rer* is the real effective exchange rate. The dynamics in equations (1) and (2) reveal that when $(\pi_t > \pi^*)$ or $(y_t > y^*)$, then the economy is 'overheating' and the central bank's response, in this case, is to raise interest rates to induce a cooling effect on the economy. The so-called Taylor principle proposes that the central bank should ensure that interest rates should move at least 'one-for-one' with the inflation rate (i.e. $f_\pi > 1$), to ensure that the real interest rate is not falling, and consequently the real purchasing power of money is not deteriorated by inflation. A second condition for the Taylor principle to hold is that the response of the central bank to output gap deviations should be less than 'one-for-one' (i.e. $0 < f_y < 1$). Moreover, a positive coefficient is expected on the real exchange rate variable (i.e. $f_{rer} > 0$), indicating a strengthening (weakening) of real currency when interest rates are increased (decreased).

However, estimating linear policy rules such as those presented in equations (1) and (2) may not be flexible enough to capture realistic behaviour of central banks. Schaling (2004), Dolado, Pedrero, and Ruge-Murcia (2004) and Surico (2007) note that central banks may be concerned with high inflation as opposed to low inflation, hence creating a bias in the policymaker's reaction function. Moreover, Enders et al. (2010) note that, in practice, it is more difficult for the central banks to reduce inflation than to increase it, hence the response that the policy rate should be greater for positive values of the inflation-gap variable than for negative values. However, Orphanides and Wilcox (2002) and

Kim, Osborn, and Sensier (2005) note that the asymmetric policy preferences by central banks with moderate inflation rates may arise due to the opportunistic 'wait and see' approach to policy conduct. Under this setting, policymakers look for favourable external situations to induce disinflation when inflation exceeds its target, hence resisting the urge to act more aggressively and being prepared to counteract the return of inflation to its previous levels, once the 'gains' from the exogenous factors materialize.

Many studies have attempted to empirically incorporate asymmetries into the policy reaction function using formal nonlinear econometric frameworks. For instance, Perruchoud (2009) makes use of the Markov switching model to examine asymmetries in Taylor rules for the Swiss National Bank. The author finds that regime-switching behaviour in which the central bank adjusts its policy preferences in the presence of unexpected events and place more weight on stabilizing the exchange rate. Enders et al. (2010) propose the instrumental variables (IV) threshold cointegration tests to simultaneously address issues of endogeneity and asymmetries in the Taylor policy rule for the US economy and find monetary authorities to respond more aggressively when inflation is below its threshold compared to values above the threshold. Alcidi, Flamini, and Fracasso (2011) employ a smooth transition regression (STR) framework to model nonlinear policy reaction rules for the US, although the author identifies credit spread and interest rates as the transition variables responsible for regime changes. Caporale et al. (2018) apply the GMM estimators to the threshold autoregressive (TAR) model in estimating nonlinear policy rules for Indonesia, South Korea, Israel, Thailand and Turkey and segregate inflation into lower and higher regimes, although the authors observe differences in estimated inflation threshold points and responses of policymakers to deviations of inflation and output from their targets in both inflation regimes for the emerging countries.

As previously mentioned, our study deviates from the methodologies previously used in the literature and uses the more powerful and flexible NARDL model of Shin, Yu, and Greenwood-Nimmo (2014) to incorporate asymmetries in the SARB policy reaction function. To do this, we decompose the inflation gap variable, $(\pi_t - \pi^*)$ into partial sum processes of positive and negative changes such that equation (2) can be re-specified as the following long-run asymmetric model:

$$i_t = \alpha_0 + f_\pi^+ \pi_t^+ f_\pi^- \pi_t^- + f_y(y_t - y^*) + f_{rer}(rer) + e_t, \tag{3}$$

where π_t^+ and π_t^- are partial sum processes of positive and negative changes in $(\pi_j - \pi^*)$, respectively, defined as:

$$\pi_t^+ = \sum_{j=1}^{i} \Delta\pi_j^+ = \sum_{j=1}^{i} \max(\Delta(\pi_t - \pi^*), 0), \tag{4}$$

$$\pi_t^- = \sum_{j=1}^{i} \Delta\pi_j^- = \sum_{j=1}^{i} \max(\Delta(\pi_t - \pi^*), 0). \tag{5}$$

Note that from the partial sum processes, various forms of asymmetries can be identified. For instance, if $f_\pi^+ > f_\pi^-$, then policymakers place a higher weight on rising inflation as opposed to disinflation episodes, hence reflecting a conservative central bank. Conversely, if $f_\pi^+ < f_\pi^-$, then policymakers place less weight on rising inflation and this is 'somewhat' consistent with an 'opportunistic' central bank. Moreover, the partial sum processes can identify opportunistic policymakers who satisfy the Taylor principle (i.e. $f_\pi^+ < f_\pi^-, f_\pi^+ > 1, f_\pi^- > 1$) or conservative monetary policymakers who satisfy the Taylor principle (i.e. $f_\pi^+ > f_\pi^-, f_\pi^+ > 1, f_\pi^- > 1$).

The NARDL (p, q)-in-levels transformation of regression (3) can be specified as:

$$i_t = \sum_{j=1}^{p} \phi_i i_{t-j} + \sum_{j=1}^{p} (\theta_j^+ \pi_{t-j}^+ + \theta_j^- \pi_{t-j}^-) + \sum_{j=1}^{p-1} \gamma_i \Delta y_{t-j} + \sum_{j=1}^{p-1} \lambda_i \Delta rer_{t-j} + \zeta_t, \tag{6}$$

where ϕ_i is the autoregressive parameter, θ_j^+ and θ_j^- are the asymmetric distributive-lag parameters and ζ_t is a well-behaved error with properties $N \sim (0, \sigma^2)$. From equation (6), the unrestricted error correction representation can be expressed as:

$$\Delta i_t = \sum_{j=1}^{p-1} \lambda_i \Delta i_{t-j} + \sum_{j=0}^{q-1} (\alpha_j^+ \Delta\pi_{t-j}^+ + \alpha_j^- \Delta_{t-j}^-) + \sum_{j=1}^{p-1} \sigma_i \Delta y_{t-j} + \sum_{j=1}^{p-1} \psi_i \Delta rer_{t-j} + \Omega\xi_{t-j} + \zeta_t, \tag{7}$$

where $\xi_{t-j} = i_t - \theta_j^+ \pi_{t-j}^{e+} - \theta_j^- \pi_{t-j}^{e-}$ is the asymmetric error correction term (ECT) and the asymmetric long-run parameters are computed as

$f_\pi^+ = -(\theta^+/\rho)$ and $f_\pi^- = -(\theta^-/\rho)$. Shin, Yu, and Greenwood-Nimmo (2014) note that the NARDL model encompasses four types of nonlinearity from which the authors propose various tests procedures to verify the difference forms of nonlinearities. Firstly, there is the generalized asymmetric cointegration effect which is analogous to the bounds test for cointegration presented in Pesaran, Shin, and Smith (2001). This asymmetric version of a bounds test for cointegration is an F-test of the joint null hypothesis, $\rho = \theta^+ = \theta^- = \gamma = \lambda = 0$, and the statistic used in testing this form of asymmetry is denoted F_{PSS}. Secondly, there are equilibrium adjustment asymmetries which are analogous to the test for significance of error correction mechanism found in Banerjee et al. (1998). This latter test uses a t-statistic which tests the null hypothesis $\rho = 0$ against the alternative $\rho < 0$. Thirdly, there is the Wald test evaluating the null hypotheses of long-run or reaction asymmetry, which evaluates the null hypotheses ($H^S_{\mathrm{LR}}: f_\pi^+ = f_\pi^-$) using a test statistic denoted W_{LR}. Lastly, there is the Wald test for short-run asymmetries, which evaluates the null hypotheses ($H^S_{\mathrm{SR}}: \alpha_j^+ = \alpha_j^-$) using a test statistic denoted as W_{SR}.

Data and Empirical Findings

DATA DESCRIPTION

The data used in the study has all been retrieved from the SARB online database, and has been captured on a quarterly frequency over the period of 2002:q1 to 2021:q4. Our main independent variable is the repo rate, which has been the SARB's official policy rate since 1998. Our main independent variable is the inflation-gap variable, which, in following Bold and Harris (2018), is constructed by subtracting inflation, π_t, from the mid-point of the SARB 3–6 target, i.e. $\pi^* = 4.5$. Our study makes use of 7 classifications of inflation in constructing the gap variable, these being total CPI, total goods, total services, all expectations (12-month forecast), financial expectations (12-month forecast), business expectations (12-month forecast) and trade union expectations (12-month forecast). Note that the employed expectation series come courtesy of the Bureau of Economic Research quarterly survey which they have been carrying out since 2002 (see Miyajima and Yetman (2019) for a more detailed discussion on the surveys). To construct the output-gap variable we take heed of previous South African literature and extract the cyclical component of the HP filter applied to the GDP growth rate (i.e. $\lambda = 1600$). Also, following the previous studies of Naraidoo and Gupta (2010) as well as Baaziz, Labidi, and Lahiani (2013), we include the real effective exchange rate to account for openness in the reaction function.

EMPIRICAL RESULTS

Table 1 presents the empirical findings from NARDL regression estimates, which induces long-run and short-run asymmetries by partitioning the inflation-gap variable into two components, the first measuring the deviations from the inflation target during periods of rising inflation (i.e. f_π^+) and the second measuring deviations during periods of falling inflation (i.e. f_π^-). Note that this differs from the conventional linear estimates which assume that policymakers have the same response to inflation deviations regardless of whether inflation is rising or falling. Further note, that under the NARDL set-up we can more appropriately evaluate whether the SARB has been able to protect the purchasing power of citizens by ensuring that the real interest rate remains positive (Nikolsko-Rzhevskyy, Papell, and Prodan 2019). For this to be proven true, the partitioned coefficients satisfy the condition $f_\pi^+ > 1$ and $0 < f_\pi^- < 1$, such that the nominal interest rate remains higher than inflation during both periods of rising and falling inflation, respectively, and the real interest rate is never decreasing. The reported F_{SYG} statistics, which are the nonlinear counterpart of the conventional bounds test statistic of Pesaran, Shin, and Smith (2001), indicates that all regressions can be modelled using NARDL specifications.

Nonetheless, to confirm the significance of long-run NARDL effects, the computed W_{LR} statistic is required to reject the null hypothesis of

TABLE 1 Full Sample: NARDL

Item	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Lag	NARDL (1,0,0,0,0)	NARDL (3,1,4,3,3)	NARDL (3,2,1,1,3)	NARDL (3,2,1,1,3)	NARDL (2,0,0,0,2)	NARDL (2,2,1,0,2)	NARDL (2,2,0,0,2)
f_π^+	0.39***	0.97**	−0.51**	−0.65	−0.17	−0.52	−0.70
	(0.12)	(3.78)	(0.18)	(0.53)	(0.29)	(0.38)	(0.58)
f_π^-	0.44***	0.99**	−0.35*	−0.46	0.01	−0.28	−0.47
	(0.12)	(3.78)	(0.18)	(0.62)	(0.30)	(0.41)	(0.66)
f_y	0.64***	0.58***	0.86***	0.64***	0.66***	0.69***	0.79***
	(0.17)	(0.14)	(0.25)	(0.17)	(0.19)	(0.24)	(0.22)
f_{er}	0.001	0.51**	0.09	0.21**	0.09	0.13	0.15
	(0.07)	(0.21)	(0.21)	(0.09)	(0.12)	(0.12)	(0.13)

Continued on the next page

TABLE 1 *Continued from the previous page*

Item	(1)	(2)	(3)	(4)	(5)	(6)	(7)
$\Delta repo(-1)$		0.40***	0.46***	0.45***	0.52***	0.50	0.46**
		(0.11)	(0.12)	(0.07)	(0.07)	(0.08)	(0.08)
$\Delta repo(-2)$		0.28**	0.11				
		(0.10)	(0.10)				
Δf_π^+		0.03	−0.002	−0.02		−0.07	−0.005
		(0.02)	(0.03)	(0.12)		[0.11)	(0.11)
$\Delta f_\pi^+(-1)$			0.05	0.41***		0.28**	0.17
			(0.03)	(0.13)		(0.12)	(0.12)
Δf_π^-		0.06	−0.009			−0.17*	
		(002)***	(0.03)			(0.09)	
$\Delta f_\pi^-(-1)$		−0.05***					
		(0.01)					
$\Delta f_\pi^-(-2)$		−0.02					
		(0.01)					
$\Delta f_\pi^-(-3)$		0.03***					
		(0.01)					
Δf_y		0.02	0.09***				
		(0.02)	(0.01)				
$\Delta f_y(-1)$		0.06***					
		(0.02)					
$\Delta f_y(-2)$		0.04*					
		(0.02)					
Δf_{er}		0.02**	0.006	0.01*	−0.002	−0.007	−0.02***
		(0.007)	(0.007)	(0.006)	(0.006)	(0.006)	(0.006)
$\Delta f_{er}(-1)$		-0.03***	−0.02**	−0.02***	−0.02***	−0.02***	
		(0.008)	(0.007)	(0.006)	(0.005)	(0.0006)	
$\Delta f_{er}(-2)$		−0.01*	0.002				
		(0.006)	(0.007)				
$ect(-1)$	−0.15***	−0.09***	−0.14***	−0.13***	−0.13***	−0.13***	−0.11***
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)

Continued on the next page

$f_\pi^+ = f_\pi^-$, which in our case only holds for total CPI (eq. 1), total goods (eq. 2), total services (eq. 3) and financial expectations (eq. 5). In narrowing down these findings, the NARDL long-run coefficients confirm the Taylor principle only for total goods inflation as both f_π^+ and f_π^- coefficients produce statistically significant estimates of 0.97 and 0.99 respectively, which are very close to unity, whereas both estimates are greater than

TABLE 1 *Continued from the previous page*

Item	(1)	(2)	(3)	(4)	(5)	(6)	(7)
F_{SYG}	15.17***	3.09***	5.33***	10.64***	9.88***	9.74***	8.34***
W_{LR}	5. 12**	4.16**	7.11***	1.23	5.90***	2.67	1.26
W_{SR}	7.60***	3.54*	2.84	1.06	3.46*	1.83	0.95
χ^2_{NOR}	2.46	39.53***	67.84***	78.59***	31.99***	61.23***	73.33***
	(0.29)	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]
χ^2_{SC}	14.08***	0.31	2.97*	0.34	0.48	0.10	0.16
	[0.00]	[0.73]	[0.06]	[0.71]	[0.62]	[0.91]	[0.85]
χ^2_{HET}	1.78	0.17	0.12	0.08	0.48	0.07	0.04
	[0.29]	[0.68]	[0.73]	[0.77]	[0.49]	[0.80]	[0.85]
χ^2_{FF}	1.17	1.04	1.44***	8.88***	4.70***	2.55*	7.26***
	[0.25]	[0.30]	[0.00]	[0.00]	[0.00]	[0.08]	[0.00]

NOTES Equations: (1) total CPI, (2) total goods, (3) total services, (4) all expectations, (5) financial expectations, (6) business expectations, (7) trade unions expectations. ***, ** and * denote 1%, 5% and 10% critical values, respectively. Standard errors of the estimates are reported in parentheses. *P*-values on diagnostic tests reported in square brackets. Optimal lag length of NARDL models are determined by the modified Schwarz criterion.

the estimate on the output gap variable. We also note positive and statistically significant estimates on the partitioned inflation-gap variable for total CPI, although the estimated coefficients of 0.39 and 0.44 for negative and positive partitions, respectively, are both 'lower-than unity' and lower in value compared to the output-gap coefficient estimate. Moreover, we note that for both total CPI and total goods regressions, $f_\pi^+ < f_\pi^-$, implying that the central bank responds more (less) aggressively to decreasing (increasing) periods of inflation, and, in this instance, we conclude for the opportunistic approach of the SARB to monetary policy as advocated by Kasa and Naraidoo (2013).

However, we also observe that the NARDL methodology fails to fit appropriate nonlinear long-run Taylor rules for services inflation (eq. 3) and different categories of inflation expectations (equations 4–7). Whilst, for the case of services inflation, the WLR statistic validates long-run asymmetries, we oddly observe negative and statistically significant estimates on the partitioned inflation-gap variable, with a higher (lower) absolute value being found for positive (negative) partitions. By interpretation this implies the SARB acts in a 'pro-inflationary' manner towards the services sectors by acting more (less) aggressively during rising (falling) periods of inflation deviations. Concerning the different classes of inflation expectations, both negative and positive partitions produce insignificant coefficient estimates. Altogether, the observed response of the SARB towards the services sector and the expectations of different economic agents is counterintuitive to the expected policy reaction function of inflation-targeters.

We also observe that whilst the W_{SR} statistics testing for short-run asymmetries produce significant estimates which reject the null hypothesis of no short-run nonlinearities at a 5% critical level in eq. 1 (total CPI), eq. 2 (total goods) and eq. 5 (financial expectations), the corresponding regression estimates are either insignificant or inconclusive. Moreover, the ECT produce their expected negative and statistically significant estimates, and the speed of reversion back equilibrium following a shock produces values ranging from −0.11 to −0.15, implying 11% to 15% correction of disequilibrium every quarter. Finally, the diagnostic tests fail to find evidence of serial correlation or heteroscedasticity for most estimated regressions, although we do observe instances where the regressions fail to pass the tests for incorrect functional form. As highlighted by Rudebusch (2005), Perruchoud (2009) and Huber (2017), unaccounted structural breaks in the Taylor rule renders the specification prone to the Lucas critique and hence increases the probability of specifying incorrect Taylor policy rules. Whilst previous studies have focused on different monetary policy regimes as the source of structural breaks in policy function, our study considers the global financial crisis as a more appropriate structural break, taking into account that our time-series data strictly corresponds to the singular monetary regime.

SENSITIVITY ANALYSIS

In line with Caporale et al. (2018), we identify the global financial crisis of 2007–2008 as the structural break in our times series. Therefore, in this section of the paper we perform a sensitivity analysis which entails segregating the data into pre-crisis (2002:q1–2008:q3) and post-crisis (2008:q4–2020:q4) periods.

Table 2 presents the NARDL estimates for the pre-crisis periods and, judging from the *F*-test for bounds cointegration and Wald test for long-run asymmetries, as well as the significance and sign of the coefficient estimates, we can fit significant nonlinear Taylor rules for 5 out of the 7 estimated regressions (i.e. total CPI, total services, all expectations, financial expectations, trade union expectations), although the nonlinear dynamics differ amongst the different inflation measures. For instance,

TABLE 2 Pre-Crisis: NARDL

Item	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Lag	NARDL (1,0,1,0,1)	NARDL (1,0,0,0,1)	NARDL (3,1,3,3,3)	NARDL (3,3,0,3,3)	NARDL (1,0,0,1,1)	NARDL (1,1,0,1,1)	NARDL (1,1,0,1,1)
f_π^+	0.27***	−0.05	0.45***	1.05***	−0.02	0.14	0.24
	(0.06)	(0.24)	(0.09)	(0.09)	(0.22)	(0.20)	(0.17)
f_π^-	0.33***	0.04	0.95***	1.39***	0.34	0.45**	0.49**
	(0.07)	(0.24)	(0.14)	(0.29)	(0.21)	(0.19)	(0.18)
f_y	0.50**	1.23*	1.04***	−0.19	0.32***	0.58***	0.51***
	(0.21)	(0.64)	(0.13)	(0.19)	(0.22)	(0.16)	(0.13)
f_{rer}	−0.35	−0.75	0.75***	−0.23*	−0.17	−0.12	−0.07
	(0.31)	(0.58)	(0.14)	(0.11)	(0.13)	(0.11)	(0.08)

Continued on the next page

we only validate the Taylor principle for all inflation expectations (eq. 4), which is the sole regression satisfying the condition $f_\pi^+ > 1, f_\pi^- > 1$. Moreover, for total CPI (eq. 1), total services (eq. 3) and all expectations (eq. 4), we find that policymakers respond more (less) aggressively during periods of decreasing (increasing) inflation (i.e. $f_\pi^+ < f_\pi^-$), which indicates an opportunistic approach to monetary policy. We also find positive and significant coefficient estimates on the negative partitions on the inflation expectation variable of the business sector (eq. 6) and trade unions (eq. 7) whilst the positive partitions produce insignificant estimates. This latter finding implies that during the pre-crisis, the Central Bank has only responded to inflation deviations of business and trade union expectations during periods of falling inflation, which also describes the opportunistic behaviour of the central bank.

Table 3 presents the NARDL estimates for the post-crisis period and, based on the F-test for bounds cointegration and Wald test for long-run asymmetries, as well as the significance and sign of the coefficient estimates, we can only fit significant nonlinear Taylor rules for 2 out of the estimated 7 regressions, i.e. total CPI (eq. 1) and business expectations (eq. 6). Out of these two regressions, only business expectations satisfies the Taylor principle during periods of rising inflation, since $f_\pi^+ > 1$, although we note that during periods of disinflation, the Reserve Bank is unresponsive. These dynamics correspond to a conservative approach conduct of monetary policy. Similarly, for total CPI, we find that policymakers have responded more (less) aggressively towards inflation deviations during periods of rising (falling) inflation, which is different from

TABLE 2 *Continued from the previous page*

Item	(1)	(2)	(3)	(4)	(5)	(6)	(7)
$\Delta i(-1)$			−0.15	−0.70**			
			(0.12)	(0.18)			
$\Delta i(-2)$			0.77***	0.72***			
			(0.10)	(0.11)			
Δf_{π}^{+}			0.02	0.70***		−0.19*	−0.24**
			(0.02)	(0.14)		(0.09)	(0.09)
$\Delta f_{\pi}^{+}(-1)$				−1.31***			
				(0.21)			
$\Delta f_{\pi}^{+}(-2)$				−0.58**			
				(0.16)			
Δf_{π}^{-}	0.10***		−0.41***				
	(0.02)		(0.05)				
$\Delta f_{\pi}^{-}(-1)$			0.30***				
			(0.04)				
$\Delta f_{\pi}^{-}(-2)$			0.14***				
			(0.02)				
Δf_{y}			−0.05**	0.06***	0.10***	0.11***	0.10***
			(0.02)	(0.01)	(0.02)	(0.01)	(0.01)
$\Delta f_{y}(-1)$			0.22***	0.15***			
			(0.03)	(0.02)			
$\Delta f_{y}(-2)$			0.15***	0.22***			
			(0.02)	(0.03)			
Δf_{rer}	−0.01	−0.03***	−0.15***	−0.06***	−0.01	−0.01	0.001
	(0.009)	(0.01)	(0.02)	(0.01)	(0.008)	(0.008)	(0.008)
$\Delta f_{rer}(-1)$			0.16***	0.11***			
			(0.02)	(0.02)			
$\Delta f_{rer}(-2)$			0.13***	0.08***			
			(0.02)	(0.01)			
$ect(-1)$	−0.16***	−0.10***	−0.48***	−0.80***	−0.29***	−0.35***	−0.41***
	(0.02)	(0.01)	(0.06)	(0.12)	(0.02)	(0.03)	(0.03)

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the results obtained for the pre-crisis and full sample estimates, and yet these dynamics correspond with the conservative approach to monetary policy. For the remaining classifications of inflation, the coefficient on the inflation gap variable either produces negative and significant (services inflation) or insignificant (i.e. total goods, all expectations, financial expectations, business expectations, trade union expectations) estimates.

TABLE 2 *Continued from the previous page*

Item	(1)	(2)	(3)	(4)	(5)	(6)	(7)
F_{SYG}	14.04***	1186***	4.36***	3.97***	8.30***	7.34***	18.56***
W_{LR}	12.51***	5.87***	35.48***	3.71**	3.25*	1.83	1.68
W_{SR}	6.54***	4.51**	7.16***	1.85	1.56	0.98	0.56
χ^2_{NOR}	0.56	1.29	0.86	0.04	1.44	1.09	1.47
	[0.75]	[0.53]	[0.65]	[0.98]	[0.49]	[0.58]	[0.48]
χ^2_{SC}	0.48	0.23	1.64	2.57	0.13	0.02	0.23
	[0.63]	[0.80]	[0.38]	[0.22]	[0.88]	(0.98)	[0.79]
χ^2_{HET}	2.22	1.81	0.91	0.20	0.68	2.31	0.05
	[0.15]	[0.15]	[0.35]	[0.66]	[0.69]	(0.14)	[0.83]
χ^2_{FF}	0.34	1.08	2.15	1.02	0.31	0.82	1.25
	[0.74]	[0.29]	[0.12]	[0.37]	[0.76]	(0.43)	[0.23]

NOTES Equations: (1) total CPI, (2) total goods, (3) total services, (4) all expectations, (5) financial expectations, (6) business expectations, (7) trade unions expectations. ***, ** and * denote 1%, 5% and 10% critical values, respectively. Standard errors of the estimates are reported in parentheses. *P*-values on diagnostic tests reported in square brackets. Optimal lag length of NARDL models are determined by the modified Schwarz criterion.

TABLE 3 Post-Crisis: NARDL

Item	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Lag	NARDL	NARDL	NARDL	NARDL	NARDL	NARDL	NARDL
	(1,1,1,0,0)	(2,1,2,0,3)	(3,1,0,2,3)	(2,0,0,2,3)	(2,0,0,2,3)	(4,1,3,4,4)	(2,0,0,2,3)
f_π^+	0.74***	0.14	−0.61*	0.25	0.10	1.19*	0.48
	(0.17)	(0.18)	(0.29)	(0.59)	(0.50)	(0.60)	(0.73)
f_π^-	0.68***	0.12	−0.61**	−0.20	−0.13	0.48	0.03
	(0.15)	(0.18)	(0.26)	(0.53)	(0.47)	(0.43)	(0.58)
f_y	0.58**	0.89***	1.42***	1.38***	1.33***	0.82*	1.19***
	(0.23)	(0.30)	(0.24)	(0.46)	(0.48)	(0.39)	(0.34)
f_{rer}	0.08	0.40***	0.50***	0.42***	0.41***	0.40***	0.38***
	(0.06)	(0.08)	(0.11)	(0.14)	(0.14)	(0.12)	(0.09)

Continued on the next page

Moreover, we observe that whilst the exchange rate variable has been predominantly insignificant during the pre-crisis period, the variable turns positive and statically significant for most regressions in the post-crisis.

Conclusion

The South African constitution mandates to the Reserve Bank the sole responsibility of protecting the value of the Rand currency against the

TABLE 3 *Continued from the previous page*

Item	(1)	(2)	(3)	(4)	(5)	(6)	(7)
$\Delta repo(-1)$		0.56***	0.39***	0.50***	0.50***	0.35**	0.50***
		(0.07)	(0.11)	(0.08)	(0.09)	(0.13)	(0.09)
$\Delta repo(-2)$			0.23*			0.21	
			(0.13)			(0.20)	
$\Delta repo(-3)$						0.51***	
						(0.21)	
Δf_{π}^{+}	0.08**	−0.02*	−0.20***			−0.09	
	(0.03)	(0.009)	(0.04)			(0.22)	
Δf_{π}^{-}	0.07***	0.02*				−0.36**	
	(0.02)	(0.01)				(0.14)	
$\Delta f_{\pi}^{-}(-1)$		−0.04***				−0.37**	
		(.001)				(0.14)	
$\Delta f_{\pi}^{-}(-2)$						−0.30**	
						(0.14)	
Δf_{y}			0.13***	0.12***	0.12***	0.13***	0.12***
			(0.01)	(0.02)	(0.02)	(0.02)	(0.02)
$\Delta f_{y}(-1)$			−0.05**	−0.05**	−0.05**	−0.001	−0.04**
			(0.02)	(0.02)	(0.02)	(0.03)	(0.02)
$\Delta f_{y}(-2)$						0.05*	
						(0.02)	
$\Delta f_{y}(-3)$						0.05***	
						(0.01)	
Δf_{rer}		0.02***	0.02***	0.01*	0.01*	0.02***	0.01*
		(0.006)	(0.006)	(0.007)	(0.007)	(0.007)	(0.006)
$\Delta f_{rer}(-1)$		−0.04***	−0.04***	−0.04***	−0.04***	−0.07***	−0.04***
		(0.007)	(0.007)	(0.008)	(0.008)	(0.02)	(0.008)
$\Delta f_{rer}(-2)$		−0.02***	−0.02***	−0.02**	−0.02**	−0.04**	−0.02**
		(0.006)	(0.006)	(0.007)	(0.007)	(0.01)	(0.007)
$ect(-1)$	−0.19***	−0.13***	−0.15***	−0.14***	−0.14***	−0.02*	−0.15***
	(0.02)	(0.02)	(0.02)	(0.03)	(0.02)	(0.009)	(0.03)

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eroding effects of inflation in the interest of promoting financial stability and sustained growth. Our study provides a re-examination of Taylor's principle for the South African economy for the post-inflation targeting era of 2002:q1 to 2021:q4 as a means of evaluating whether the Reserve Bank has been successful in protecting the purchasing power of currency against inflation. Our empirical analysis differs from those of previous studies in three ways. Firstly, we employ an array of inflation and infla-

TABLE 3 *Continued from the previous page*

Item	(1)	(2)	(3)	(4)	(5)	(6)	(7)
F_{SYG}	10.04***	8.07***	6.09***	5.35***	5.28***	3.97***	5.37***
L_{LR}	6.14***	3.08*	3.16***	2.42	6.36***	3.48*	4.89***
L_{SR}	4.95***	1.52	2.12	0.89	3.91**	1.86	2.74
χ^2_{NOR}	3.88	2.89	4.02	4.53	1.33	1.80	1.36
	[0.16]	[0.24]	[0.13]	[0.10]	[0.52]	[0.36]	[0.53]
χ^2_{SC}	8.95***	0.83	0.58	0.43	0.52	.95	0.37
	[0.00]	[0.45]	[0.57]	[0.65]	[0.60]	[0.40]	[0.70]
χ^2_{HET}	2.48	0.001	0.05	0.12	0.13	0.41	0.15
	[0.12]	[0.97]	[0.82]	[0.73]	[0.72]	[0.53]	[0.70]
χ^2_{FF}	1.09	0.06	0.66	0.26	0.21	0.31	0.37
	[0.28]	[0.95]	[0.42]	[0.80]	[0.84]	[0.58]	[0.72]

NOTES Equations: (1) total CPI, (2) total goods, (3) total services, (4) all expectations, (5) financial expectations, (6) business expectations, (7) trade unions expectations. ***, ** and * denote 1%, 5% and 10% critical values, respectively. Standard errors of the estimates are reported in parentheses. *P*-values on diagnostic tests reported in square brackets. Optimal lag length of NARDL models are determined by the modified Schwarz criterion.

tion expectations classifications in constructing the inflation-gap variable in the policy reaction function. Secondly, we estimate the policy reaction function using the NARDL framework, which is flexible enough to capture different forms of asymmetric policy preferences. Lastly, we provide a sensitivity analysis in which we split our empirical data into two subsamples corresponding to the pre-crisis periods and post-crisis periods.

Our baseline NARDL estimates reveal that the Taylor principle is confirmed for the total goods inflation, although the observed nonlinear dynamics emulate that of an opportunistic central bank. However, in performing our sensitivity analysis, we find stark differences between the pre-crisis and post-crisis eras. For instance, the NARDL estimates show that in the pre-crisis era the Taylor principle was fulfilled when all inflation expectations are used to compute the inflation gap, hence providing evidence of a forward-looking Taylor policy rule. Conversely, in the post-crisis era, the Taylor rule is solely satisfied for business expectations, during periods when inflation is increasing. Moreover, our results show that the central bank's behaviour has changed from being opportunistic in the pre-crisis era to being conservative in the post-crisis era and only in the post-crisis period does the real exchange rate significantly enter the policy reaction.

All in all, when taking into account asymmetries and structural breaks, we find that that the Taylor principle has been fulfilled in the forward-looking Taylor specifications in both the pre-crisis and post-crisis period, with the SARB providing appropriate policy responses to all inflation expectations during periods of falling and rising inflation during the pre-crisis era and for business sector expectations during periods of rising inflation in the post-crisis era. This implies that the SARB's scope of protecting the economic units' purchasing power has narrowed in the post-crisis period, with the reaction function placing more weight on the business sector expectations.

Considering that the structural breaks were incorporated into the estimation process in an arbitrary manner, an avenue for future research would be to examine the Taylor principle, making use of econometric models which can simultaneously account for time-varying and asymmetric adjustments dynamics within the Taylor rule.

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