

# Inflation, Output and Monetary Policy in South Africa

Harold Ngalawa  
and  
Coretha Komba

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# Inflation, Output and Monetary Policy in South Africa

By

Harold Ngalawa<sup>1</sup>

School of Accounting, Economics and Finance,  
University of KwaZulu Natal, Westville Campus, South Africa

and

Coretha Ngalawa<sup>2</sup>

Mzumbe University, Dar es Salaam Campus College,  
Dar es Salaam, Tanzania

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# Abstract

South Africa adopted inflation targeting as its monetary policy framework in February 2000. The country's monetary authorities, however, have struggled to keep inflation within the targeted 3%-6% band. A review of the literature reveals that an understanding of the inflation-output trade-off is essential for the achievement of price stability. The effects of policy may be different depending on whether the inflation-output trade-off is symmetric or asymmetric; and when it is asymmetric, the outcome may vary contingent on whether the asymmetry is convex or concave. In South Africa, the nature of this relationship is not known. Estimation of the inflation-expectations augmented Phillips curve using the difference Generalized Method of Moments on quarterly time series data for the period 2000:3 to 2015:1 reveals that South Africa's Phillips curve is concave asymmetric. These estimation results, however, may not be policy-invariant because they are obtained from "highly" aggregated historical data and the model parameters are not structural. Consistent with the Lucas Critique, we formulate a New Keynesian dynamic stochastic general equilibrium model calibrated on South African data. Simulation results of the model show that a negative demand shock reduces inflation and output while a positive demand shock of the same magnitude leads to a smaller increase in inflation and a larger increase in output, confirming the concave asymmetric inflation-output relationship found earlier. Concavity of the Phillip's curve implies declining sensitivity of inflation to the strength of the economy, suggesting that any given change in inflation requires an increasingly larger adjustment in output.

**Keywords:** *Phillips curve, inflation-output trade-off*

JEL Classification: E52, E58



# 1. Introduction

South Africa experienced a period of high and volatile inflation in the 1970s and 1980s when the rate of inflation rose from 6.00% in 1970 to 18.52% in 1985, the highest since 1958. Following a period of reforms recommended by a special commission of inquiry into the country's monetary system and monetary policy, popularly known as the De Kock Commission, South Africa managed to bring down the rate of inflation to 2.24% in 1998. Eager to keep inflation low, the country adopted inflation targeting as a monetary policy framework in February 2000 and specified 3%-6% as the target range of inflation. The primary element of inflation targeting is a public commitment by the Central Bank of South Africa to achieve an explicit numerical inflation target (Bernanke and Woodford, 2006). During the period 2000-2013, however, annual inflation in the country was recorded outside the targeted band in nine out of the 14 years, clearly indicating that the South African Reserve Bank (SARB) has not succeeded in keeping inflation within target.<sup>1</sup>

In carrying out its mandate, the SARB is also expected to aim at output stability. It is stipulated in the country's 1996 constitution that the primary objective of the bank is to protect the value of the local currency in the "interest of balanced and sustainable growth" (Casteleijn, 2015). Since monetary policy responses to shocks induce price level surprises, immediately creating a conflict between the output and inflation stability objectives (Cecchetti and Kim, 2006), it is important that the SARB understands the nature of this relationship to achieve its inflation and output goals. The primary objective of this study, therefore, is to investigate the relationship between inflation and output responses to monetary policy in South Africa. The findings are expected to enhance understanding of the monetary policy framework in the country and to guide the SARB on how to keep inflation within the targeted band.

Monetary authorities may be slow or quick in response to an aggregate demand shock, contingent on whether they regard it as temporary or permanent. In either case, the effects of policy may be different if the inflation-output trade-off is symmetric or asymmetric. In a symmetric relationship, prices respond similarly to positive and negative shocks (Ball and Mankiw, 1994). Conducting monetary policy symmetrically, therefore, suggests responding in an equal measure to excess demand and excess supply (Razzak, 1997; Laxton, Rose and Tetlon, 1993). With an asymmetric inflation-output trade-off, the outcome may not be the same in the event of a positive demand shock as in the case of a negative demand shock of the same magnitude depending

on whether the asymmetry is convex or concave. In a convex asymmetric relationship, the inflationary effects of a positive demand shock will be larger than the deflationary effects of a negative demand shock of similar magnitude. In a concave asymmetric relationship, a positive demand shock will increase inflation by a smaller margin than a negative demand shock of similar magnitude will decrease it.

Clearly, policy makers need to react promptly when the economy shows signs of strengthening rather than weakening if the asymmetric trade-off is convex. A policy that is slow to respond to positive demand shocks will result in higher inflation and greater losses in output than would be the case with a linear relationship (Razzak, 1997). In contrast, if the inflation-output trade-off is concave asymmetric, policy makers need to react promptly when the economy shows signs of weakening rather than strengthening (Nell, 2006).

Whether the relationship between inflation and output is symmetric or asymmetric is an outstanding debate in the literature. Gordon (1997) found a symmetric relationship for the United States (US), and Nell (2006) also found a symmetric relationship for South Africa during the period 1971-1984. Laxton, Rose and Tambakis (1999), however, found a convex asymmetric relationship for the US and Razzak (1997) came up with similar results for New Zealand. Underscoring the depth of the debate, Stiglitz (1997) argued that the inflation-output trade-off in the US is asymmetric concave. Eisner (1997) found similar results, also for the US and Nell (2006) showed that the relationship in South Africa changed to asymmetric concave for the period 1986-2001 from a symmetric relationship during the period 1971-1984.

There are several studies on monetary policy generally in South Africa. Woglom (2003) attempted to gather evidence on whether the country's inflation targeting has affected the conduct of monetary policy and whether inflation targeting has made monetary policy more predictable or transparent. Aron and Muellbauer (2005) examined the monetary policy experience of South Africa's inflation targeting regime, and Aron and Muellbauer (2008) investigated monetary policy in a more open South Africa following the country's integration in the world economy from the 1990s after many years of isolation, and the country's consequent adoption of inflation targeting as a monetary policy framework. In addition, a few other studies have attempted to analyse the South African economy using a dynamic stochastic general equilibrium framework. These include studies by Alpanda, Kotze and Woglom (2011), Steinbach, Mathuloe and Smit (2009) and Liu and Gupta (2007). However, none of these has studied the symmetric/asymmetric relationship between inflation and output in South Africa, apart from Nell (2006).

Nell (2006) found a symmetric inflation-output trade-off for the period 1971-1984 (dominated by a liquid asset ratio-based system with quantitative controls over interest rates and credit) and an asymmetric concave relationship for the period 1986-2001 (dominated by a cost of cash reserves-based system with pre-announced monetary targets (M3)). With different studies arguing for convexity, concavity and linearity, and the only South African study suggesting that the relationship in the country was symmetric in one period dominated by a particular monetary policy

framework, and asymmetric concave in another period dominated by a different monetary policy framework, it is clear that the literature, and certainly Nell's (2006) study, is not adequately informative for policy during the inflation targeting period in South Africa. This paper, therefore, contributes to the literature by investigating the inflation-output trade-off in the country during the inflation-targeting period with the aim of determining whether the relationship is symmetric or asymmetric, and in the case of the latter, whether it is convex or concave. Furthermore, studies that use dynamic stochastic general equilibrium (DSGE) models to establish how inflation and output in South Africa are related are hard to find. Therefore, this study contributes to the extant literature by analysing how the two variables evolve within a DSGE model, given certain shocks.

The rest of the paper is organized as follows. Section 2 is a brief overview of monetary policy, inflation and output growth in South Africa. This is followed by a discussion of related literature in Section 3. The methodology in Section 4 presents a variant of the expectations-augmented Phillips curve, which is used to investigate the asymmetry hypothesis; and a dynamic stochastic general equilibrium model for further analysis. Findings of the study are presented in Section 5. A summary and conclusion conclude the paper in Section 6.

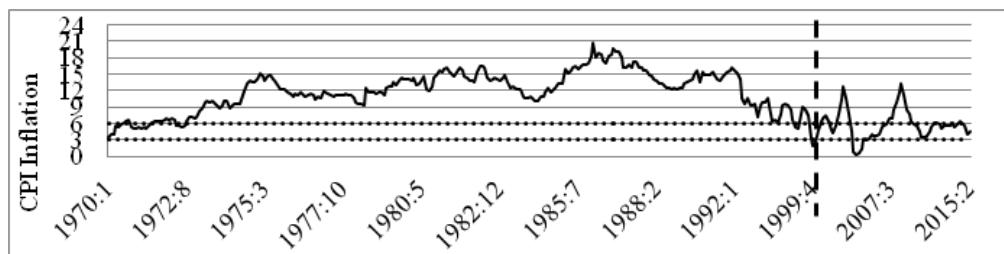
## 2. Monetary policy, inflation and output growth in South Africa

The primary objective of monetary policy in South Africa is to achieve price stability. Consistent with this objective, the country adopted inflation targeting as a framework for monetary policy in February 2000. Between 1960 and 1998, the country's monetary policy framework included exchange rate targeting, discretionary monetary policy, monetary aggregate targeting and an eclectic approach (Van der Merwe, 2004).

Inflation targeting is a monetary policy approach in which the central bank makes public an explicit inflation target and implements policy to achieve the specified target. The targeted inflation can be a point as in the cases of Brazil (4.5%), Chile (3%) and Poland (2.5%), or a range as in the cases of Australia (2%-3%), New Zealand (1-3%) and South Africa (3%-6%), among others. In an inflation targeting regime, the central bank is also expected to provide the public with regular updates on monetary policies being implemented and the direction of the fundamentals.

Inflation in South Africa rose from 5.30% in 1970 to 18.70% in 1986, the highest since 1958. Thereafter, it started falling but remained above 6.00% until January 1998 when it reached 5.47%. In February 2000, when the country adopted inflation targeting, the rate of inflation was 4.93% (within the band), up from 2.80% in January 2000. In March 2000, the rate of inflation went above the band to 6.50% and fluctuated above the band until January 2001 when it dropped to 4.77%. Since the adoption of inflation targeting in February 2000, the rate of inflation has been fluctuating in and outside the band (Figure 1).

Figure 1: Inflation in South Africa

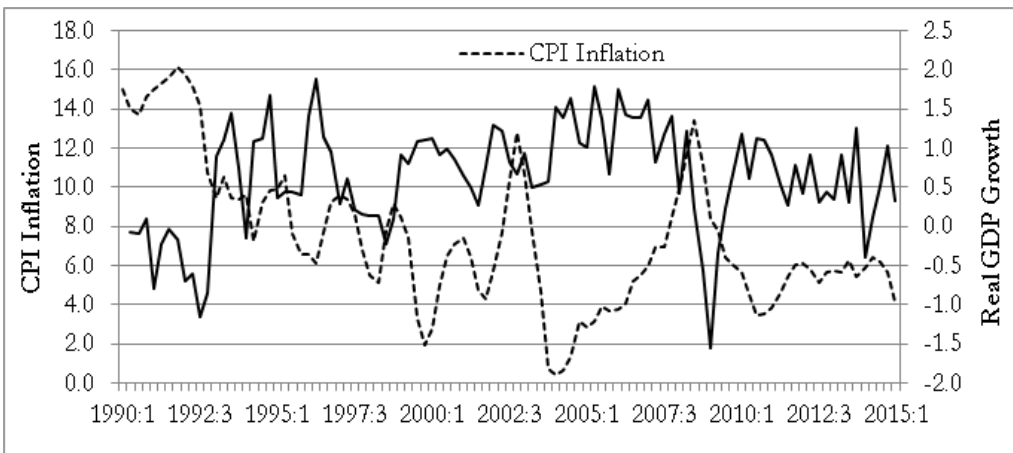


Source: Statistics South Africa

The rate of inflation reached the lowest level since 1958 at 0.44% in 2004:1. In August 2008, inflation rate was 13.7%, the highest since the adoption of the inflation targeting framework. Overall, the monetary authorities have managed to keep inflation low during the inflation targeting regime relative to the period 1967-1998 (Figure 1).

Gross Domestic Product (GDP) growth in South Africa averaged 2.86% between 1993:2 and 1999:4, which is nearly half a percentage point lower than during the inflation targeting regime, where it averaged 3.29% between 2000:1 and 2014:2 (Figure 2). In 2008:4, 2009:1 and 2009:2, GDP growth was -1.7%, -6.3% and -2.3%, respectively, which was the worst performance since 1994.

Figure 2: CPI inflation and GDP growth in South Africa

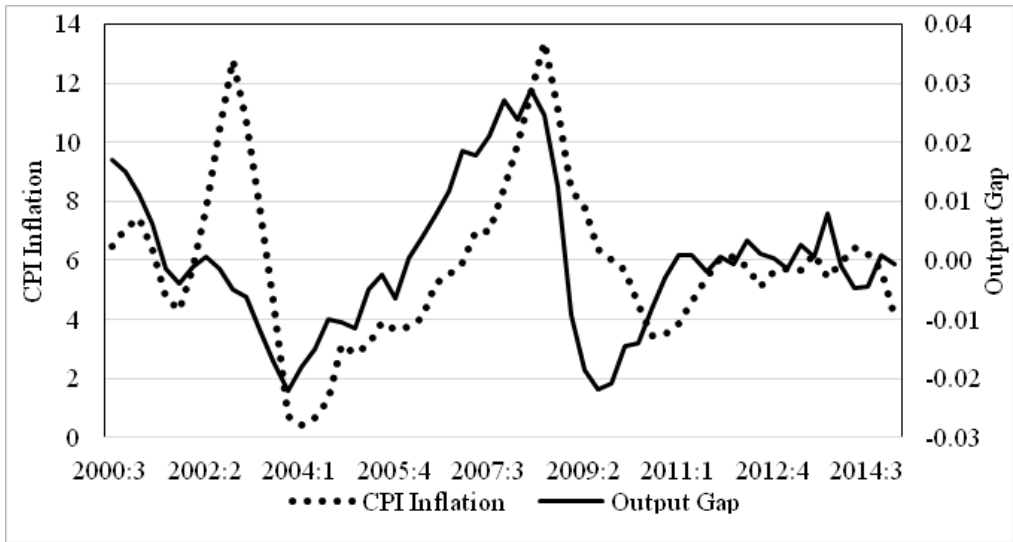


Source: Statistics South Africa

Eyeball inspection of Figure 2 shows no clear pattern of co-movements of real GDP growth and the rate of inflation. The two variables show indications of co-movement from about 1991 to 2002, 2007 to 2010 and 2014 to 2015, and inverse correlation from about 2002 to 2007 and 2010 to 2014. Given that the effect of monetary policy depends on the relationship between inflation and output, the available data do not provide adequate guidance to monetary authorities in South Africa on how to manage inflation and achieve price stability.

The literature suggests that inflation and the output gap tend to move together in the same direction (Laxton, Rose and Tambakis, 1999; Huh and Jang, 2007). Figure 3 plots inflation and the output gap in South Africa using monthly frequency data for the period 2000:3 to 2015:1. Inflation is plotted on the primary axis while the output gap is plotted on the secondary axis. The figure reveals a clear co-movement between the two variables.

Figure 3: CPI inflation and output gap in South Africa



Source: South African Reserve Bank and Statistics South Africa

At the centre of monetary policy making and implementation in South Africa is the South African Reserve Bank, a privately-owned institution formed in 1921. At the time of its establishment, most banks worldwide had private shareholders and a similar structure was introduced in South Africa (Van der Merwe, 2004). In 1935 and 1936, New Zealand and Denmark, in that order, nationalized their central banks followed by many other countries, consequently changing the landscape of central banking. Presently, there are only a few countries in the world that have central bank shareholders other than the governments of their respective countries. These include South Africa, Switzerland, the United States of America, Turkey and Japan.

### 3. Literature review

There is no consensus in the literature on whether the relationship between inflation and output is symmetric or asymmetric, and in the case of the latter, whether it is concave or convex. A symmetric inflation-output relationship occurs when both positive and negative demand shocks of the same magnitude lead to identical price responses, with differences only in the direction of the response depending on whether the shock is positive or negative. Thus, matching policy responses to demand shocks leads to identical excess supply and demand effects with equal timing. Nobay and Peel (2000) and Gordon (1997) define a symmetric inflation-output relationship as a case where an equal amount of resources is needed to remove inflation bias to have the output target equal to the natural rate. Schaling (1999) describes a symmetric inflation-output relationship as a situation where a positive output gap and a negative output gap of the same size attract an equal response, different only in direction.

Several studies have found a symmetric relationship between inflation and output. In a study of the USA, Gordon (1997) finds a symmetric inflation-output relationship for the period 1955:2-1996:2. He maintains that for the USA, the relationship is resolutely linear. In South Africa, Nell (2006) demonstrates that between 1971 and 1984, a linear inflation-output relationship with an output gap in levels accurately describes the economy's non-trended inflation experience.

Other studies have found empirical evidence for the existence of asymmetric inflation-output relationships (see, for example, Laxton, Meredith and Rose, 1995; Clark, Laxton and Rose, 1996; Bean, 1996). In this case, the cost of lowering inflation following a positive demand shock is not the same as the cost of stimulating output growth following a decline in production due to a negative demand shock of equal magnitude.

In the case of an asymmetric inflation-output relationship, there is further debate on the nature of the asymmetry. While some studies have found a convex relationship, others have found a concave relationship. The convexity of the Phillips curve can be traced to the traditional Keynesian assumption that nominal wages are flexible upwards but rigid downwards (see for example, Layard, Nickell and Jackman, 1991; Nickell, 1997). Huh and Jang (2007) argue that in a convex inflation-output relationship, the unemployment cost of lowering inflation will fall as the economy strengthens. This argument is supported by Laxton, Rose and Tambakis (1999), Turner (1995), Debelle and Laxton (1997) and Clark, Laxton and Rose (1996) who maintain that in a convex

inflation-output relationship, as output increases above the full employment level, the upward pressure on inflation rises increasingly on the margin and unemployment falls below its sustainable level. Further studies on the convex Phillips curve have been carried out by Lois and Pablo (2000) and Gerlach (2000), who have shown that inflationary tendencies of capacity constraints on prices imply a considerably steeper Phillips curve when the output gap is positive than when it is negative.

In the absence of any knowledge on the nature of the inflation-output trade-off, monetary authorities have been called upon to assume the traditional convex relationship since the costs of errors of incorrect presumption tend to be very high. If the Phillips curve is convex, but policy is based on the presumption of a symmetric relationship, or even worse, concavity, the consequences can be severe. Policy errors that lead to relatively severe overheating will be costly to correct, and the data will be characterized by boom-and-bust cycles with deep and protracted recessions (Laxton, Rose and Tambakis, 1999).

Ball et al (1988) and Dotsey, King and Wolman (1999) maintain that the convex inflation-output relationship may be a result of costly price adjustments. When a change in a firm's activity is costly, the firm may be reluctant to implement it when the level of inflation is high. Thus, a positive demand shock is expected to have a greater impact on prices and a relatively smaller impact on increasing production.

Laxton, Rose and Tambakis (1999) found that a Phillips curve with traditional convexity fits the US data in a study spanning the period 1972:1-1997:1. Clark, Laxton and Rose (1996) found evidence supporting the proposition that there is a significant (convex) asymmetry in the US output-inflation process during the period 1964:1-1990:4. Akerlof, Dickens and Perry (1996) and Turner (1995) also found similar results. In a study of New Zealand during the period 1982:3-1996:1, Razzak (1997) also concluded that the inflation-output relationship in the country is asymmetric and convex.

Stiglitz (1997), however, argued that the inflation-output trade-off in the US may not be convex. He maintained that the Phillips curve may be concave because firms face monopolistic competition and are more willing to reduce prices under weak demand (when the output gap is negative) than to increase them under high demand to avoid being overtaken or undercut by rival firms. Eisner (1997) found similar results also for the US. Nell (2006) showed that the relationship in South Africa changed to asymmetric concave during the period 1986-2001 from a symmetric relationship in the period 1971-1984. Similar results have been reported by Bean (1996), Clark and Laxton (1997), Tambakis (1998) and Amano, Coletti and Macklem (1999), among others. In these studies, it is argued that the Phillips curve is flatter when the unemployment rate is below the conventional non-accelerating-inflation rate of unemployment (NAIRU) and steeper when the unemployment rate is above the conventional NAIRU.

According to Huh and Jang (2007), concavity implies that the unemployment cost of lowering inflation increases with the strength of the economy. However, in the event of supply shocks, the unemployment cost of lowering inflation falls as the economy strengthens. This agrees with Laxton, Meredith and Rose (1995) who also found that



the Philips curve is asymmetric concave in seven major Organization for Economic Cooperation and Development (OECD) countries. That is, excess demand increases inflation by more than excess supply reduces it. This finding is also consistent with Clark, Laxton and Rose (1996).

In South Africa, Nell (2006) found an asymmetric concave Phillips curve for the period 1986 to 2001. Although the study reports a deflationary bias, it concludes that the expansionary demand-side policies that stabilize output growth around its potential during the downswing phase of a business cycle can offset this bias.

Notwithstanding the foregoing debate, Filardo (1998) used US data to conclude that the Phillips curve is not purely convex or concave, but instead convex-concave. He found that the Phillips curve is convex when the output gap is positive and concave when the output gap is negative. He further showed that the cost of fighting inflation is higher when the economy is weak (5% of output gap) than when it is overheated (2.1%). Therefore, he pointed out that proponents of a convex or concave Phillips curve have studied only one case and overlooked the other. This demonstrates that the output cost of fighting inflation is more complex than previously thought.

## 4. Methodology and data

### Inflation-Expectations Augmented Phillips Curve

The asymmetry hypothesis in the context of the Phillips curve states that the relationship between inflation and the output gap is non-linear. This section tests the hypothesis using the inflation-expectations augmented Phillips curve, which is based on the notion that the output gap depends on the excess of inflation over what was expected (Clark, Laxton and Rose, 1996), given by:

$$\pi_t - E_{t-1}\pi_t = \beta(y_t - y_t^p) + \varepsilon_t^{PC} \quad (1)$$

where  $\pi_t$  is the rate of inflation,  $E_t$  is an expectations operator,  $y_t$  is real output,  $y_t^p$  is potential output,  $(y_t - y_t^p)$  is the output gap,  $\beta \in \mathbb{R}$ , and  $\varepsilon_t^{PC}$  is an error term. Accounting for inflation inertia, equation (1) can be rewritten as:

$$\pi_t = \delta_1\pi_{t-1} + \delta_2E_{t-1}\pi_t + \beta(y_t - y_t^p) + \varepsilon_t^{PC} \quad (2)$$

We commence with estimation of the linear Phillips curve specified in Equation 2. The estimated equation is plotted and superimposed on a scatter diagram of actual data in a Phillips curve framework. This is used as a baseline in the empirical analysis.

Equation 2 presumes that the Phillips curve is linear. However, a review of the literature in Section 3 indicates that the Phillips curve may not be linear. To establish whether the Phillips curve in South Africa is indeed linear or non-linear, we estimate a variant of the inflation-expectations augmented Phillips curve, given by two conjoined linear functions:

$$\pi_t = \phi_1\pi_{t-1} + \phi_2E_{t-1}\pi_t + \eta_1(y_t - y_t^p) + \eta_2 \left[ \frac{(y_t - y_t^p) + |y_t - y_t^p|}{2} \right] + \mu_t^{PC} \quad (3)$$

where  $\phi_i, \eta_i \in \mathbb{R}$ , and  $\mu_t^{PC} \mu_t^{PC}$  is a disturbance term. Equation 3 has two linear segments. The first segment has three variables, namely, lagged inflation ( $\pi_{t-1}$ ), expected inflation ( $E_{t-1}\pi_t$ ) and output gap ( $y_t - y_t^p$ ), which are components of the linear Phillips curve in Equation 2. The second segment (in square brackets) is a positive output gap that introduces a kink whenever  $\eta_2 \neq 0$ . The use of a positive output gap conjoined to a linear Phillips curve to test the asymmetry hypothesis is standard practice in the literature (see for example, Clark, Laxton and Rose, 1996; Razzak, 1997; Schaling, 1999).<sup>2</sup>

We test the null hypothesis that  $\eta_2 = 0$ . Failure to reject the hypothesis (i.e. the absence of evidence that  $\eta_2 \neq 0$ ) suggests that the Phillips curve is symmetric, and Equation 3 collapses to Equation 2. If  $\eta_2 > 0$ , then the slope of the second linear segment (positive output gap) is larger than that of the output gap in the first linear segment and the two form a non-linear curve that becomes steeper (slopes upwards) at the point of the kink (where the two linear curves conjoin). In this case, the Phillips curve is convex asymmetric. On the other hand, if  $\eta_2 < 0$ , then the slope of the second linear segment (positive output gap) is smaller than that of the output gap in the first linear segment and the two form a non-linear curve that becomes flatter at the kink (where the two linear curves conjoin). In this case, the Phillips curve is concave asymmetric.

Equation 2 and Equation 3 present a few estimation challenges. First is an endogeneity problem. The literature states that causality can run from inflation to output (see, for example, Caporale, 2011; Fountas, Karanasos and Kim, 2002), making the output gap (and positive output gap) correlated with the error term with the implication that ordinary least squares (OLS) and weighted least squares (WLS) estimates would be biased and inconsistent. Second, the presence of lagged inflation and expected inflation among the regressors and the expected close association between actual inflation, and lagged and expected inflation, is expected to render the parameter estimates inconsistent and biased in an OLS or WLS regression. To avoid these problems, we estimate the two equations using the difference Generalized Method of Moments (GMM) approach. This method involves the use of instrumental variables (that are correlated with the endogenous variables on the right-hand-side but not with the error term). The GMM estimation results for Equation 3. provide the values for  $\eta_2$ , which are used to establish whether the inflation-output trade-off is symmetric or asymmetric, and if the latter, whether it is convex or concave. Consistent with the literature, we use lagged values of the endogenous variables as instruments.

Quarterly time series data for the period 2000:3 to 2015:1 are used for analysis. The cut-off dates are chosen to capture the period when South Africa adopted inflation targeting while remaining as current as possible. Both real output and potential output are in natural logs and are obtained from Statistics South Africa (StatsSA) and the South African Reserve Bank (SARB). Inflation data are also obtained from StatsSA and the SARB. Expected inflation data are obtained from the University of Stellenbosch's Bureau for Economic Research (BER). Every quarter, the BER conducts what is referred to as a "Survey of Inflation Expectations", collecting data on behalf

of the SARB from financial analysts, business executives and representatives of the trade union movement on their expectations of inflation, economic growth, salaries and wages, interest rates, bond yields, exchange rates, M3 money supply growth and utilization of production capacity in manufacturing. In this study, we use the data on average expected Consumer Price Index (CPI) inflation of financial analysts, business executives, representatives of the trade union movement and a weighted average of the three (also referred to as “all surveyed participants”).

Potential output ( $y_t^P$ ) is computed using the Hodrick-Prescott (HP) Filter with  $\lambda = 1600$ . The HP filter is widely used to obtain a smooth estimate ( $x_t$ ) of the long-term trend component of a series ( $X_t$ ) by minimizing the variance of  $X_t$  around  $x_t$ , subject to a penalty that constrains the second difference of  $x_t$  ( $x_t - x_{t-1} - x_{t-2}$ ) (Quantitative Micro Software, 2009). The output gap is measured as the difference between real output ( $y_t$ ) and potential output ( $y_t^P$ ), i.e.  $y_t - y_t^P$ .

While the estimated inflation expectations augmented Phillips curve give insights into the nature of the relationship between inflation and output in South Africa, we cannot generalize the applicability of the results outside the sample period. According to the Lucas Critique, it is naïve to predict effects of a change in economic policy based on non-structural relationships that are derived from ‘highly’ aggregated historical data. Our models in (2) and (3) are not built from micro-foundations. This indicates that the model parameters are not structural, suggesting that they are policy invariant. Thus, they may change whenever there is a policy change. To understand how collective decisions of rational individuals coordinated over a range of variables relate to both the present and the future, and the consequent wider effects of the inflation-output trade-off and dynamic effects of policy responses by the monetary authorities, we formulate a dynamic stochastic general equilibrium (DSGE) model calibrated using South African data.

There are several reasons why a DSGE model enhances the findings in the estimated (2) and (3). First, “it is possible” with this approach to “avoid” the Lucas Critique, where only models in which the parameters that do not vary with policy interventions are suited to evaluate the impact of a policy change (Tovar, 2008). This is feasible because DSGE models are derived from microeconomic foundations of constrained decision-making. That is, they describe the general equilibrium allocations and prices in the economy where all agents dynamically maximize their objectives subject to budget or resource constraints (Tovar, 2008). Indeed, according to Woodford (2003), DSGE models should not, at least in principle, be vulnerable to the Lucas Critique, unlike the more traditional macroeconomic forecasting models (Ngalawa and Vieg, 2013). Second, the DSGE models allow for precise and unambiguous examination of random disturbances, which is facilitated by the stochastic design of the models. Third, DSGE models are structural, implying that each equation has an economic interpretation which allows clear identification of policy interventions and transmission mechanisms (Peiris and Saxegaard, 2007). Fourth, DSGE models are forward looking in that agents optimize model-consistent forecasts about the future evolution of the economy (Peiris and Saxegaard, 2007).

## General equilibrium framework

The model has four sectors, namely: households, final goods firms, intermediate goods firms, and government. The household maximizes an intertemporal utility function separable in consumption and labour subject to a budget constraint. The final goods firm bundles intermediate goods to produce final goods, while the intermediate goods firm hires workers from a labour bundler, which it uses to produce differentiated intermediate goods. Finally, government consists of the fiscal and monetary authorities. The former are responsible for fiscal policy while the latter are responsible for monetary policy. The monetary authorities use a policy rule of the Taylor type that calls for adjustment of the Repurchase Agreement (REPO) rate based on a deviation of inflation from the target inflation. Consistent with most of the literature, the model does not incorporate financial intermediation (see for example Smets and Wouters, 2003). This omission is expected to have no impact on the operationalization of the model and the study results.

The basic structure of the model follows Steinbach, Mathuloe and Smit (2009). It is a two-country New Keynesian open economy framework, where the foreign country is the rest of the world and the domestic country is South Africa, which is assumed to be a small open economy.<sup>3</sup> The model assumes a staggered price- and wage-setting mechanism akin to that used by Calvo (1983). Unlike Steinbach, Mathuloe and Smit (2009), the model assumes that there is no habit formation in consumption, and that there is no (partial) indexation of prices and wages to past inflation.

There are several studies that have been carried out on South Africa using DSGE models. These include Alpanda, Kotze and Woglom (2011), Steinbach, Mathuloe and Smit (2009) and Liu and Gupta (2007). None of these has studied the symmetric/asymmetric relationship between inflation and output.

### *Household sector*

We assume there is a continuum of identical households (with identical endowments and preferences). The objective of a representative household of constant size with a constant amount of time per period and an infinite planning horizon is to maximize the expected sum of a discounted stream of instantaneous utilities separable in consumption ( $C_t$ ) and time  $t$  labour ( $N_t$ ) given by:

$$\text{Max } E_0 \sum_{t=0}^{\infty} \beta^t \left( \frac{1}{1-\varphi} C_t^{1-\varphi} - \frac{1}{1+\Phi} N_t^{1+\Phi} \right) \quad (4)$$

where  $\beta \in (0,1)$  is a consumer subjective intertemporal discount factor;  $\varphi$  is the inverse of the intertemporal elasticity of substitution for consumption;  $\Phi$  is the inverse of the elasticity of labour supply; and  $E$  is an expectations operator. The

utility function  $U_t(\dots)U_t(\dots)$  is assumed to satisfy  $U_{t,C_t} > 0$ ,  $U_{t,N_t} > 0$ ,  $U_{t,C_t,C_t} < 0$ , and  $U_{t,N_t,N_t} < 0$ . Following Steinbach, Mathuloe and Smit (2009), we assume the household's consumption bundle is composed of domestic ( $C_{h,t}$ ) and foreign goods ( $C_{f,t}$ ) given by a composite consumption function of the form:

$$C_t \equiv \left( \gamma^{\frac{1}{\theta}} C_{f,t}^{\frac{\theta-1}{\theta}} + (1-\gamma)^{\frac{1}{\theta}} C_{h,t}^{\frac{\theta-1}{\theta}} \right)^{\frac{\theta}{\theta-1}} \tag{5}$$

where the import share of domestic consumption is described by  $\gamma \in [0,1)$ ; and  $\theta$  is the intertemporal elasticity of substitution between domestic and foreign goods. The household's demand for foreign goods is given by:

$$C_{f,t} = \gamma \left( \frac{P_{f,t}}{P_t} \right)^{-\theta} C_t \tag{6}$$

and its demand for domestic goods is given by:

$$C_{h,t} = (1-\gamma) \left( \frac{P_{h,t}}{P_t} \right)^{-\theta} C_t \tag{7}$$

where  $P_{f,t}$  is the foreign price index and  $P_{h,t}$  is the domestic price index. The all items composite consumer price index is given by:

$$P_t \equiv \left( \gamma P_{f,t}^{1-\theta} + (1-\gamma) P_{h,t}^{1-\theta} \right)^{\frac{1}{1-\theta}} \tag{8}$$

Maximization of the household's objective function is subject to the following intertemporal budget constraint:

$$P_{f,t} C_{f,t} + P_{h,t} C_{h,t} + B_t + T_t = W_t N_t + (1 + R_t^B) B_{t-1} + D_t \tag{9}$$

where  $B_t$  are government bonds,  $R_t^B$  are yields on government bonds,  $T_t$  are lumpsum taxes,  $W_t$  is the wage rate and  $D_t$  are dividends from firms.<sup>4</sup> The first order equation with respect to consumption is given by:

$$\frac{1}{P_t C_t^\varphi} = \beta (1 + R_{t+1}^B) E_t \left( \frac{1}{P_{t+1} C_{t+1}^\varphi} \right) \tag{10}$$

where equation (10) is the Euler equation (intertemporal consumption function).

## Labour market

We assume households supply differentiated labour, which is bundled into a single type of labour by a labour bundling firm. Effectively, the households exercise some monopoly power in setting their wage rates. The labour bundler is assumed to aggregate the workers according to the following function:

$$N_t(k) = \left[ \int_0^1 N_t(i)^{\frac{\tau_N-1}{\tau_N}} di \right]^{\frac{\tau_N}{\tau_N-1}} \quad (11)$$

where  $N_t(k)$  is time  $t$  labour input of each firm  $k$  and  $N_t(i)$  is the amount of differentiated labour supplied by household  $i$ . The labour bundling firm's demand for each type of differentiated labour, therefore, is described by the following function:

$$N_t(i) = \left( \frac{w_t}{W_t(i)} \right)^{\tau_N} N_t \quad (12)$$

where  $\tau_N$  is a constant elasticity of labour demand. The nominal wage paid by the labour bundling firm is specified as:

$$W_t = \left[ \int_0^1 W_t(i)^{1-\tau_N} di \right]^{\frac{1}{1-\tau_N}} \quad (13)$$

Consistent with the Calvo (1983) type rule of staggered pricing, we assume that in each period, a randomly selected proportion of workers  $\rho_N$  do not adjust their wage rates ( $W_t(i) = W_{t-1}(i)$ ) while the remaining proportion  $(1 - \rho_N)$  reset their wage rates ( $W_t^*(i)$ ). Accordingly, aggregate wages are given by:

$$W_t = \left[ (1 - \rho_N)(W_t^*)^{1-\tau} + \rho_N(W_{t-1})^{1-\tau} \right]^{\frac{1}{1-\tau}} \quad (14)$$

Given the time  $t$  wage rate, we assume that labour demand will be met by labour supply. In period  $t$ , each household that does not adjust its wage rate  $W_t(i)$  will supply:

$$N_t(i) = \left( \frac{w_t}{W_t(i)} \right)^{\tau_N} N_t \quad (15)$$

A household that resets its wages in period  $t$  faces the probability  $\rho^N$  that the re-optimized wage  $W_t^*(i)$  will remain unchanged in the following period. This household's labour supply will be given by:

$$N_{t+1}(i) = \left(\frac{W_{t+1}}{W_t^*(i)}\right)^{\tau N} N_{t+1} \tag{16}$$

### Final goods firm

We assume there is a continuum of intermediate goods firms indexed by  $k \in [0,1]$ , producing differentiated intermediate goods  $Y_t(k)$ . These goods are bundled into final goods  $Y_t$  using a Dixit-Stiglitz constant elasticity of substitution aggregation function given by:

$$Y_t = \left[ \int_0^1 Y_t(k)^{\frac{\tau_h - 1}{\tau_h}} dk \right]^{\frac{\tau_h}{\tau_h - 1}} \tag{17}$$

where  $\tau_h > 0$  is the elasticity of substitution in production. To maximize profits  $(\Pi_t)$ , the final goods firm maximizes the following objective function:

$$\Pi_t = P_{h,t} Y_t - \int_0^1 P_{h,t}(k) Y_t(k) dk \tag{18}$$

subject to the production function given by Equation 15. The firm's problem, therefore, can be specified as:

$$\max P_{h,t} \left[ \int_0^1 Y_t(k)^{\frac{\tau_h - 1}{\tau_h}} dk \right]^{\frac{\tau_h}{\tau_h - 1}} - \int_0^1 P_{h,t}(k) Y_t(k) dk \tag{19}$$

Taking the first order condition with respect to  $Y_t(k) Y_t(k)$  we obtain:

$$P_{h,t} \left[ \int_0^1 Y_t(k)^{\frac{\tau_h - 1}{\tau_h}} dk \right]^{\frac{1}{\tau_h - 1}} Y_t(k)^{\frac{-1}{\tau_h}} = P_{h,t}(k) \tag{20}$$

Equation 20 can be reduced to an equation for  $Y_t(k)$ , which represents a demand function for the intermediate good  $k$ :

$$Y_t(k) = \left(\frac{P_{h,t}}{P_{h,t}(k)}\right)^{\tau_h} Y_t \tag{21}$$



Substituting Equation 21 into the production function given by equation (17), we get the pricing rule equation for the final goods firm:

$$P_{h,t} = \left[ \int_0^1 \left[ Y_t \left( \frac{P_{h,t}}{P_{h,t}(k)} \right)^{\tau_h} \right]^{\frac{\tau_h-1}{\tau_h}} dk \right]^{\frac{1}{\tau_h-1}} \quad (22)$$

$$Y_t = Y_t P_{h,t}^{\tau_h} \left[ \int_0^1 \left( \frac{1}{P_{h,t}(k)} \right)^{\tau_h-1} dk \right]^{\frac{1}{\tau_h-1}} \quad (23)$$

$$P_{h,t} = \left[ \int_0^1 P_{h,t}(k)^{1-\tau_h} dk \right]^{\frac{1}{1-\tau_h}} \quad (24)$$

where Equation 24 is the final goods pricing rule.

### Intermediate goods firms

Each intermediate goods producing firm  $k$  produces a differentiated good  $Y_t(k)$  using a linear production function given by:

$$Y_t(k) = A_t N_t(k) \quad (25)$$

where  $A_t > 0$  captures technology. The technology factor is assumed to evolve according to a first order autoregressive process given by:

$$A_t = \rho_A A_{t-1} + \mu_t^A \quad (26)$$

where  $\mu_t^A \sim iid N(0, \sigma_{\mu^A})$ . The firm's nominal total cost is given by:

$$TC_t = W_t N_t(k) \quad (27)$$

From Equations 25 and 27, we can derive the firm's marginal cost as:

$$MC_t = \frac{W_t}{P_{h,t} A_t} \quad (28)$$

Following Calvo (1983), we assume that in each period  $t$ , a proportion  $1 - \rho_{P,h}$  of firms randomly selected among the intermediate goods producing firms reset their price to  $P_{h,t}^r(k)$ . The remaining proportion  $\rho_{P,h}$  keep their prices the same as in the previous period, i.e.  $P_{h,t}(k) = P_{h,t-1}(k)$ . Consistent with the Calvo (1983) staggered price setting mechanism, the proportion  $1 - \rho_{P,h}$  of firms that can re-optimize their prices choose price  $P_{h,t}^r(k)$  to maximize:

$$\max E_t \sum_{j=0}^{\infty} \beta^j \rho_{P,h}^j Y_{t+j}(k) (P_{h,t}^r - MC_{t+j} P_{h,t+j}) \tag{29}$$

subject to the final goods producers' demand for intermediate goods given by Equation 21. Equation 29 holds when the re-optimized price  $P_{h,t}^r(i)$  is in effect; and Equation 21 states that the intermediate goods firm's total production will be just equal to the demand by the final goods firms. The optimal solution is, therefore, given by:

$$\text{Max } E_t \sum_{j=0}^{\infty} \beta^j \rho_{P,h}^j Y_{t+j}(k) (P_{h,t}^r - (1 + \xi) MC_{t+j} P_{h,t+j}) = 0 \tag{30}$$

where  $\xi$  is a mark-up over a discounted stream of expected marginal costs.

### International transactions

Following Steinbach, Mathuloe and Smit (2009), we assume that there are retailers in the domestic economy that import differentiated goods and pay for them in the domestic currency equivalent of the world market prices (i.e. the law of one price holds). These goods are sold in an imperfectly competitive market in the domestic economy, which necessitates a deviation from the law of one price given by:

$$T_{f,t} = \frac{X_t^N P_t^W}{P_{f,t}} \tag{31}$$

where  $P_{f,t}$  is the domestic currency price of imports,  $X_t^N$  is the nominal exchange rate,  $P_t^W$  is the world price and  $T_{f,t}$  is the law of one price gap. We assume the retailers in the domestic economy also adjust prices of the imported goods following the Calvo (1983) staggered price setting mechanism. A randomly selected proportion  $(\rho_f)$  of the importing retailers do not adjust their prices while the remaining proportion  $(1 - \rho_f)$  adjust their prices. The price index of the imported goods, therefore, is given by:

$$P_{f,t} = \left[ \int_0^1 P_{f,t}(k)^{1-\tau_f} dk \right]^{\frac{1}{1-\tau_f}} \tag{32}$$

The price index of imported goods is assumed to evolve according to:

$$P_{f,t} = \left[ \rho_f P_{f,t-1}^{1-\tau_f} + (1 - \rho_f) (P_{f,t})^{1-\tau_f} \right]^{\frac{1}{1-\tau_f}} \quad (33)$$

We define terms of trade (the relative price of exports in terms of imports) as the ratio of export prices to import prices:

$$Y_t \equiv \frac{P_{f,t}}{P_{h,t}} \quad (34)$$

The real exchange rate is the world price in terms of the domestic currency expressed as a ratio of the domestic price level:

$$X_t^R \equiv \frac{X_t^N P_t^W}{P_t} \quad (35)$$

## Government

Government consists of a monetary authority that implements monetary policy and a fiscal authority that implements fiscal policy.

### Monetary authority

We assume the monetary authorities follow a forward-looking policy rule of the Taylor type that treats the Repo rate ( $R_t^{REPO}$ ) as an operating tool of monetary policy. The specification allows the central bank to consider a broad array of information to form beliefs about the future condition of the economy (Clarida, Gali and Gertler, 2000). The rule calls for adjustment of the REPO rate based on output gap and a deviation of inflation from the target inflation:

$$R_t^{REPO} = \zeta R_{t-1}^{REPO} + (1 - \zeta) [\chi_1 (Y_t - Y_t^P) + \chi_2 (\pi_t - \pi^*)] + \mu_t^{MP} \quad (36)$$

where  $\zeta$  is a policy smoothing parameter;  $\chi_1$  and  $\chi_2$  are the relative weights of the importance placed on output and inflation, respectively;  $\pi^*$  is the target rate of inflation; and  $\mu_t^{MP}$  is a disturbance term assumed to be white noise.

## Fiscal policy

We assume government levies lumpsum taxes,  $T_t$ , and issues one-period nominal debt in period  $t - 1$  maturing in period  $t$  with the face value  $B_{t-1}$  (Rabanal and Rubio-Ramirez, 2003). Accordingly, the fiscal budget constraint is given by:

$$G_t + (1 + R_t^B)B_{t-1} = T_t + B_t \quad (37)$$

## Market equilibrium

Following Steinbach, Mathuloe and Smit (2009), clearing of the final goods market implies that in equilibrium, aggregate production ( $Y_t$ ) is just enough to satisfy demand for domestic goods ( $C_{h,t}$ ), foreign demand for domestically produced goods or exports ( $C_{h,t}^*$ ) and government consumption ( $G_t$ ):

$$Y_t = C_{h,t} + C_{h,t}^* + G_t \quad (38)$$

## Foreign country

The foreign economy is assumed to be large relative to South Africa, and it is modelled as 'an approximated closed economy' where aggregate demand is equal to aggregate supply. Thus,

$$Y_t^* = C_t^* + G_t^* \quad (39)$$

Following Steinbach, Mathuloe and Smit (2009), it can be shown that the closed economy model collapses into an investment/savings (IS) curve given by:

$$y_t^* = E_t y_{t+1}^* + y_{t-1}^* - \frac{1}{\varphi} (r_t^* - E_t(\pi_{t+1}^*) + \varepsilon_t^*) \quad (40)$$

where the lower case letters indicate natural logarithms. Similarly, we can derive a New Keynesian Phillips curve given by:

$$\pi_t^* = \beta E_t \pi_{t+1}^* + \frac{(1-\theta^*)(1-\theta^*\beta)}{\theta^*} mc_t^* \quad (41)$$

where  $mc_t^*$  is defined as:

$$mc_t^* = (\varphi^* + \Phi^*)y_t^* - (1 + \Phi^*)a_t^* + \varepsilon_t^{*mc} \quad (42)$$

It is also assumed that productivity follows a first order autoregressive process specified as:

$$a_t^* = \rho_a^* a_{t-1}^* + \varepsilon_t^{*a} \quad (43)$$

where  $\varepsilon_t^{*a}$  is assumed to be white noise.

## Calibrations

The calibrated parameters of our model are borrowed from Steinbach, Mathuloe and Smit (2009) and Ortiz and Sturzenegger (2008). A large number of them are consistent with studies by Liu and Gupta (2007) and Alpanda, Kotze and Woglom (2011). Table 1 presents a summary of the parameters, their description and respective sources.

Table 1: Parameter estimates

Parameter	Description	Value	Source
$\beta$	Consumer subjective discount factor	0.99	Steinbach, Mathuloe and Smit (2009), Liu and Gupta (2007)
$\gamma$	Import share of domestic consumption	0.2	Steinbach, Mathuloe and Smit (2009)
$\Phi$	Inverse of the elasticity of labour supply	3.0	Steinbach, Mathuloe and Smit (2009)
$\tau_N$	Constant elasticity of labour demand	1.0	Steinbach, Mathuloe and Smit (2009)
$\rho_N$	Proportion of workers that do not adjust wages between any two periods	0.5	Steinbach, Mathuloe and Smit (2009)
$\zeta$	Policy smoothing parameter	0.73	Steinbach, Mathuloe and Smit (2009)
$\chi_1$	Output gap elasticity of REPO rate changes	1.11	Ortiz and Sturzenegger (2008)
$\chi_2$	Factor of importance of inflation deviation from target	0.27	Ortiz and Sturzenegger (2008)
$\varphi^*$	The foreign country's inverse of the elasticity of substitution for consumption	1.0	Steinbach, Mathuloe and Smit (2009)
$\Phi^*$	The foreign country's inverse of the elasticity of labour supply	3.0	Steinbach, Mathuloe and Smit (2009)
$\zeta^*$	The foreign country's policy smoothing parameter	0.8	Steinbach, Mathuloe and Smit (2009)

## 5. Results and interpretations

Estimation results of the linear Phillips curve in Equation 2 are presented in Table 1. Four different regressions are estimated distinguished by the population group from which the BER/SARB inflation expectations data were collected (Regression 1: inflation expectations of all surveyed participants; Regression 2: inflation expectations of financial analysts; Regression 3: inflation expectations of business representatives; Regression 4: inflation expectations of trade unions). Since the model is semilog (lin-log), the absolute change in the regressand is 0.01 of the estimated slope coefficient. The figures in Table 1 show the estimated coefficients with this operation already carried out.

The estimation results show that the coefficient of lagged inflation is statistically insignificant in all regressions, suggesting the absence of any evidence of inflation inertia (Table 2). Expected inflation, however, is positive in all regressions and statistically significant in regressions 1 (inflation expectations of all surveyed participants) and 3 (inflation expectations of business analysts). In addition, the estimation results show that the output gap is positive and statistically significant in all regressions, which is consistent with a priori theoretical expectations.

Table 2: Estimation results: Linear Phillips curve

Dependent Variable: CPI inflation				
Variable	Regression 1	Regression 2	Regression 3	Regression 4
Inflation (-1)	-0.5597 (0.7609) [0.4620]	-0.9648 (1.5312) [0.529]	0.1026 (0.3476) [0.7680]	0.1396 (0.3744) [0.709]
Expected inflation	1.7356* (0.9934) [0.0810]	1.9434 (1.8757) [0.3000]	0.8800* (0.4562) [0.0540]	0.8171 (0.4972) [0.1000]
Output gap	1.4722*** (0.5183) [0.0050]	0.9086*** (0.3077) [0.0030]	1.3504*** (0.4073) [0.0010]	1.1988*** (0.3913) [0.002]
Constant	-1.5533 (1.8427) [0.3990]	0.0398 (2.1809) [0.9850]	-0.3298 (1.0797) [0.7600]	0.0110 (1.1173) [0.9920]
Wald chi <sup>2</sup> (3)	93.09	88.28	147.07	117.48
Prob>chi <sup>2</sup>	0.0000	0.0000	0.0000	0.0000
R-squared	0.6745	0.6852	0.7365	0.7363
Root MSE	1.678	1.6501	1.5096	1.5102
Notes: *, **, *** represent 10%, 5% and 1% level of significance, respectively Robust standard errors in round brackets P-values in square brackets  Inflation expectations Regression 1: All surveyed participants Regression 2: Financial analysts Regression 3: Business representatives Regression 4: Union representatives				

Using the estimated parameter  $\beta\beta$  in Equation 2, we plot the linear Phillips curve superimposed on a scatter plot of the output gap and the difference between actual and expected inflation, which reflects the Phillips curve framework (Figure 4). It is difficult to conclude using eyeball inspection of Figure 4 that the estimated linear function fits the data best in the absence of any comparison with a non-linear estimation.

Figure 4: The linear Phillips curve

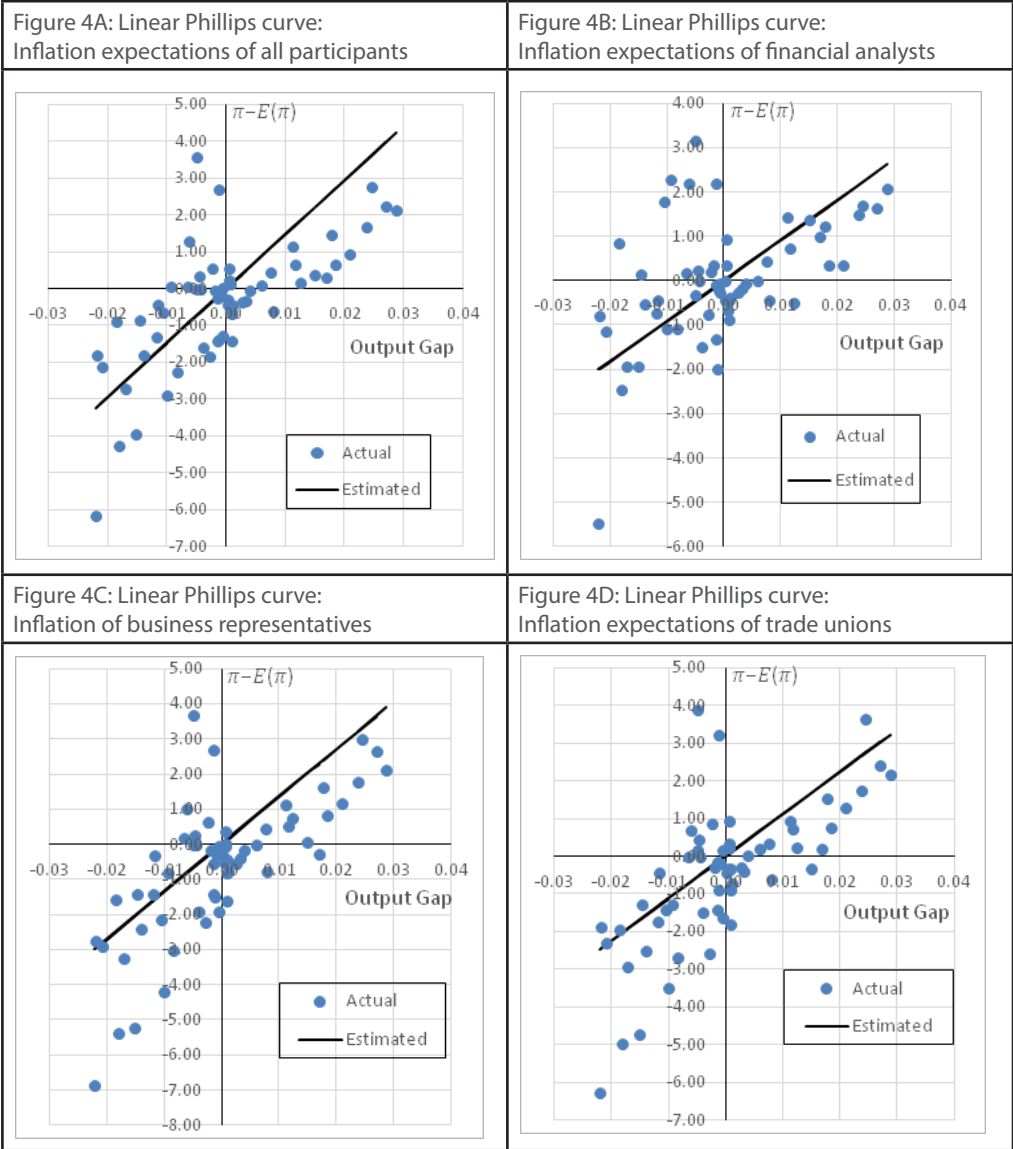


Table 2 presents estimation results of the kinked Phillips curve specified in Equation 3. The results show that the coefficient of the positive output gap is negative and statistically significant (at 5% in regressions 1, 3 and 4, and at 10% in regression 2), indicating that the Phillips curve in South Africa is concave asymmetric. This finding is consistent in all regressions regardless of the population group from which inflation expectations data were collected.

In agreement with estimation results of the linear Phillips curve, the coefficients of lagged inflation are statistically insignificant in all regressions, which is consistent with the earlier findings, suggesting the absence of evidence of inflation inertia.



The implication of inflation inertia is that the New Keynesian Phillips curve (NKPC) may not explain or reproduce observed persistence of inflation (Rabanal and Rubio-Ramirez, 2003). The observed absence of inflation inertia in the case of South Africa shows that monetary authorities can achieve disinflation without increasing the unemployment rate if they commit to keep the output gap at zero in the future and the policy is credible (Moriyama, 2011).

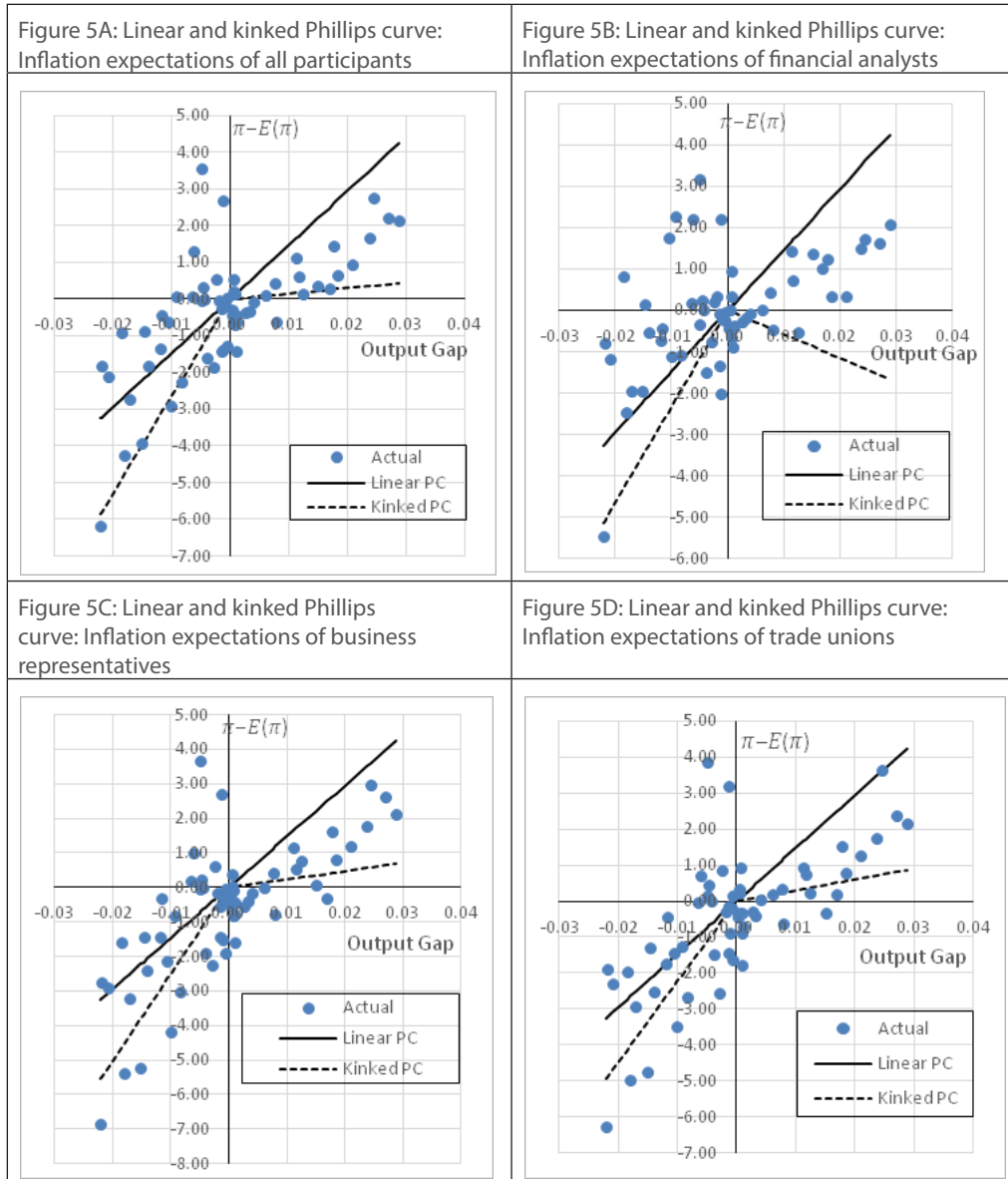
Expected inflation exerts a positive and statistically significant effect (except in regression 2) on current inflation (Table 3). This is an important finding. Since South Africa is inflation targeting, it is important that the authorities commit to keep inflation within the targeted band. This will help to anchor inflation expectations within the band, which has the effect of keeping the rate of inflation low and within the target – as long as the authorities do not renege on their commitment.

Table 3: Estimation results: Kinked Phillips curve

Dependent Variable: CPI inflation				
Variable	Regression 1	Regression 2	Regression 3	Regression 4
Inflation (-1)	-0.4758 (0.5797) [0.4120]	-2.5200 (2.9337) [0.3900]	0.1303 (0.2764) [0.6370]	0.0637 (0.3748) [0.8650]
Expected inflation	1.8817** (0.8296) [0.0230]	4.0622 (3.2462) [0.2110]	1.1053** (0.4516) [0.0140]	1.1630* (0.6173) [0.0600]
Output gap	2.6492*** (0.8294) [0.0010]	2.3239** (1.0630) [0.0290]	2.5133*** (0.7569) [0.0010]	2.2340*** (0.7794) [0.004]
Positive output gap	-2.4960** (1.1422) [0.0290]	-2.9003* (1.4850) [0.0510]	-2.2791** (1.1053) [0.0390]	-1.9343* (1.1122) [0.0820]
Constant	-1.8367 (1.7332) [0.2890]	-2.1280 (2.2707) [0.3490]	-0.9204 (1.3198) [0.4860]	-0.8365 (1.6505) [0.612]
Wald chi <sup>2</sup> (4)	88.60	78.6700	97.82	62.52
Prob>chi <sup>2</sup>	0.0000	0.0000	0.0000	0.0000
R-squared	0.7328	0.3350	0.7820	0.7506
Root MSE	1.5202	2.3984	1.3733	1.4688
Notes    *, **, *** represent 10%, 5% and 1% level of significance, respectively Robust standard errors in round brackets P-values in square brackets  Inflation expectations Regression 1: All surveyed participants Regression 2: Financial analysts Regression 3: Business representatives Regression 4: Union representatives				

Using the estimated value of parameter  $\beta$  in Equation 2, we plot the linear Phillips curve superimposed on a scatter plot of the output gap and the difference between actual and expected inflation (Figure 5). In the same diagram, we superimpose the kinked Phillips curve plotted using estimated values of parameters  $\eta_1$  and  $\eta_2$ . The figure shows that on the whole, the kinked Phillips curve is a more realistic approximation of the actual relationship between inflation and output than the linear curve.

Figure 5: The linear and non-linear Phillips curves



We also experiment with the naïve approach of measuring expected inflation to check the robustness of the results in Tables 1 and 2. In the naïve method, expected inflation is approximated by lagged inflation. We assume that at time  $t - 1$ , the observed inflation  $(\pi_{t-1})$  is equal to the expected inflation at time  $t$ , i.e.  $E_{t-1}\pi_t = \pi_{t-1}$ . Equations (2A) and (3A) are approximations of equations (2) and (3):

$$\pi_t = \xi E_{t-1}\pi_t + \psi(y_t - y_t^p) + v_t^{PC}\pi_t = \xi E_{t-1}\pi_t + \psi(y_t - y_t^p) + v_t^{PC} \quad (2A)$$

$$\pi_t = \zeta E_{t-1}\pi_t + \eta_1(y_t - y_t^p) + \eta_2 \left[ \frac{(y_t - y_t^p) + |y_t - y_t^p|}{2} \right] + \omega_t^{PC}$$

$$\pi_t = \zeta E_{t-1}\pi_t + \eta_1(y_t - y_t^p) + \eta_2 \left[ \frac{(y_t - y_t^p) + |y_t - y_t^p|}{2} \right] + \omega_t^{PC} \quad (3A)$$

Since the proxy of expected inflation is lagged inflation, we do not include inflation inertia in equations (2A) and 3(A). The estimation results from the naïve approach of approximating expected inflation as summarized in Table 4 show similar results to the estimations in Tables 1 and 2 that use survey data to proxy expected inflation. The estimation results (in Table 3) show that the coefficient of expected inflation is positive and statistically significant in both regressions.<sup>5</sup> It is also observed that the output gap is positive and statistically significant in both regressions. Most importantly, the coefficient of the positive output gap is negative and statistically significant, corroborating the previous findings that the Phillips curve in South Africa is concave asymmetric.

We also carried out four simulation experiments using the DSGE framework. Consistent with the GMM exercise, these experiments are classified by the source of expected inflation (inflation expectations of all surveyed participants (experiment 1); inflation expectations of financial analysts (experiment 2); inflation expectations of business representatives (experiment 3); and inflation expectations of trade unions (experiment 4)). In each experiment, we investigated the impact of positive and negative demand shocks of the same magnitude on the relationship between inflation and output. Figure 6 summarizes impulse responses of inflation and output to positive (Figure 6A) and negative (Figure 6B) demand shocks given inflation expectations of all surveyed participants.

In agreement with a priori theoretical expectations, a positive demand shock increases both output and inflation, which return to equilibrium within a relatively short period of time (about seven quarters in the case of inflation and six quarters in the case of output) (Figure 6A). It is further observed that a negative demand shock of the same magnitude leads to a larger decrease in inflation and a smaller decrease in

output, which return to equilibrium after about eight quarters in the case of inflation and nearly seven quarters in the case of output (Figure 6B), confirming the concave asymmetric nature of the inflation-output relationship.

Table 4: Estimation results: Linear Phillips curve

Dependent Variable: CPI inflation		
Variable	Regression 1	Regression 2
Expected inflation	0.8247*** (0.0941) [0.0000]	0.9768*** (0.1576) [0.0000]
Output gap	0.5951*** (0.1627) [0.0000]	1.6894*** (0.6351) [0.0080]
Positive output gap		-2.3700* (1.3506) [0.0790]
Constant	1.0652** (0.4809) [0.0270]	1.2257 (0.8031) [0.1270]
Wald chi <sup>2</sup> (2)	156.8000	
Wald chi <sup>2</sup> (3)		53.0600
Prob>chi <sup>2</sup>	0.0000	0.0000
R-squared	0.8218	0.7613
Root MSE	1.1709	1.4370

Notes

\*, \*\*, \*\*\* represent 10%, 5% and 1% level of significance, respectively

Robust standard errors in round brackets

P-values in square brackets

We repeat the experiment using inflation expectations of financial analysts only (Figure 7). Similar to the preceding results, a negative demand shock reduces inflation by a larger magnitude and output by a smaller amount while a positive demand shock of exactly the same magnitude leads to a smaller increase in inflation and a larger increase in output, confirming the concave asymmetric inflation-output relationship found earlier.

Figure 6: Inflation expectations of all surveyed participants: Impulse response functions

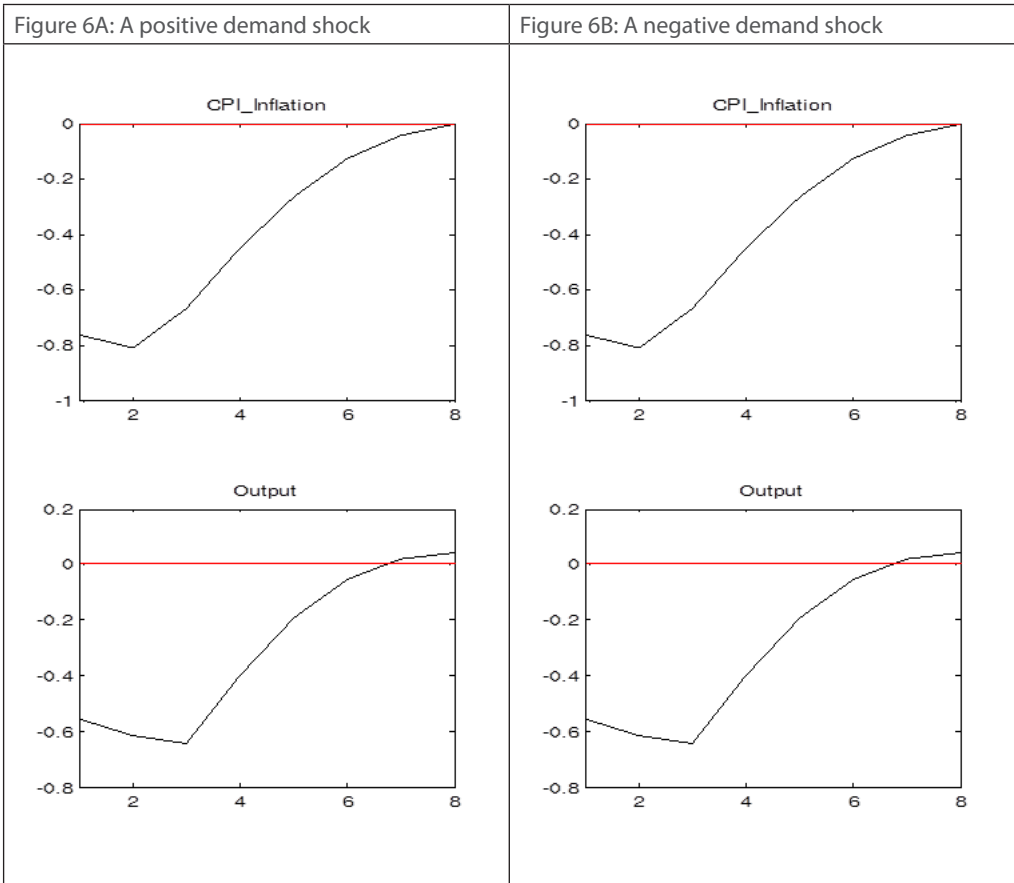
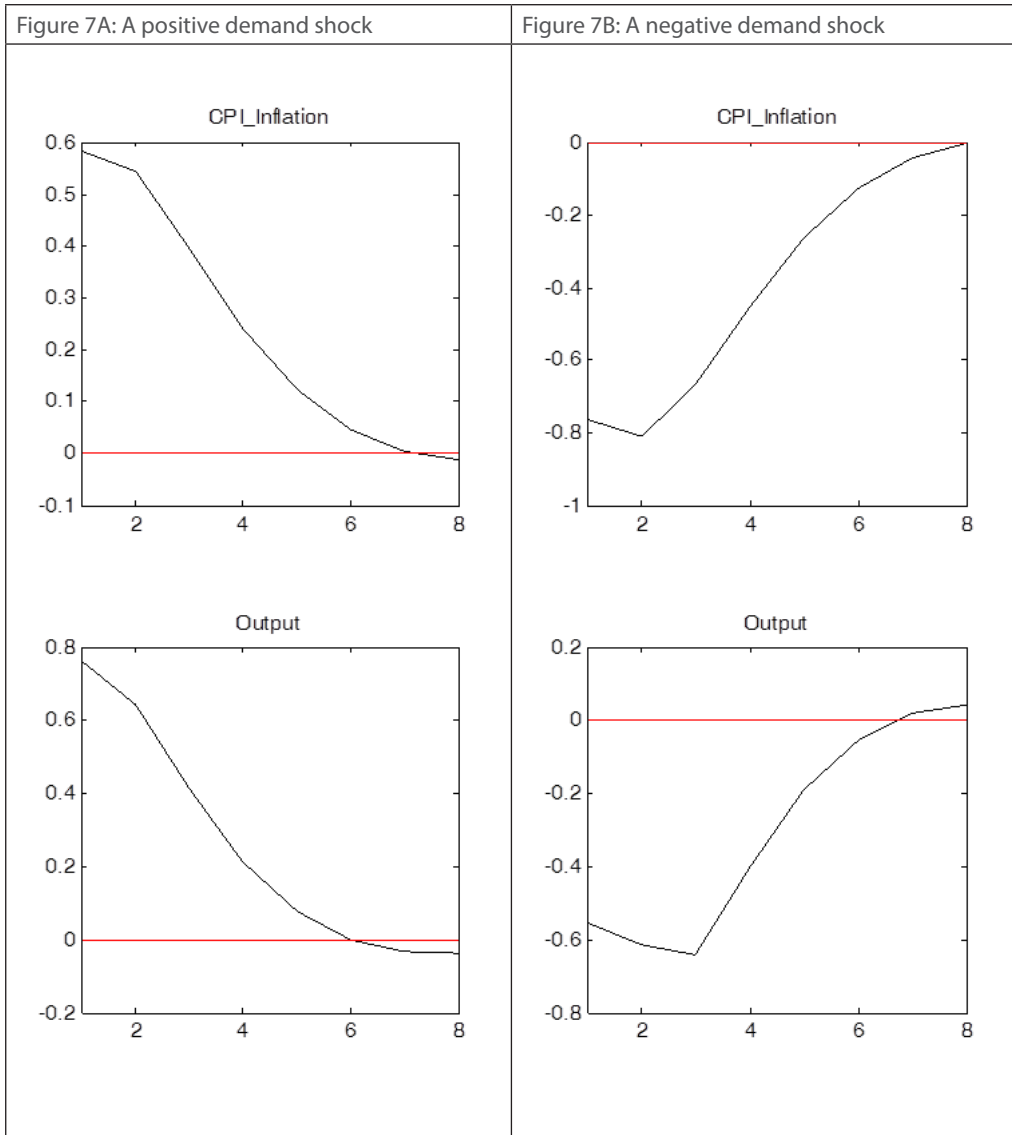


Figure 7: Inflation expectations of financial analysts: Impulse response functions



A further two experiments are carried out using inflation expectations of business representatives (Figure 8) and trade unions (Figure 9) and the results are consistent. It can be concluded, therefore, that the response of inflation to a positive demand shock in South Africa is smaller than the disinflation response to a negative demand shock of similar magnitude. Conversely, this result indicates that the unemployment cost of lowering inflation increases as the economy strengthens (Huh and Jang, 2007). This outcome is consistent with the findings of Nell's (2006) study of South Africa for the period 1986-2001. It is, however, in contrast with Nell's (2006) finding for the same economy in the period 1971-1984.

Figure 8: Inflation expectations of business representatives: Impulse response functions

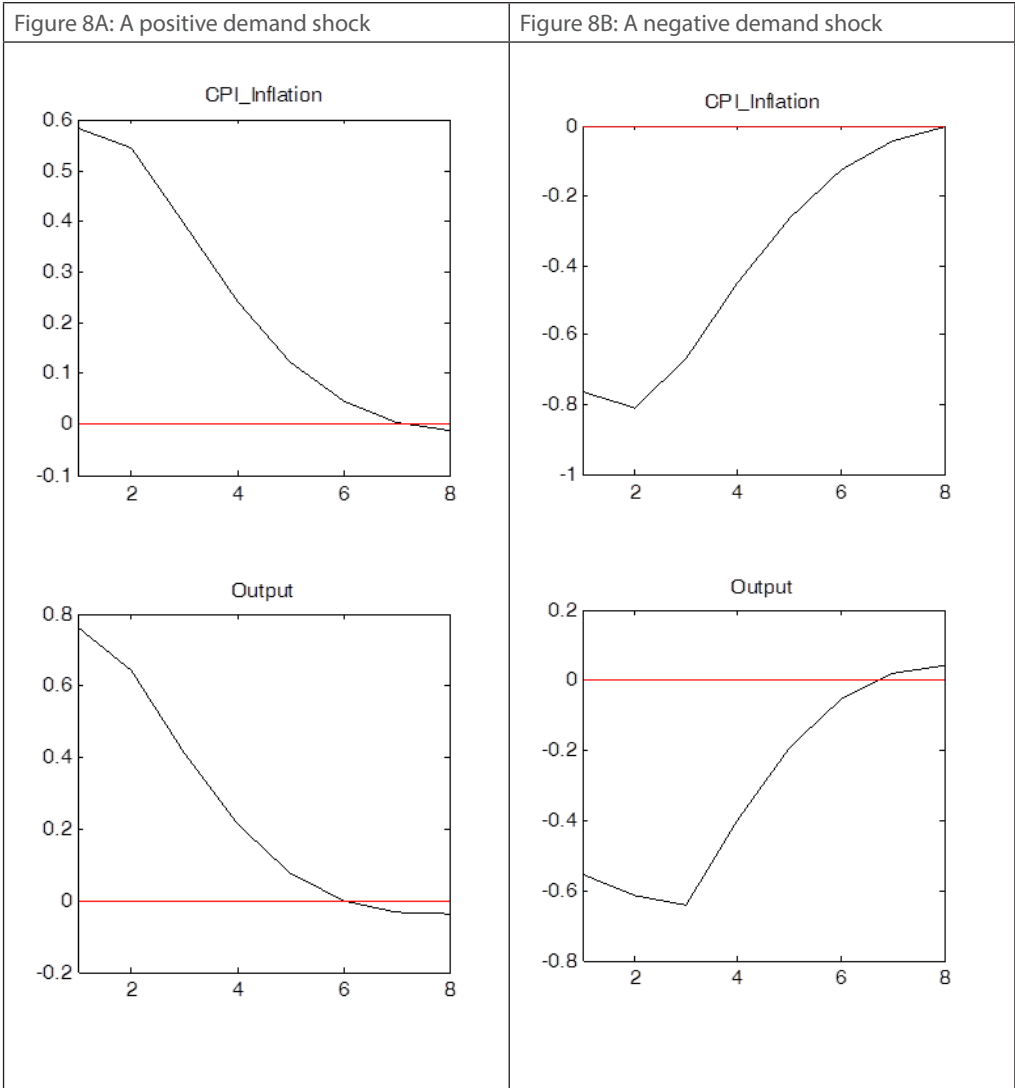
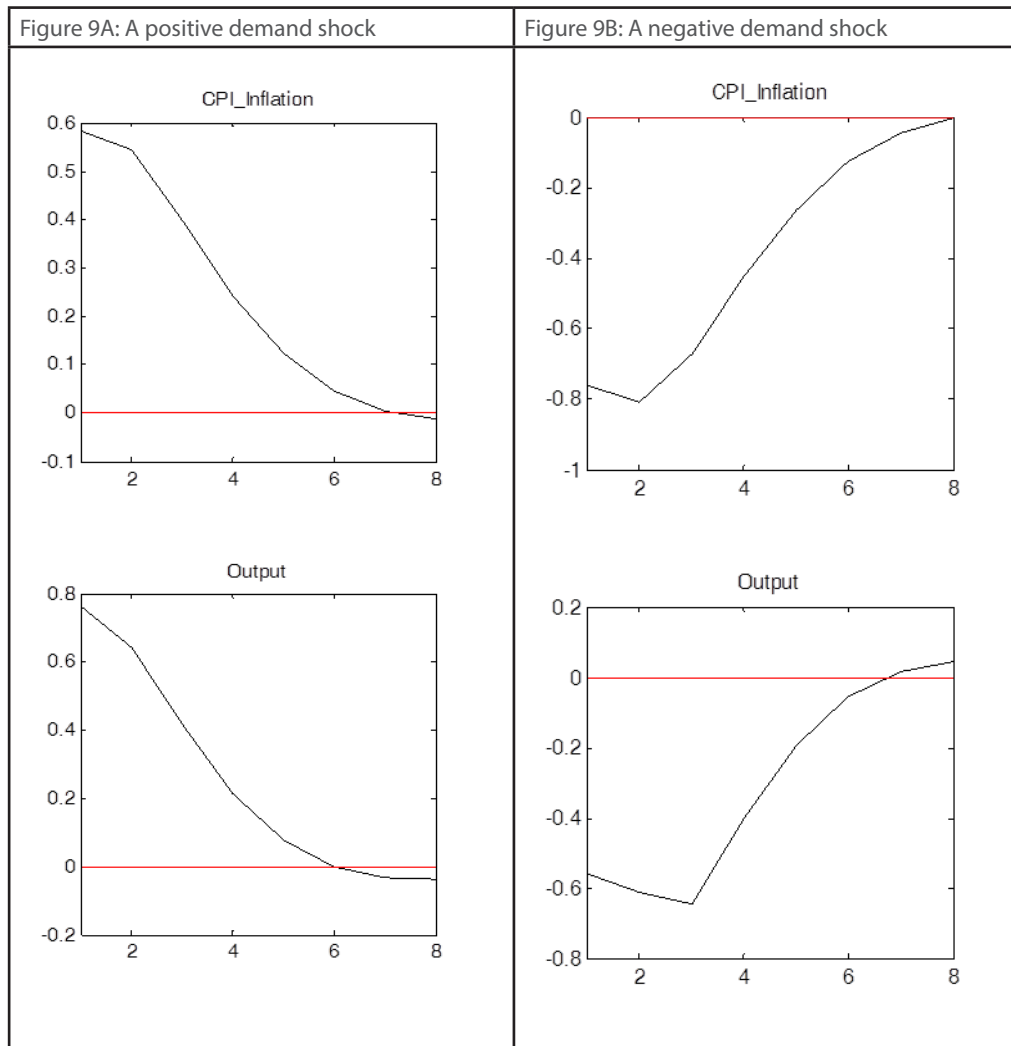


Figure 9: Inflation expectations of trade Unions: Impulse response functions



During the 15 years of inflation targeting in South Africa (2000:3 – 2015:3), CPI inflation has averaged 5.89%. Since the country has targeted 3%–6% inflation, it is evident that although the average rate of inflation has been within the targeted range, it is higher than the average of the target. Indeed, according to Figure 1, the authorities have struggled to keep inflation within the 3–6% band. During the inflation targeting period (2000:4–2015:1), real GDP in South Africa has grown at 0.72% quarter-on-quarter, on average, and the size of the economy in 2015:1 was 48% larger than it was in 2000:3. Real GDP went up in 43 of the 58 quarters and declined in the other 15 quarters. Thus, while the quarter-on-quarter real GDP growth rate has been low, the economy has generally been expanding in most of the quarters. Given the concavity of the country’s Phillips curve and the correspondingly high cost (in terms of unemployment) of bringing inflation down, it is not surprising that the monetary



authorities in the country have only succeeded in keeping inflation near the upper band of the inflation target. The problem is that as the economy continues to register growth quarter-on-quarter, the cost of reducing inflation will continue to increase, making it even harder to bring the inflation rate further down, say to the average of the inflation target.

A concave Phillips curve is consistent with the South African economy where firms are on the whole imperfectly competitive (Aghion, Braun and Fedderke, 2008). If firms have some pricing power and thus the ability and desire to influence their market share, they will be more reluctant to raise prices than to lower them (Filardo, 1998). Thus, the firms may be disinclined to raise their prices when economic activity shows signs of strengthening, but more willing to lower their prices when actual output falls below potential (Nell, 2006). This implies that firms will tend to respond to an increase in economic activity with more muted price changes and large output changes than to a similar decrease in economic activity (Filardo, 1998).

## 6. Conclusion

This paper set out to investigate the inflation-output trade-off in South Africa during the country's inflation targeting period with the objective of establishing whether the country's Phillips curve is symmetric or asymmetric, and in the case of the latter, whether it is convex or concave. South Africa adopted inflation targeting as a monetary policy framework in February 2000, with 3%–6% inflation as the target range. However, the country's monetary authorities have struggled to keep inflation within the targeted band.

Estimation of a variant of the inflation-expectations augmented Phillips curve using the Generalized Method of Moments approach on quarterly frequency data for the period 2000:3 to 2015:1 reveals that South Africa's Phillips curve is concave asymmetric. This finding is replicated in a calibrated New Keynesian small open economy model for South Africa akin to that of Steinbach, Mathuloe and Smit (2009).

Concavity of the country's Phillips curve implies declining sensitivity of inflation to the strength of the economy, suggesting that any given change in inflation requires an increasingly larger adjustment in output (Filardo, 1998). Using expected inflation data from different population groups, we carried out separate regressions for different population groups (all surveyed participants; business representatives; financial analysts; and trade unions) and the results are consistent in all cases. This finding, consistent with Nell (2006), indicates that in South Africa, the response of inflation to a positive demand shock is smaller than its response to a negative demand shock of similar magnitude. A low-cost option to disinflation in this scenario is the 'cold turkey' or 'hard landing' (as opposed to gradualism), an approach that attempts to reduce inflation as quickly as possible towards the target.

The regression results also show that expected inflation exerts a positive and statistically significant effect on current inflation. This finding has important policy implications. Since South Africa is inflation targeting, it is essential that inflation expectations are appropriately anchored. To achieve this, the authorities may have to commit to keep inflation within the targeted band. Economic agents, in turn, will adjust their expectations accordingly and the authorities will be able to achieve and maintain a targeted rate of inflation, which can be maintained as long as the authorities do not renege on their commitment.

## Notes

1. The period 2000 to 2013 was practically normal for South Africa. Besides the 2007-2008 global financial crisis, which did not have any significant adverse effects on the economy, there were no other occurrences with a notable negative impact on the country's macroeconomic variables.
2. We experimented with both negative and positive output gaps. We also experimented with a regression of two equations, one with positive output gap data and the other with negative output data. In either case, we found ourselves caught in a trap of inadequate degrees of freedom. This led us to the adoption of the model with two conjoined linear functions, where the first is a linear Phillips curve and the second is a positive output gap. This approach is consistent with most of the literature (Clark, Laxton and Rose, 1996; Razzak, 1997; Schaling, 1999).
3. The model is built against New Keynesian norms. Thus, it is a macroeconomic model constructed within a general equilibrium framework with solid micro-foundations of macroeconomics; it portrays nominal wage and price rigidities, and the markets are imperfectly competitive.
4. The reason we assume that all government debt is held by households is to keep the model as simple as possible (while retaining the important elements of the model) so that we do not lose sight of the primary objective of the study.
5. Tables 2 and 3 show that there is no evidence of inertia in the inflation dynamics in South Africa. When the lag of inflation is used as a proxy for inflation expectations, however, it is positive and significant (Table 4). This should not be confused with the existence of inflation inertia. The lag of inflation becomes significant when the variable that directly measures inflation expectations is not included because inflation expectations are now captured by the lagged inflation (Table 4). If the lagged inflation, used as a measure of inflation expectations was capturing inertia, then it should remain significant when inflation expectations are measured directly and separately (Tables 2 and 3).

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