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Inflation or output targeting? Monetary policy appropriateness in South Africa

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Introduction

The South African Reserve Bank (SARB) implements its monetary policy objective of inflation targeting based on the notion of a Phillips curve (PC). The design and implementation of the monetary policy have thus been based on the idea of a trade-off between inflation and output growth (du Plessis and Burger, 2006). The current monetary policy instrument of repo rate seeks to target inflation by constraining economic growth and may be entirely inappropriate if the trade-off predicted by the PC were not existent in South Africa.

The current controversy regarding the targeting of an inflation rate stems from this uncertainty and fuels the argument of the Congress of South African Trade Unions (COSATU), that the SARB should be targeting employment and output rather than inflation (Epstein, 2005). This is especially so as South Africa has one of the highest levels of unemployment in the world and has recorded lackluster economic growth in recent times. It is therefore critical to test the existence of Philips curve in South Africa.

The objective of this paper is to determine whether a stable PC exists in South Africa and to ascertain whether backward-looking or forward-looking components determine inflation dynamics, using a hybrid New Keynesian Phillips Curve (HNKPC) model.

We estimate a HNKPC model for South Africa and observe its sensitivity jointly to proxy variables, data frequency and estimation techniques. This is relevant because various studies have shown the

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sensitivity of the estimates of a PC to various variable measurements, data frequency and econometric techniques. Although previous studies have already investigated the existence of a PC in South Africa, there is no consensus on the conclusions. Moreover, while many studies have considered dynamic models, only Malikane, 2013, explored the HNKPC using an appropriate GMM technique in the South African context (though with a different set of variables than the present study).

The rest of the paper proceeds as follows: the development of the HNKPC model and the relevant literature for the case of South Africa are presented in the next section. Section 2 explores the micro foundations of our HNKPC model, as well as the methodology used. This is followed by a description of the data used, in section 3, while the results are discussed in section 4. Section 5 concludes, with a summary of findings and policy recommendations.

1. Brief literature review

Although an inflation expectations variable was fully integrated into estimates of the PC in the late 1960s to mid-1970s, criticisms against using adaptive-expectations and error-learning models (the so-called sticky prices approach) as expectations-generating mechanisms, led to the rational expectations approach and the natural rate of unemployment hypothesis, developed by Phelps, 1968, and Friedman, 1968. Their contention, contrary to that of traditional PC models, was that there is no trade-off between the unemployment rate and the inflation rate both in the short and the long runs, although others (like Humphrey, 1985; King, 2008) believed that there could be a trade-off in the short run as a result of "inflationary surprises".

Modigliani and Papademos, 1975, developed the non-accelerating inflation rate of unemployment (NAIRU) concept within a PC framework. The NAIRU does not imply any commitment to a stable inflation rate over time, and was seen as an improvement over the concept of a natural rate of unemployment. According to it, when the actual unemployment rate equals the NAIRU, the change in the inflation rate will be zero (Fuhrer *et al.*, 2009).

Especially when the rate of inflation in the USA moved below the rate of the NAIRU, the concept of a NAIRU started being seen as flawed, with uncertain estimates in the early to mid-1990s (Mishkin and Estrella, 1999). According to Fuhrer *et al.*, 2009, the uncertain estimates would confirm the unreliability of the NAIRU in providing assistance to monetary policy makers. A problem of uncertainty in the NAIRU is its very modeling, whereby the correct form of model specification is not known. The NAIRU came to be seen as a short-run rather than a long-run concept of unemployment.

Subsequently, following the extension of the new Keynesian PC models through the inclusion of terms for expected inflation, the focus shifted from wage inflation to price inflation. Researchers concerned themselves with changes in the mark-up of prices over wages. Therefore, the price-change version of models based on the PC later incorporated changes in the other input prices too.

The New Keynesian Phillips Curve (NKPC), which incorporates expected inflation, was later criticized as it was found to be inconsistent with empirical studies (Furher and Moore, 1995; Rudd and Whelan, 2007; Dufour *et al.*, 2006; and Hornstein, 2007). Moreover, Keynesian economics was believed to lack good micro-foundations, because the Keynesian underpinnings believed in a complex economy characterized by oligopolistic market structures. This is where firms are confronted with market rigidities with horizontal short-run marginal cost curves. By contrast, New Classical economists believed in an economy with monopolistic firms and consumers (Lipsey and Scarth, 2011).

Other criticisms of NKPC models include their inability to explain the dynamic behavior of output and inflation, as well as to exhibit enough inflation and output persistence despite the assumption of price stickiness (Lendvai, 2004).

In the seminal works by Taylor, 1980, and Calvo, 1983, price setting forward-looking firms were incorporated into the NKPC model, while Gali and Gertler, 1999, combined the NKPC model with backward-looking effects, thereby developing a “hybrid” NKPC model (HNKPC). The assumption on which NKPC models were based relates to agents facing high decision-making costs. In the HNKPC, agents use a simple rule-of-thumb to follow the optimizing agents, with a one-period time lag. Therefore, the HNKPC includes both past and actual inflation terms, as well as a term for inflation expectations.

Thus, the motivation of our study to use a HNKPC model as the estimation model stems not only from the fact that it is a commonly-used and widely-accepted model in mainstream macroeconomics, but also because the HNKPC allows us testing the existence of a PC as well as understanding inflation dynamics better as a forward and/or backward looking phenomenon.

However, empirical estimations of HNKPC models have yielded different results. Some studies, using GMM estimation techniques, found a significant forward-looking inflation term (Gali and Gertler, 1999), while others found evidence of a backward-looking inflation (Basarac *et al.* , 2011), and yet others found mixed components (Linde, 2005). Similarly, while some studies that used ECM techniques found that inflation is backward-looking (Bhanthumnavin, 2002; Hodge, 2002), others found it to be forward-looking (Olubusoye and Oyaromade, 2008).

In general, given that different results were obtained for various countries using different or identical econometric techniques, so far no technique has been proven as clearly superior to the other, although it may also be that different countries have different inflation dynamics.

In the estimates, conflicting results were obtained concerning the output gap variable too. While some studies found output gap to be statistically significant and with a sign consistent with the theoretical model (Loungani and Swagel, 2001; Fedderke and Schaling, 2005; Burger and Marinkov, 2006; Rudd and Whelan, 2007; and Basarac *et al.*, 2011), others found otherwise (Gali and Gertler, 1999; Rudd and Whelan, 2005). Likewise, different results were obtained based on whether quarterly or annual data series were used. Many studies used quarterly data (Gali and Gertler, 1999; Linde, 2005; Rudd and Whelan, 2005; Basarac *et.al*, 2011); while Fuhrer, 1997, and Roberts, 2001, argue that the HNKPC model does not give the true inflation dynamics when quarterly data are used.

Loungani and Swagel, 2001, used a VAR model to examine the interrelationship of variables, including output gap, to current inflation in 53 developing countries. Their results show that inflation in African countries exhibits a backward looking behaviour. Basarac *et al.*, 2011) estimated a hybrid Phillips curve for nine transition economies, using both a dynamic fixed effect (DFE) and a Pooled Mean Group (PMG) approach, while GMM was used to test for robustness. They also used the output gap as a proxy for real marginal cost. Their results show that inflation i.s backward-looking, as this term has larger magnitude and it is highly statistically significant. The output gap term was found to be positive and statistically significant for all the estimate models. They therefore concluded that the HNKPC model with the output gap as an explanatory variable is consistent with theory in all the countries considered.

Many studies have examined the applicability of the PC in South Africa, dating as far back as more than four decades, without reaching a consensus. Different types of variables as well as different techniques were used to determine the current inflation level. While some of these studies have found evidence of a stable PC in South Africa (Krogh, 1967; Hume, 1971; Hodge, 2002), others, like Burger and Marinkov, 2006, and Malikane, 2013, refute this claim.

The different measures used range from the Gross Domestic Product (GDP) deflator (Fedderke and Schaling, 2005) to the Consumer Price Index (CPI) and nominal wages (Hodge, 2002; Burger and Marinkov, 2006). Using PC-based models, some studies considered whether inflation is a necessary condition for faster economic growth (Nell, 2000, and Burger and Marinkov, 2006).

Hodge, 2002, did not find evidence of a trade-off between unemployment gap and inflation in South Africa, using the traditional New Keynesian PC model with a single-equation error correction model (ECM). The study, however, found a highly significant positive relationship between inflation and output growth. This therefore would imply that a trade-off between inflation and the unemployment gap does not exist, but there is a trade-off between inflation and output growth. In addition, in the study the variation in inflation was found to be dependent on its lagged values, thus inflation was found to be backward looking.

By contrast, Fedderke and Schaling, 2005, adopted a vector error correction model (VECM) to estimate a pure NKPC model for South Africa, using quarterly data from 1963Q4 to 1998Q2. They generated a measure of inflation expectations by using adaptive expectations, rational expectations and the Hodrick-Prescott filter approach, and found South African inflation to be forward-looking.

In conclusion, the studies developed so far demonstrate a mix of results and conclusions. Using different econometric techniques, measurements and data frequency, different conclusions were reached on whether the trade-off implied by the PC exists, and whether inflation is forward-looking or backward-looking.

We therefore deem it necessary to test the sensitivity of our results to various variable measurements, data frequency and estimation techniques; moreover, we use two different estimation techniques, OLS and GMM, unlike all previous studies which only used one.

2. Micro foundation of HNKPC and methodology

2.1. HNKPC

The HNKPC is a widely accepted model in mainstream macroeconomics, derived from the New Keynesian model. It assumes that monopolistically-competitive firms are confronted with short run price rigidity (Gali and Gertler, 1999; Basarac *et al.*, 2011). The baseline model of the HNKPC relates inflation to its lag, expectations, and real marginal costs. Therefore, the hybrid Phillips curve, which includes an inflation inertia component, is obtained by combining the aggregate price index, the adjusted price index and the prices set by forward-looking and backward-looking firms. Thus, Gali and Gertler's hybrid Phillips curve model is:

$$\bar{\pi}_t = \gamma_b \bar{\pi}_{t-1} + \gamma_f E_t(\bar{\pi}_{t+1}) + \lambda_s \bar{s}_t \,, \qquad 1)$$

where $\bar{p}_t$ is inflation at time *t*, $\bar{\pi}_{t-1}$ is lagged inflation, $\bar{\pi}_{t+1}$ represents inflation expectations and $\bar{s}_t$ marginal costs; γ and λ are the coefficients. The hybrid PC includes inflation inertia if $\gamma_b > 0$, i.e. the fraction of firms with backward-looking pricing behavior introduces inflation inertia.

A HNKPC model has both inflation expectations and demand pressure variables. The demand pressure variable may be measured by the labour share (or real unit labour costs) as a proxy for marginal costs, as in the Gali and Gertler, 1999, model. However, Agenor and Bayraktar, 2010, argued that the use of labour share, especially in the case of a developing country, may result in unreliable inferences as a result of errors in the data. These errors arise from the fact that there are large numbers of individuals in the labour force who are involved in the informal economy and whose incomes are thus not captured in the data. They consequently proposed a model that replaces the labour share with the output gap, Malikane, 2012.

They thus assume that empirically $\bar{s}_t = ky_t$, where the latter term is the output gap, and the model becomes:

$$\bar{\pi}_t = \gamma_b \bar{\pi}_{t-1} + \gamma_f E_t(\bar{\pi}_{t+1}) + \beta y_t \qquad (2)$$

where $\beta = k\lambda$.

In this work we estimate a PC model by incorporating the HNKPC model as given in equation 2.

In addition, output growth will be used in order to validate the results of the output gap model, while also following Lucas, 1973, and Hodge, 2002. Another reason for the use of output growth is that output-gap is believed to be ridden with measurement errors resulting from the inability to observe potential output.

The common belief under New Classical theory is that there exists a negative relationship between inflation and output growth, whereby a high output growth is needed in order to have low inflation (Gokal and Hanif, 2004). However, following the Keynesian idea of the PC trade-off, in order to reduce inflation and keep it low, some amount of output growth must be sacrificed, indicating a positive (and significant) relationship between the inflation rate and output growth.

Neither a positive or negative output gap is ideal. This is because while a positive output gap shows that an economy operates at an inefficient rate by overworking its resources, a negative output gap equally shows the inefficiency of an economy by under-utilizing its resources (Jahan and Mahmud, 2013).

Fuentes *et al.*, 2007, indicate that a positive relationship exists between inflation and the output gap, because a positive output-gap indicates that inflationary pressures are building up. An alternative theory indicates that the output gap is expected to be negatively related to inflation, as an indication of the trade-off in the PC (Batini *et al.*, 2005). This is because a positive output gap is an indication that inefficiencies increase at an increasing rate when output is high. However, a negative output gap shows that inefficiencies in production increase at a decreasing rate. This means that the inflation rate will decline if output gap increases; that is, increased inefficiencies at an increasing rate will cause the inflation rate to fall. Thus, according to the trade-off indicated by the PC, the coefficient of the output gap is expected to be negative.

In summary, we observe that different theories predict the relationship between output and inflation to be positive, negative or non-existent. Nevertheless, the monetary policy in South Africa is based on the belief of the trade-off between inflation and output growth and hence we will test the null hypothesis that the PC exists in South Africa. Thus, the expected sign in the HNKPC model is negative for output gap and positive for output growth.

2.2 Estimation methods

All variables were firstly tested for stationarity using the Augmented Dickey-Fuller (ADF), Phillips-Perron (PP) and the Dickey-

Fuller GLS (DF-GLS) detrended[1] tests. Then, we examined the possible long-run relationship between them.

The stationarity test results are presented in the Appendix (Tables A1 and A2). For the annual series, only the inflation rate and expected inflation, measured by the HP-filter, were found to be integrated of order one, I(1). Output growth and the output gap were found to be integrated of order zero, I(0). The variables in quarterly series were tested for stationarity and were all found to be stationary at levels. Thus, there was no need to test for co-integration among the variables of the quarterly data series.

We could not make use of the standard Johansen co-integration test because of the inclusion of a backward-looking component in the HNKPC model. For the same reason, we could not use the Vector Error Correction Model (VECM) method. The autoregressive distributed lag (ARDL) could also not be adopted as an approach to co-integration due to the problem of having backward looking inflation as an explanatory variable. Hence, the best alternative approach to co-integration used in this study is the Fully-Modified Ordinary Least Squares (FMOLS), popularized by Phillips and Hansen, 1990) to formally test the presence of possible long-run co-integrating relationships among the variables. Some of the advantages of using this technique are that the FMOLS estimator employs a semi-parametric correction, which eliminates the bias resulting from endogeneity. This technique performs better in small samples and also incorporates the corrections for possible serial correlation. FMOLS does not depend on lag length, the *t*-ratios obtained from FMOLS are asymptotically normally distributed and the results are robust.[2]

The cointegrating equation is shown in equation (3) below (where μ_t is the error term).

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[1] Since this study includes two dummy variables, the above tests were used instead of the Zivot-Andrews test of unit root, which is used in the case of unknown structural breaks.

[2] For more details on FMOLS, see Borland and Ouliaris, 1994.

$$\overline{\pi}_t = \gamma_b \overline{\pi}_t^b + \gamma_f \overline{\pi}_t^e + \lambda_y y_t + \lambda_{IT} D\_IT + \lambda_{FC} D\_FC + \mu_t \qquad (3)$$

Ordinary Least Squares (OLS) estimates are the Best Linear Unbiased estimates (BLUE) in their class of linear estimates. OLS however, assumes Cov(u_i, X_i) = 0, which may be violated in the presence of reverse causality between variables like inflation and output growth, leading to a problem of endogeneity. We therefore follow up the OLS estimation by using GMM estimation. In most economic models, one or more explanatory variables are found to be endogenous; hence, the two main reasons for the application of a GMM technique in this study are to correct for autocorrelation of the residuals in a standard OLS estimation and to address the possible problem of endogeneity.

3. Data

3.1. Model specification and data

We explore the existence of the PC in South Africa using equation (2). Robustness will be tested by using different variable proxies, estimation techniques and data frequency. The models estimated are:

Including output growth:

$$\overline{\pi}_t = \underset{+}{\gamma_b} \overline{\pi}_t^b + \underset{+}{\gamma_f} \overline{\pi}_t^e + \underset{+}{\lambda_y} \overline{y}_t + \underset{-}{\lambda_{IT}} D\_IT + \underset{+}{\lambda_{FC}} D\_FC + \mu_t \qquad (4)$$

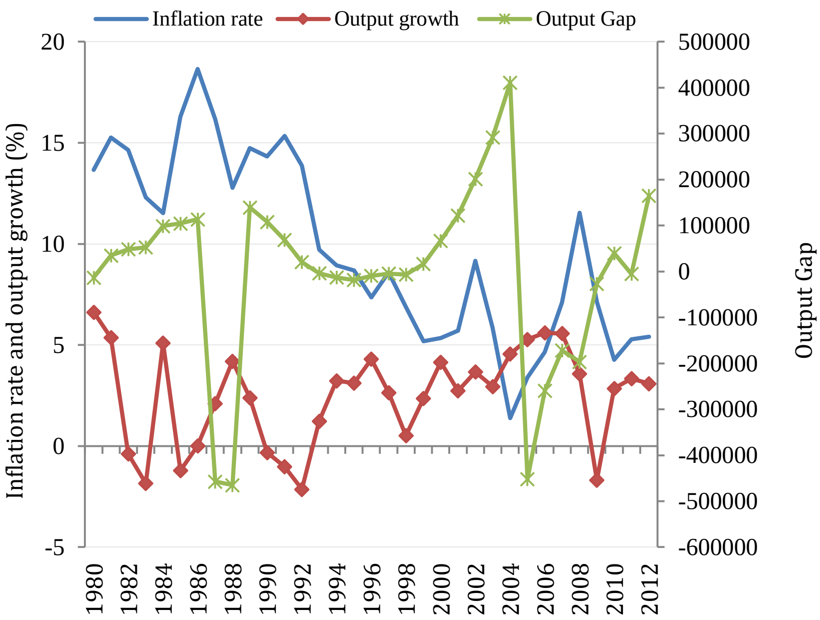
Including the output gap:

$$\overline{\pi}_t = \underset{+}{\gamma_b} \overline{\pi}_t^b + \underset{+}{\gamma_f} \overline{\pi}_t^e + \underset{-}{\lambda_y} y_{gap(t)} + \underset{-}{\lambda_{IT}} D\_IT + \underset{+}{\lambda_{FC}} D\_FC + \mu_t \qquad (5)$$

where $\overline{\pi}_t^b$ is the lag of inflation, which captures the backward-looking component of inflation expectations. Inflation expectations are further measured in two other ways: a demand-side variable that captures output growth, $\bar{y}_t$ (expected to have a positive relation to inflation under PC), and one for the output gap, y_{gap} (expected to have an inverse relation to inflation under PC). HNKPC models are usually estimated without a constant term, as in equations (4) and (5).

For period considered, the demand-side variables, output growth and output gap, are presented along with the inflation rate in figure 1. The variables inflation rate and output gap appear to move closely together. The co-movement of output growth and inflation is visually less evident.

Figure 1 – *Annual inflation, output growth and the output gap*



Source: International Monetary Fund, *International Financial Statistics* (*IMF/IFS*).

Two time dummy variables are introduced, to account for two major events during the period of the study, i.e. the adoption of inflation targeting as the officially monetary policy of the South African

Reserve Bank in 2000 (D_IT), and the global financial crisis in the period 2008-2011 (D_FC). Thus, the two dummies are defined as follows:

$$D\_IT = \begin{cases} 1 \; IT \; from \; 2000 \; onwards \\ 0 \; othrerwise \end{cases} \tag{6}$$

$$D\_FC = \begin{cases} 1 \; for \; 2008 \; to \; 2011 \; financial \; crisis \\ 0 \; otherwise \end{cases}$$

Annual data from 1980 to 2012 and quarterly data from 1980Q1 to 2013Q3 and separately for 2000Q3 to 2013Q2 were used, because data from inflation surveys are only available from 2000Q3 to 2013Q2.

Indeed, we use three different ways of obtaining inflation expectations in South Africa. These are: the Hodrick-Prescott filter, ARIMA estimation of the time series, and data from surveys carried out by by the Bureau of Economic Research (BER) and the Reuters Inflation Expectations (RIE). Data on inflation expectations from the BER survey are available quarterly starting from the first quarter of 2000, while the data from RIE are available monthly from December 1999 (Ehlers and Steinbach, 2007). The survey on inflation expectations conducted by BER is published on behalf of the SARB. This survey is based on four groups of respondents: households, the business sector, the financial sector and the trade union sector. Although these surveys are useful, they are however prone to biases. Such biases include forecasters not revealing their true forecasts, lack of sufficient incentives that will allow them make use of the available resources when answering the survey questionnaire and the lack of attaching weights to responses according to the number of respondents and who they are (Woodward, 1992).

The three different measures of inflation expectations are presented in figure 2, using quarterly data from 2003Q3 to 2013Q2. As shown, the inflation expectations from surveys data show more variability than inflation expectations based on the Hodrick-Prescott filter and the ARIMA model. However, we will consider all measures as a robustness check.

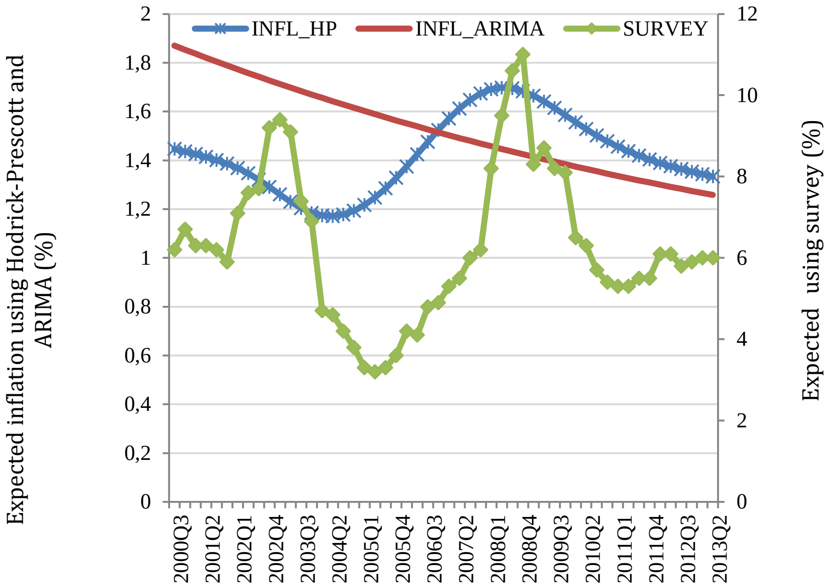
While three different measures of inflation expectations were separately included in the regressions alongside the output gap and output growth using quarterly data, only the Hodrick-Prescott filter measure of inflation expectations was used to estimate annual data. Thus, the models to be estimated are as follows.

Annual series:

Model 1:

$$\bar{\pi}_t = \gamma_b \bar{\pi}_t^b + \gamma_f \bar{\pi}_t^e (HP) + \lambda_y y_{gap} + \lambda_{IT} D\_IT + \lambda_{FC} D\_FC + \mu_t \quad (7)$$

Figure 2 – *Three measures of inflationary expectations (2000Q3 to 2013Q2)*



Source: International Monetary Fund, *International Financial Statistics* (*IMF/IFS*).

While three different measures of inflation expectations were separately included in the regressions alongside the output gap and output growth using quarterly data, only the Hodrick-Prescott filter measure of inflation expectations was used to estimate annual data. Thus, the models to be estimated are as follows.

Annual series:

Model 2:

$$\bar{\pi}_t = \gamma_b \bar{\pi}_t^b + \gamma_f \bar{\pi}_t^e (HP) + \lambda_y \bar{y}_t + \lambda_{IT} D\_IT + \lambda_{FC} D\_FC + \varepsilon_t \tag{8}$$

Quarterly series:

Model 3:

$$\bar{\pi}_t = \gamma_b \bar{\pi}_t^b + \gamma_f \bar{\pi}_t^e (survey) + \lambda_y y_{gap} + \lambda_{IT} D\_IT + \lambda_{FC} D\_FC + \mu_t \tag{9}$$

Model 4:

$$\bar{\pi}_t = \gamma_b \bar{\pi}_t^b + \gamma_f \bar{\pi}_t^e (survey) + \lambda_y \bar{y}_t + \lambda_{IT} D\_IT + \lambda_{FC} D\_FC + \varepsilon_t \tag{10}$$

Model 5:

$$\bar{\pi}_t = \gamma_b \bar{\pi}_t^b + \gamma_f \bar{\pi}_t^e (HP) + \lambda_y y_{gap} + \lambda_{IT} D\_IT + \lambda_{FC} D\_FC + \mu_t \tag{11}$$

Model 6:

$$\bar{\pi}_t = \gamma_b \bar{\pi}_t^b + \gamma_f \bar{\pi}_t^e (HP) + \lambda_y \bar{y}_t + \lambda_{IT} D\_IT + \lambda_{FC} D\_FC + \varepsilon_t \tag{12}$$

Model 7:

$$\bar{\pi}_t = \gamma_b \bar{\pi}_t^b + \gamma_f \bar{\pi}_t^e (ARIMA) + \lambda_y y_{gap} + \lambda_{IT} D\_IT + \lambda_{FC} D\_FC + \mu_t \tag{13}$$

Model 8:

$$\bar{\pi}_t = \gamma_b \bar{\pi}_t^b + \gamma_f \bar{\pi}_t^e (ARIMA) + \lambda_y \bar{y}_t + \lambda_{IT} D\_IT + \lambda_{FC} D\_FC + \varepsilon_t \tag{14}$$

Table 1 provides the variables' definitions and frequency. All variables were sourced from the database of the International Monetary Fund, *International Financial Statistics* (*IMF/IFS*).

4 Empirical results

4.1. Co-integration and OLS results

The quarterly data series are not tested for co-integration because they were all stationary at levels (table A2 in appendix). Since the variables for the annual series were integrated of different orders (table A1 in appendix), co-integration among the variables were tested using the Fully-Modified Ordinary Least Squares (FMOLS) approach to co-integration. The co-integration tests results showed that there is a stationary linear combination of these non-stationary variables (table 2), indicating a long-run relationship. Although the demand side variable, the output-gap, has the expected sign, it is not statistically significant. Output growth is also not statistically significant. While inflation dynamics seem to be both forward and backward looking, at high levels of significance, the inflation expectations variable appears to have a higher magnitude, indicating a more pronouncedly forward looking behavior in both models in the long-run.

Having established co-integration for the annual series, we run co-integrating regression models using OLS (models 1 and 2), reported in table 3. The results show that there is no trade-off between the demand-side variables and inflation, as would be suggested by the PC. Output gap is not statistically significant in any of the models, except model 3 (where the positive sign of the coefficient indicates no trade-off anyways).

Thus, on the basis of an OLS analysis we would conclude that there is no evidence of a PC in South Africa, irrespective of the demand-side measures or data frequency used. The same findings were obtained by Hodge, 2002, who used an error correction mechanism to estimate the traditional PC for South Africa.

Table 1 – *Variables and definitions for the Hybrid NKPC model*

Variable	Variable definition	Frequency
Inflation $\overline{\pi}$	Inflation rate, derived from the consumer price index at 2005 prices	1980 to 2012; 1980Q1 to 2013Q3
Lagged inflation $\overline{\pi}_t^b$	Lag of the inflation rate	1980 to 2012; 1980Q1 to 2013Q3
D_IT	Dummy variable capturing the adoption of inflation targeting in year 2000	1980 to 2012; 1980Q1 to 2013Q3
D_FC	Dummy variable, capturing the period of global financial crisis, 2008 to 2011.	1980 to 2012; 1980Q1 to 2013Q3
Measures of Expected inflation variables, $\overline{\pi}_t^e$		
i) Survey, $\overline{\pi}_t^e$ (survey)	i) Bureau of Economic Research Survey data	i) 2000Q3 to 2013Q2
ii) Hodrick Prescott (HP) filter, $\overline{\pi}_t^e$ (HP)	ii) Hodrick Prescott (HP) filter approach (Fedderke and Schaling, 2005)	ii) 1980 to 2012; 1980Q1 to 2013Q3
iii) ARIMA, $\overline{\pi}_t^e$ (ARIMA)	iii) ARIMA is obtained using the forecast approach	ii) 1980Q1 to 2013Q3
Demand side variables		
i) Output gap y_{gap}	i) difference between actual and potential output, using the Hodrick Prescott (HP) trend	i) 1980 to 2012; 1980Q1 to 2013Q3
ii) Output growth $\overline{y}$	ii) growth rate of real GDP: $\Delta\overline{y} = \left(\frac{y_t}{y_{t-1}}\right) - 1$	ii) 1980 to 2012; 1980Q1 to 2013Q3

Table 2 – *Results of FMOLS co-integration tests, dependent variable: inflation rate (annual data: 1980 to 2012)*

	Model 1	Model 2
$\bar{\pi}_t^b$	0.36***	0.31***
	(0.10)	(0.12)
$\bar{\pi}_t^e(HP)$	0.64***	0.71***
	(0.10)	(0.13)
$\bar{y}_t$		-0.09
		(0.09)
y_{gap}	-0.000001	
	(0.000001)	
Phillips-Ouliaris test	Tau stat: -4.59***	Tau stat: -4.41**
Hansen Instability test	Lc stat: 1.97***	Lc stat: 1.64**

Notes: in all tables *** denotes statistical significance at 1%, ** at 5%, and * at 10%, respectively; standard errors are reported in parentheses. The model, estimated in a non-differenced form, includes an intercept with no additional deterministic trend. Null hypothesis is that series are not co-integrated.

Although inflation dynamics in South Africa seem to be relatively more forward-looking, the results also shows a mix in terms of the significance of both components. Forward-looking components are usually significant, except in models 3 and 4 where the survey measure of inflation expectations is used. The backward-looking variable is statistically significant in most quarterly data models.

The results reaffirm the FMOLS findings that the forward-looking component has larger magnitudes compared to the backward-looking inflation component, except when using survey measures of inflation expectations. This shows that, according to both FMOLS and OLS results, economic agents are both rational and adaptive in predicting inflation, although the sensitivity of the HNKPC model to different measures of inflation expectations is evident.[3]

[3] All models passed the usual battery of diagnostic tests, as shown in table A3 in appendix.

Table 3 – *OLS estimation results, dependent variable: inflation rate*

	Annual data: co-integrated regression		Quarterly data: stationary series					
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
$\overline{\pi}_t^{\,b}$	0.26	0.14	0.16	0.37**	0.25***	0.24***	0.41***	0.39***
	(0.18)	(0.20)	(0.16)	(0.15)	(0.08)	(0.09)	(0.08)	(0.08)
$\overline{\pi}_t^e(HP)$	0.74***	0.89***			0.74***	0.78***		
	(0.19)	(0.22)			(0.09)	(0.09)		
$\overline{\pi}_t^e(survey)$			0.10*	0.09				
			(0.06)	(0.06)				
$\overline{\pi}_t^e(ARIMA)$							0.57***	0.61***
							(0.08)	(0.09)
$\bar{y}_t$		-0.23		0.09		-0.11		-0.12
		(0.17)		(0.22)		(0.09)		(0.10)
$y_{gap(t)}$	-0.0000005		0.00002***		0.0000002		-0.0000002	
	(0.000002)		(0.00001)		(0000003)		(0.0000004)	
D_IT	-0.199	0.50	0.63**	0.37	0.14	0.23	0.07	0.16
	(0.82)	(0.96)	(0.30)	(0.40)	(0.15)	(0.17)	(0.17)	(0.18)
D_FC	0.92	0.68	-0.10	-0.26	-0.32	-0.39	-0.12	-0.18
	(1.36)	(1.33)	(0.28)	(0.32)	(0.27)	(0.28)	(0.29)	(0.29)
Adj.-R^2	0.79	0.81	0.30	0.19	0.57	0.57	0.52	0.52
DW-*d* stat	1.85	1.80	1.80	1.89	1.95	1.91	2.01	1.97

4.2. Generalized Method of Moments (GMM) results

Establishing valid and reliable results requires that robustness checks be carried out. This can be done by either using the same technique but changing the variables, or using a different technique. In this section we therefore use a GMM technique to further affirm the OLS results above. Valid instruments for estimating the HNKPC model may not be easily identified, but studies, Gali and Getler, 1999; Malikane, 2013) have shown that the instruments that are used must be lagged. This is because the instruments have to be uncorrelated with the residual in the HNKPC model. The instruments were chosen following Gali and Gertler, 1999, Gali *et al.,* 2005, and Nason and Smith, 2008. Results are presented in table 5 below, while diagnostic tests for the validity of the instruments, as well as for normality, endogeneity and stability of the model, are shown in table A4 in appendix.

The GMM technique produces results that lead us to assert that the PC curve does not exist in South Africa (table 4). In model 1, the output growth variable does not have the sign predicted by the PC model: we find a statistically significant inverse relationship with inflation rates, instead of the expected positive relationship. In models 2 and 4, the output gap has a statistically significant positive sign, thus refuting again the hypothesis of a PC. In the other models (3, 5, 6, 7 and 8), output growth and the output gap do not significantly affect inflation.

Therefore, this study concludes that the South African economy does not exhibit a PC during the period of study, based on either the relationship of output gap or of output growth with inflation. These findings are, on one hand, contrary to the results of Hodge, 2002, who found that there is a short-run trade-off between inflation and output growth. On the other hand, our evidence supports his findings of no trade-off when he estimated the relationship between inflation and the unemployment gap.

The GMM results further show mixed evidence on whether inflation is forward-looking or backward-looking in South Africa. Although both components are statistically significant in many instances, the magnitudes of the coefficients of the forward-looking variables are higher than those of the inflation lag variable, when the HP filter and ARIMA are taken as the proxies for inflation expectations. This finding is in line with the study by Fedderke and Schaling, 2005, who used VECM technique, and also found that inflation in South Africa is forward-looking. Thus, one may say that although economic agents in South Africa are both rational as well as adaptive in nature, they seem to be more rational than adaptive.

Furthermore, the results show that HP-filter and ARIMA are better measures of inflation expectations than survey. The coefficients of HP-filter and ARIMA are not only economically significant, having the expected signs; they are also highly statistically significant. Apart from these, they have larger values compared to the value of the inflation lag. Although survey was expected to be the best measure of inflation expectations, the results show otherwise. This may be attributed to the fact that while HP-filter and ARIMA are directly obtained from the inflation rate series, survey data may have limitations. Although the survey is based on four groups of respondents (namely the households, the business sector, the financial sector and the trade union sector) they are prone to biases. Such biases include forecasters not revealing their true forecasts, insufficient incentives that will allow them making use of the available resources when answering the survey questionnaire, and the lack of attaching weights to responses according to the number of respondents and who they are, (Woodward, 1992; Thomas, 1999).

These results show that the HNKPC model is not sensitive to data frequency as no one model give better results of inflation dynamics in South Africa, over the periods of study. This study therefore could not affirm the findings of Fuhrer, 1997, and Roberts, 2001, who argued that the HNKPC model does not give the true inflation dynamics when using quarterly data. Also, between the two dummy variables used, only that capturing inflation targeting, D_IT, is statistically significant in some of the models.

Table 4 – *GMM inflation estimation results*

	Annual data: 1980 – 2012		Quarterly data: 2000Q3 – 2013Q2					
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
γ_b	0.05	0.36***	0.40***	0.22	0.29**	0.28**	0.45***	0.47***
	(0.12)	(0.12)	(0.11)	(0.17)	(0.12)	(0.14)	(0.08)	(0.19)
$\gamma_f(HP)$	1.03***	0.62***			0.66***	0.70***		
	(0.14)	(0.13)			(0.14)	(0.15)		
$\gamma_f(survey)$			0.07	-0.01				
			(0.16)	(0.10)				
$\gamma_f(ARIMA)$							0.53***	0.52***
							(0.09)	(0.19)
$\bar{y}_t$	-0.54**		0.13		0.20		-0.06	
	(0.22)		(0.41)		(0.25)		(0.17)	
$y_{gap(t)}$		0.000003*		0.00002**		- 0.000002		0.000003
		(0.000002)		(0.00001)		(0.000003)		(0.000003)
λ_{IT}	1.34*	0.40	0.57	1.14**	-0.73*	-0.29	0.10	-0.75
	(0.71)	(0.91)	(1.13)	(0.49)	(0.43)	(0.34)	(0.46)	(1.23)
λ_{FC}	0.05	-1.20	-0.84	0.12	1.85	1.07	-0.28	2.02
	(1.26)	(1.44)	(0.69)	(1.00)	(1.48)	(1.39)	(1.00)	(3.67)
R^2	0.80	0.75	0.20	0.31	0.36	0.43	0.53	0.006
Adj.-R^2	0.77	0.72	0.12	0.25	0.34	0.41	0.52	-0.025

Notes: instruments for GDP growth include a constant term, three lags of current inflation, expected inflation (HP-filter, survey and ARIMA), inflation lag and two lags of output growth; instruments for GDP gap: constant term, two lags of current inflation, expected inflation (HP-filter, survey and ARIMA), inflation lag and output gap.

5. Conclusions

This study explores the sensitivity of the HNKPC model to various variable measurements, data frequency and estimation techniques in investigating the existence of an output-based HNKPC in South Africa. The motivation for the study was to inform monetary policy how output affects inflation in South Africa.

The results obtained confirmed that a stable PC does not exist in South Africa. This was demonstrated through various measures of demand-side variables. These findings are robust across estimation methodologies, as well as different measurements of inflation expectations and data frequency. The implication of the finding is far-reaching in the context of the current controversy in South Africa regarding whether the SARB should be targeting inflation or growth. Our findings support the argument that, given the lack of a trade-off between output growth and inflation, growth targeting makes more sense than inflation targeting.

While our findings indicate that economic agents in South Africa are both rational and adaptive in predicting inflation, the results clearly indicate the dominance of forward looking variables over the backward looking ones in determining inflation. This is contrary to the findings of Malikane, 2012, that backward-looking processes determine inflation in South Africa. The conclusions, however, are seen to be sensitive to the measure of inflation expectations, with the survey measure of inflation expectations not yielding meaningful indications. We attribute this to the limitations of the survey methodology as our results with two other measures of inflation expectations are consistent across methodologies and data frequencies.

While our analysis indicates no trade-off between inflation and output growth in South Africa, leading to the recommendation that monetary authorities give more attention to increasing output without worrying about the inflation effect of output growth, it is imperative to also check for consistent results with different model specifications by including monetary, fiscal and structural variables. This has been beyond the scope of the current analysis but forms the agenda for further research in keeping with the view of Gruen *et al.*, 1999, that, for the trinity of benefits[4] of PC to hold, it must be augmented to allow for the effects of additional supply side, monetary and fiscal variables.

Appendix

Table A1 – *Stationarity tests: annual data (1980–2012)*

	LEVELS			FIRST DIFFERENCE			
	ADF	PP	DF-GLS	ADF	PP	DF-GLS	Decision
$\overline{\pi}$	-2.830	-2.786	-2.850	-2.492	-8.930***	-3.297**	I(1)
$\overline{\pi}_t^e$ (HP)	-4.586***	-1.276	-1.535	-4.583***	-1.435	-4.007***	I(1)
$\overline{y}$	-4.526***	-4.548***	-3.928***	NA	NA	NA	I(0)
y_{gap}	-3.782**	-3.494*	-3.915***	NA	NA	NA	I(0)

[4] Stiglitz, 1997, highlighted the three benefits of PC as; explaining the determinants of inflation, for policy purpose and for inflation forecasting.

Table A2 – *Stationarity tests: quarterly data (2000Q –2013Q2; 1980Q–2013Q3)*

	LEVELS			
	ADF	PP	DF-GLS	Decision
$\bar{\pi}$ (a)	-4.218***	-4.218***	-4.251***	I(0)
$\bar{\pi}$ (b)	-7.528***	-7.718***	-5.457***	
$\bar{\pi}_t^e$ (b) (HP)	-3.316*	-1.347	-3.080**	I(0)
$\bar{\pi}_t^e$ (a) $(Survey)$	-2.980**	-2.097	-2.838***	I(0)
$\bar{\pi}_t^e$ (b) $(ARIMA)$	-10.60***	-10.85***	-6.692***	I(0)
$\bar{y}$ (a)	-3.570**	-3.295*	-3.523**	I(0)
$\bar{y}$ (b)	-6.142***	-6.164***	-2.725*	
y_{gap} (a)	-3.517**	-3.552**	-3.592**	I(0)
y_{gap} (b)	-9.113***	-60.77***	-9.188***	

Notes: the rows denoted by (a) report the results for the 2000Q3–2013Q2 series, (b) those for the 1980Q1–2013Q3 series.

Table A3 – *Results of the diagnostic tests of the OLS models*

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
Normality Test (Jarque-Bera)	2.60 (0.27)	1.70 (0.43)	3.82 (0.15)	1.15 (0.56)	5.64 (0.06)	3.69 (0.16)	1.51 (0.47)	0.62 (0.73)
Serial Correlation LM Test (Breusch-Godfrey *F*-statistic)	0.61 (0.55)	0.15 (0.86)	0.31 (0.73)	0.31 (0.73)	0.26 (0.77)	0.79 (0.46)	1.77 (1.17)	0.41 (0.66)
Heteroskedasticity Test (Breusch-Pagan-Godfrey *F*-statistic)	0.34 (0.91)	0.84 (0.55)	0.42 (0.90)	0.64 (0.70)	0.13 (0.99)	1.20 (0.31)	0.21 (0.97)	0.54 (0.80)
Ramsey RESET Test (*F*-statistic)	0.04 (0.85)	0.003 (0.95)	2.22 (0.15)	0.72 (0.40)	0.29 (0.59)	0.58 (0.45)	1.83 (1.18)	2.21 (0.14)

Notes: figures in parentheses report *p*-values.

Table A4 – *Results of the diagnostic tests of the GMM model*

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
Normality test (Jarque-Bera)	3.264 (0.195)	3.297 (0.192)	1.667 (0.435)	0.211 (0.90)	1.354 (0.508)	0.496 (0.780)	1.641 (0.44)	1.451 (0.484)
Endogeneity test (*J*-stat)	1.599 (0.809)	0.703 (0.873)	3.450 (0.178)	2.065 (0.356)	3.567 (0.168)	7.38 (0.117)	0.038 (0.846)	0.257 (0.879)
Stability test of over-identifying restrictions: Hall and Sen test (2008) (*O*-stat)	7.304 (0.967)	7.304 (0.967)	6.318 (0.984)	6.365 (0.784)	19.265 (0.505)	8.135 (0.775)	5.246 (0.874)	0.628 (0.730)
Stability test of over-identifying restrictions: Hall and Sen test (2002) (*O*-stat)	7.461 (0.963)	5.580 (0.849)		2.431 (0.992)	19.182 (0.510)	7.949 (0.789)	5.03 (0.889)	0.145 (0.930)
Weak Instrument test (Stock-Yogo TSLS *F*-stat)	8.158	0.461	1.341	NA	8.33	NA	NA	NA

Notes: figures in parentheses report *p*-values.

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