South African Reserve Bank
Working Paper Series
WP/16/03

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Authorised for distribution by Chris Loewald

May 2016

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Inflation in South Africa: An Assessment of Alternative Inflation Models*

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April 1, 2016

Abstract

We consider the relative empirical performance of a range of inflation models for South Africa. Model coverage is of Phillips-curve, New Keynesian Phillips curve, monetarist, and structural models of inflation. Our core findings are that the single most robust covariate of inflation is unit labour cost. We further decompose unit labour cost into changes in the nominal wage and real labour productivity. The principal association is a strong positive relationship between inflation and nominal wages, while improvements in real labour productivity report only a relatively weak negative association with inflation. Supply side shocks also consistently report an association with inflation. As to demand-side shocks, the output gap does not return a robust statistical association with inflation. Instead, it is growth in the money supply and government expenditure which return robust and theoretically consistent associations with inflationary pressure.

KEYWORDS: inflation, South Africa

JEL Code:

*We thank Christopher Loewald for useful comments on an earlier draft. Fedderke acknowledges the research support of Economic Research Southern Africa. All responsibility for the reported results remains ours alone. All views expressed in this paper are those of the authors alone, and do not necessarily reflect those of the South African Researve Bank.

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1 Introduction

What accounts for inflationary pressures in the South African economy?

Inflation has received a disproportionate amount of attention in the South African macroeconomic literature. Unusually for South African debates, empirically motivated papers on inflation have shown a close adherence to theoretical priors. A core feature of the South African empirical studies has been a resolute search for a Phillips curve type of trade off between prices and demand-side inflationary pressure associated with real economic activity. A second constant that emerges from the empirical literature is the consistent failure to successfully support the Phillips curve trade off.[1] Instead, a far more pervasive finding in the South African empirical literature has been a strong association between inflation and wage costs.

Given the extensive struggle surrounding confirmatory evidence in support of the Phillips curve, a further surprise in the South African empirical inflation literature is the very limited search over alternative theoretical accounts of inflation. Thus very few studies even consider monetary accounts of inflation. Nor is there much evidence of an exploitation of the well-established link between the first and second moments of the inflation time series.[2] This is all the more surprising since a cursory consideration of South African inflation, suggests that ARCH structure is plausible both for the CPI and GDP deflator time series - see Figure 1.

The current paper innovates in three distinct senses in relation to the South African debate.

First, we consider the relative performance of a range of alternative inflation models. This includes, but is not restricted to Phillips curve type models of inflation. We extend consideration to long-run structural models of price determination, a New Keynesian Phillips curve model, and monetary models of inflation.

Second, we consider the utility of incorporating ARCH structure into the modelling in improving the performance of inflation models. We do so across the full range of theoretical alternatives, with the exception of the structural model where econometric considerations preclude this possibility. A crucial means of considering the relative performance of the inflation models is not only goodness of fit of the models, but their forecast performance over a twelve (12) quarter window at the end of the sample period under consideration in this study.

Third, unlike previous studies we abandon theoretical purity. Instead we allow for all the potential covariates of inflation identified under the alternative theoretical models to compete empirically, in order to establish their relative robustness in modelling inflation.

In summary, our core findings are that the single most robust covariate of inflation is unit labour cost. We further decompose unit labour cost into changes in the nominal wage and real labour productivity. The principal association is a strong positive relationship between inflation and nominal wages, while improvements in real labour productivity report only a relatively weak negative association with inflation. Supply side shocks also consistently report an association with inflation. As to demand-side shocks, the output gap does not return a robust statistical association with inflation. Instead, growth in the money supply and government expenditure return more persistent and theoretically consistent associations with inflationary pressure.

The difficulty in finding a reliable impact of the output gap on inflation may well be due to the difficulties in developing reliable output gap measures - see Fedderke and Mengisteab (2016). But precisely given this limitation, it may be desirable to use alternative measures of demand side pressure instead, such as money supply growth and government expenditure stances.

The paper is structured as follows. In Section 2 we describe the alternative approaches to modelling inflation that have been used in South Africa. Section 3 adds important observations on the modelling of costs of production for inflation models in South Africa. Section 4 outlines the modelling approach of the current paper and section 5 the data we employ. Section 6 presents our results, while section 7 concludes and evaluates.

[1] The principal exception we have found in the South African literature is associated with a New Keynesian Phillips curve estimation, but which has to abandon adherence to the rational expectations foundations of the NKPC by allowing for habit persistence, and which has to estimate under the assumption of perfectly clearing and flexible markets - something of a reach in the South African context. See Burger and Du Plessis (2013).

[2] After all, the seminal Engle (1982) introduction of ARCH estimation focussed precisely on inflation.

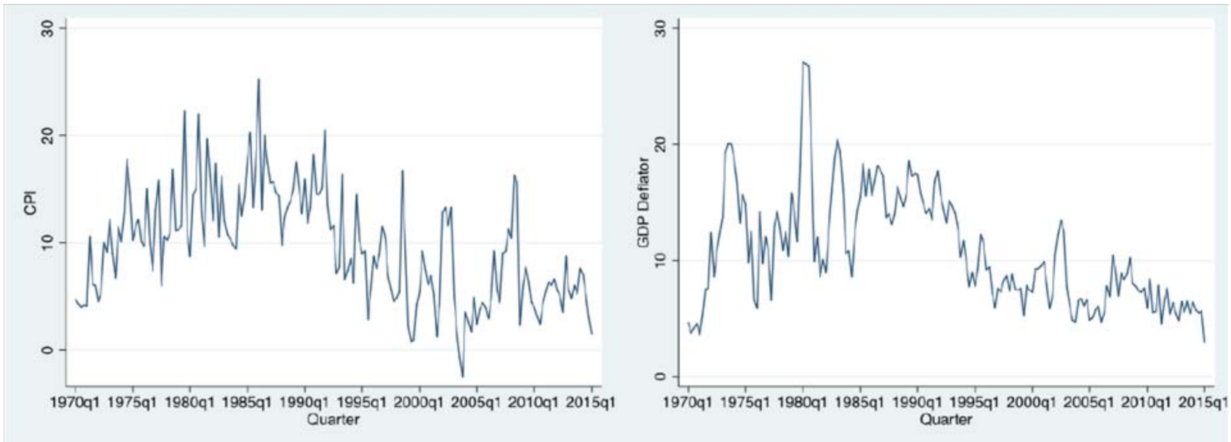

Figure 1: Inflation under CPI and GDP Deflator

2 Approaches to Modelling South African Inflation

The simplest possible model of inflation is that agents formulate expectations adoptively. This approach is devoid of theoretical justification, and issues in the time series model given by:

$$\pi_t = \beta_0 + \sum_{i=1}^{k} \beta_i \pi_{t-i} + \varepsilon_t \tag{1}$$

where π_t is the inflation rate in period t, and ε_t denotes the error term. Despite the lack of theoretical foundations of this model, in this study we employ it as a benchmark against which alternatives are judged, given the surprising empirical resilience of the approach noted by many studies.

A second class of models is based on a structural theoretical framework given by a version of the Phillips curve. Thus for instance Gordon (1997) proposes:

$$\pi_t = \sum_{i=1}^{k} \alpha_i \pi_{t-i} + \sum_{j=1}^{m} \beta_j D_{t-j} + \gamma c_t + \delta z_t + \varepsilon_t \tag{2}$$

where D_t denotes excess demand, c_t unit labor cost, and z_t supply shocks. Measures of D_t are provided by the unemployment gap $\left(U - \overline{U}\right)$ where U and $\overline{U}$ are the actual unemployment rate and the NAIRU respectively, or the output gap $(y - \overline{y})$ where y and $\overline{y}$ are the log of actual output and long-run trend or potential output respectively. Supply shocks are captured by for instance changes in relative food prices (see Pretorius and van Rensburg, 1996) or real exchange rate shocks. Burger and Marinkov (2006) further extend the Gordon model by classifying the excess demand variable D_t in terms of the extent of inflationary pressure being generated. They do so by including variables for excess demand, one for excess demand deemed to "overheat" the economy, D_t^{overh}, another for weak excess demand D_t^{weak}.[3] This represents an attempt to capture the possibility of a non-linear form of the Phillips curve, a direction in which the South African debate has moved in the face of difficulties in confirming a Phillips curve type structure in relation to the output gap.[4] Burger and Marinkov (2006) do not find an impact from the output gap on inflation, either in linear or non-linear form.

An alternative approach to incorporating a Phillips curve relationship rests not on a short-run dynamic specification, but on a long-run structural model of price determination. This specification of the Phillips curve association has been applied to South Africa in Fedderke and Schaling (2005), who follow work by Ghali (1999) for the USA. Their model is given by:

[3] D_t^{overh} during the weak-economy years is set to be zero, and symmetrically D_t^{weak} during overheating periods.

[4] See Schaling (2004) and Phiri (2015). Burger and Marinkov (2006) offer one such test. Evidence elsewhere is mixed - with support for non-linearity in Australia and Sweden, and linearity for the USA - see for instance Eliasson (2001).

$$p_t = \alpha_0 + \alpha_1 c_t + \alpha_2 \widehat{y}_t + \alpha_3 S_t + \varepsilon_{1t} \quad (3)$$
$$c_t = \beta_0 + \beta_1 p_t^e + \beta_2 \widehat{y}_t + \beta_3 S_t + \varepsilon_{2t} \quad (4)$$

where p_t denotes the price level (given by the GDP deflator), $\widehat{y}_t$ denotes the output gap as a measure of excess demand, and z_t denotes supply shocks proxied by the real exchange rate, with other notation as defined above. The model does not rely on a time series representation of inflation, maintains both demand ($\widehat{y}_t$) and supply side (S_t) shocks, and links unit labor costs to inflationary expectations (derived from a Hodrick-Prescott filter in the empirical model). The core empirical finding from the South African application surrounding the strength of the α_1 coefficient, which suggested that inflationary pressure in South Africa has strong cost-push structure, and that producers in South Africa have substantial pricing power.[5] By contrast, the output gap featured only in short run adjustment, and only weakly so (it does not prove statistically significant).

It is worth emphasizing that the struggle to find an impact of the output gap on inflation in South Africa is not specific to the Burger and Marinkov (2006) and Fedderke and Schaling (2005) results. As the review of the literature and empirical findings of Hodge (2002) make clear, the problem is pervasive. By contrast, measures of the marginal cost of production prove to be robustly and statistically significantly positively associated with inflation.

South African studies are not alone in struggling to confirm a Phillips curve structure to inflation. Especially the stagflation of the 1970s in developed economies, demonstrated that the predicted trade-off between output and employment and inflation has little empirical support. One response has been the development of a New Keynesian Phillips curve (NKPC), which introduces nominal rigidities in the presence of rational expectations and hence forward looking intertemporal optimizing behaviour.[6] The standard approach is to introduce nominal rigidities through output markets,[7] through the existence of pricing power of a proportion $(1-\theta)$ of the producers. This results in optimal pricing as a mark-up on expected marginal cost of production, and the New Keynesian Phillips curve in which inflation is dependent on expectations of future inflation, $E_t(\pi_{t+1})$, and the marginal cost of production, x_t,:

$$\pi_t = \beta_1 E_t(\pi_{t+1}) + \beta_2 x_t \quad (5)$$

where $0 \leq \beta_1 \leq 1$ denotes the rate of time discount, and $\beta_2 = (1-\theta)(1-\beta_1\theta)/\theta$, where θ denotes the proportion of firms without pricing power. It should be noted that this formulation is an alternative to $\pi_t = \beta_1 E_t(\pi_{t+1}) + \gamma\widehat{y}_t$, where $\widehat{y}_t$, denotes the output gap, such that the marginal cost of production is an alternative control for the output gap. This substitution is feasible due to a $x_t \propto \widehat{y}_t$ condition that holds in the absence of capital accumulation, and it should be noted that the strict proportionality breaks down once capital accumulation is introduced into the model.[8] Burger and Du Plessis (2013) nonetheless adopt the marginal cost formulation for South Africa in an open economy variant,[9][10] in order to avoid the limitations of using a filtered output series as a proxy for potential output, particularly since filtering cannot reflect time-varying productivity shocks. The Burger and Du Plessis (2013) measure of marginal cost is the gap between actual labour share in come and trend labour share as provided by a filter.[11] Alternative specifications have

[5] This finding is consistent with separate evidence supporting the existence of significant pricing power of producers in South Africa - see Fedderke et al (2007), Aghion et al (2008, 2013), and Fedderke et al (2016).

[6] See the discussion in Mankiw (2001).

[7] The influential contribution by Calvo (1983) is structured around forward-looking rational households, and monopolistically competitive output markets in which a proportion of firms has pricing power.

[8] See the discussion in Gali and Gertler (1999).

[9] In their application to South Africa, Burger and Du Plessis (2013) offered a calculation of marginal cost of production under open economy conditions given by:

$$x_t = S_t + \frac{(1-\mu s)}{\mu s}(\sigma - 1)(pm_t - w_t)$$

where S_t is the share of income accruing to labour, s denotes the steady state value for the labour income share, μ the steady state mark-up in the domestic economy, σ the elasticity of substitution between (domestic) labour and imported intermediate inputs, pm_t the log of import prices, and w_t the log of remuneration per worker.

[10] A concern with their measure of marginal cost is that it presupposes the existence of perfectly clearing and flexible labour markets, such that the share of labour income in final output is a direct measure of marginal cost. It is not at all clear that this is appropriate in a labour market which generates unemployment rates in excess of 25%.

[11] It is not clear why filtering is acceptable in this instance, given their rejection of filtering otherwise and with respect to the output gap in particular.

employed real unit labor cost directly (see Nason and Smith, 2008). Unfortunately New Keynesian Phillips curves have not fared well empirically, particularly in terms of accounting for the dynamics of inflation - see Mankiw (2001). A solution to this empirical difficulty proposed by Fuhrer (1997, 2000) is allow for "habit formation" on the part of household consumption, thereby introducing a lagged dependent variable into specification (5). It is clear, however, that theoretically this is distinctly *ad hoc* in nature in the context of any rational expectations framework. Despite this, Burger and Du Plessis (2013) also adopt this specification for South Africa. On the basis of their reported results they infer an impact of the output gap (measured by means of marginal cost of production) on inflation, given a statistically significant β_2.

A third set of models rely on monetary explanations of inflation, as being rooted in the growth rate of the money supply.[12] Thus, for instance:

$$\pi_t = \alpha_0 + \sum_{i=0}^{q} \alpha_i \Delta M_{t-i} + \sum_{j=0}^{r} \beta_j G_{t-j} + \sum_{k=0}^{s} \gamma_k z_{t-k} + \varepsilon_t \qquad (6)$$

where M_t denotes the money supply, G_t government expenditure (as a demand shock), with other notation defined as before. The supply shocks, z_{t-k}, are intended to capture shocks emanating from shifts in the supply curve resulting from changes in relative prices. Proxies employed for the supply shock variable include food prices, as well as real exchange rate shocks. Despite the attention that monetary models of inflation have received empirically in the international literature, in the South African context interest has been limited.[13]

A final approach to inflation that has emerged for South Africa is the multiple equation structural approach adopted by Aron et al (2004), which echoes Hendry's (2001) modelling of UK inflation. The result is a specification with a far greater range of consumer price inflation-determining variables than in the preceding specifications, including: the producer price index, unit labour cost, home prices, import prices, oil prices, the real exchange rate as well as the terms of trade, the output gap, the current account balance and a measure of trade openness, indirect tax rates and interest rates. The model also includes equations for the determination of producer prices, the nominal exchange rate and import prices. Reassuringly, despite the greater econometric complexity of the Aron et al (2004) modelling approach, the findings from their model are not inconsistent with the findings of other South African studies: drivers of inflation rest on wage shocks[14] and supply side shocks (oil price shocks, terms of trade shocks), though they also identify a role for the nominal exchange rate. Excess demand has a more limited role, and exercises its influence through trade deficits or surpluses, domestic asset price shocks (housing in particular), rather than via the output gap. While there has been additional exploration of the role of openness on inflation under the structural modelling approach,[15] the structural system of equations approach has not otherwise appeared to have seen further emulation for South Africa.

A surprising absence from the South African debate on inflation modelling, has been the exploitation of ARCH/GARCH representations linking the first and second moments of the distribution.[16] This omission is all the more surprising given the extensive concerns expressed in South African policy debates surrounding the impact of exchange rate volatility on inflation. After all, the relevant estimation techniques were pioneered on UK inflation in the seminal contribution by Engle (1982). Modelling the UK inflation rate, Engle employed:

$$\dot{p}_t = \beta_0 + \beta_1 \dot{p}_{t-1} + \beta_2 \dot{p}_{t-4} + \beta_3 \dot{p}_{t-5} + \beta_4 (p - w)_{t-1} + \varepsilon_t \qquad (7)$$

with p denoting the log of the consumer price index, $\dot{p}$ its first difference, w and the log of the index of manual wage rates. The representation of the real wage, $(p - w)_{t-1}$ is obtained from the error correction term of a Davidson, et al. (1978) VECM model, which serves to provide a stationary long-run real wage. The residual term ε_t follows an ARCH/GARCH structure to adjust for the change in the volatility of South African inflation over time. Theoretical justification of the error correction term is the rigidity of unemployment with respect to inflation in the long-run, which serves to contradict a Phillips curve trade-off. To date, we are not aware of any empirical work that has operationalized the Engle (1982) structure for South Africa directly.

[12] See Stockton and Glassman (1987) and Glassman and Stockton (1983). For a South African application see Pretorius and Van Rensburg (1996).

[13] As far as we are able to ascertain, to the single Pretorius and Van Rensburg (1996) study.

[14] Aron and Muellbauer (2004) expand on wage determination in South Africa.

[15] See Aron and Muellbauer (2007).

[16] We found only Ben Nasr et al (2014) and Kumo (2015) that make some use of ARCH surrounding inflation.

Yet a consideration of the evidence contained in Figure 1, suggests that an association between the level and the volatility of inflation may apply to South African inflation also, especially in the case of the aggregate measure provided by the GDP deflator. Note that prior to 1995, GDP-deflator based inflation averaged at 13.65%, with a standard deviation of 4.68, while after 1994 it averaged 7.40% with a standard deviation of 2.02. The symmetrical observations for CPI-based inflation are a 12.34% average and standard deviation of 4.40 prior to 1995, and 6.11% and 3.74 after 1994. In both instances there is a positive association between the level and volatility of inflation, though the pattern is more dramatic in the case of the GDP deflator than for the CPI based measure.

The only use of ARCH-structure in connection with inflation in South Africa has focussed on a more specific question. This arises from the fact that if the first moment of inflationary processes is not independent of the second moment of the time series, this leaves both the direction of causality between the level and volatility of the series, and the sign of the association undetermined. A number of studies view causality as running from the level of inflation to its volatility, with both a positive association and a negative association being predicted.[17] The reverse direction of causality from variance to mean is also supported, and again with both positive and negative signs of association.[18] Ben Nasr et al (2014) report evidence for South Africa of a positive causal association running from the level to the volatility of inflation. However, the direct exploitation of ARCH structure in standard inflation models is to the best of our knowledge either rare, or entirely absent.

3 An Observation on Costs of Production in South Africa

A number of the models of inflation control for a measure of the cost of production, using a measure of unit labour cost. One measure for this cost of production employed in the literature has been the real cost of labour.

But consideration of the real cost of labour in South Africa raises an immediate puzzle for any attempt to account for inflation in terms of the labour cost measure. Consider the evidence of Figure 2, which reports the real wage rate for both the private and public sectors. What emerges is that while real wages were effectively stationary (constant) over the 1970Q1 - 1994Q4 period, they have risen steadily since. Yet, in terms of recorded inflation, the post 1990 period was also the period in which inflation moderation has set in - recall Figure 1. Finding a positive link between real wages and inflation will thus be both unlikely and implausible.

So what might account for the rising real wage in South Africa?

One possibility might be that it reflects an increase in real output per worker, i.e. an increase in labour productivity. We report real labour productivity (RY/L) for our sample period in Figure 3. The post 1994 period does show an increase in labour productivity. It also shows an unusual spike in productivity in the period leading up to 2000, with a sharp subsequent downward correction. The spike arises due to the employment series - see Figure 4 - which shows a sharp upward correction in recorded employment corresponding to 2000. The implication is that the 1994 - 2000 period was underrecording job creation, thereby artificially inflating the measure of productivity. Accordingly, elimination of the 1994-2000 spike, implies a relatively smooth increase in real labour productivity from approximately ZAR23,000 to ZAR27,000, an increase of 17%. Since the increase in the real wage over the same period is recorded as approximately 57% for both private and public sector workers, productivity increases can account for some, but certainly not all of the real wage increase.

What else might be at work? Given the existing literature recording the stickiness of inflationary expectations in South Africa (see Kabundi et al, 2014), a possible explanation is that high inflationary expectations have institutionalized nominal wage settlements at levels in excess of inflation, and at rates above those man-

[17] For instance, Ball (1992) finds a positive association, consistent with the prediction of Friedman (1977) that rising inflation leads to increased policy, and hence inflation uncertainty. By contrast, Pourgerani and Maskus (1987) and Ungar and Zilberfab (1993) both show declining inflation volatility with rising inflation, attributing it to the increased incentive of agents to forecast inflation under higher first moment conditions.

[18] Cukierman and Meltzer (1986) support a positive association, running from volatility to mean values of inflation, on the grounds that inflation volatility contains incentives for monetary policy makers to generate additional policy shocks in support of real growth. Holland (1995) argues the reverse, with higher inflation volatility raising the prospect of contractionary monetary policy, and hence a falling level of inflation.

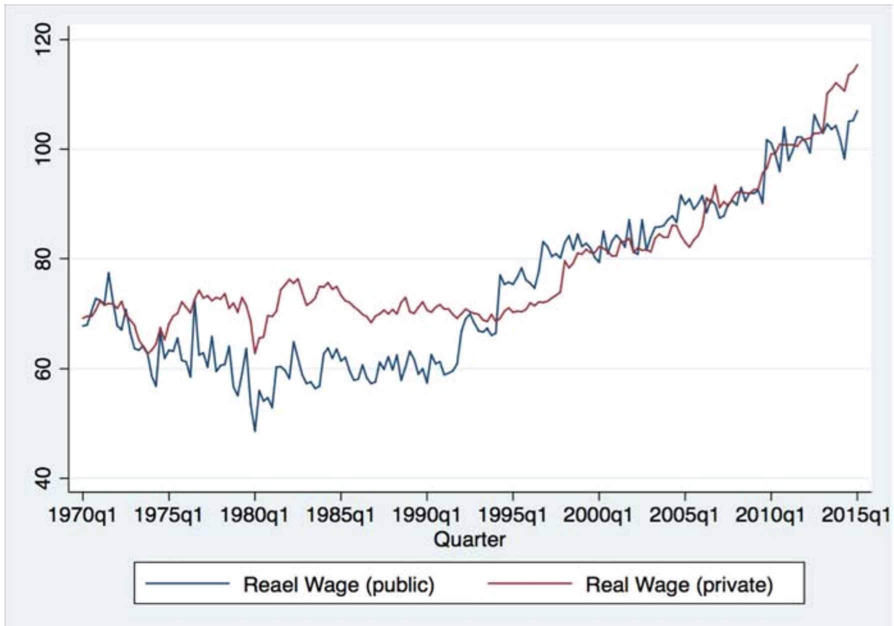

Figure 2: Real Wage for Public and Private Sector

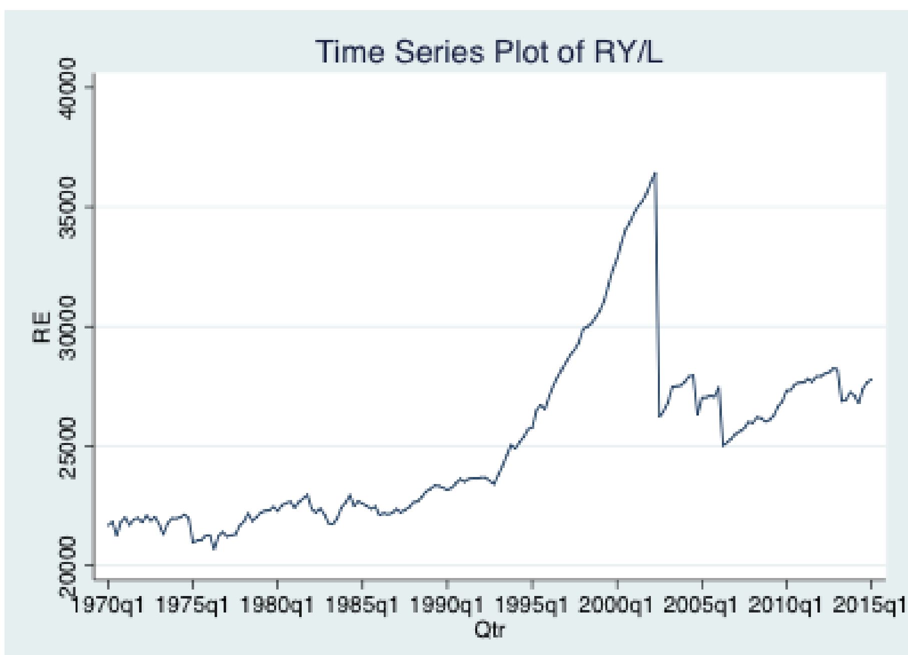

Figure 3: Real Output per Worker (RY/L).

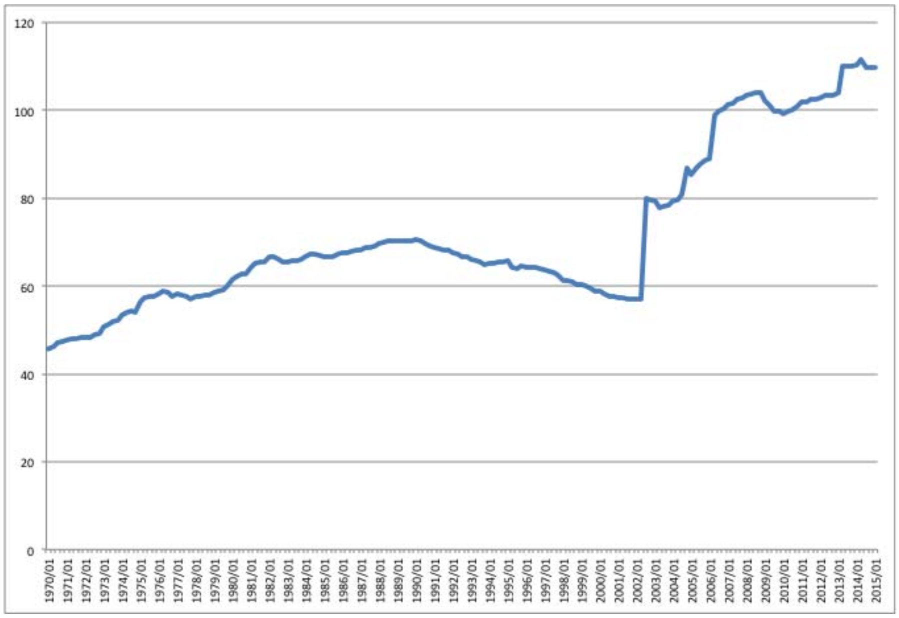

Figure 4: Employment

dated by productivity growth. Figure 5 reports the growth rate of the nominal wage rate in South Africa. The striking feature is that the trend structure of growth in nominal wages closely mirrors the structure of inflation, with a decline post 1990, though the series also reports a very high degree of volatility.

In the light of this evidence, in what follows our modelling strategy will thus be to account for both the aggregate impact of nominal unit labour cost, as well as to decompose the impact of nominal unit labour cost into the separate impacts of changes in the nominal wage rate and changes in the real productivity of labour. The prior is that nominal wage changes should be positively associated with inflation, while productivity growth of labour should be negatively associated with inflation. As we will see, the decomposition carries significant information for the dynamics of inflation in South Africa.

4 Modelling Strategy of the Present Paper

The approach of the present paper is to consider the range of inflation models proposed for South Africa, in terms of their explanatory power and forecast accuracy. To do so, we consider each of the models encountered in the South African literature, both in original specification, and augmented by a possible ARCH structure in the residual term.

In order to provide a benchmark for comparison, we begin with a pure time series model, without theoretical structure, incorporating only inertia effects in inflation.

Second, we consider a set of models that follow broadly a Phillips curve type structure. Under the Phillips curve type models, we consider a Gordon-type model, allowing for augmentation of the model by the nominal exchange rate, and decomposing the unit labour cost measure into changes in the nominal wage rate and labour productivity. A second Phillips curve type model follows the two equation Ghali specification, incorporating price expectations. Finally we also allow for a New Keynesian Phillips curve model.

As an alternative to the Phillips curve models we also consider a monetary specification which has received much less attention in the South African literature.

Finally, we also consider evidence from a hybrid model, which allows for all explanatory variables that appear across the alternative theoretical explanations to be incorporated.

We note at the outset that in general inflation models under virtually all the theoretical specifications we consider allow for some autoregressive lag specification in inflation. We do not do so, in order to obtain an understanding of the performance of the alternative inflation models against the benchmark time series model,

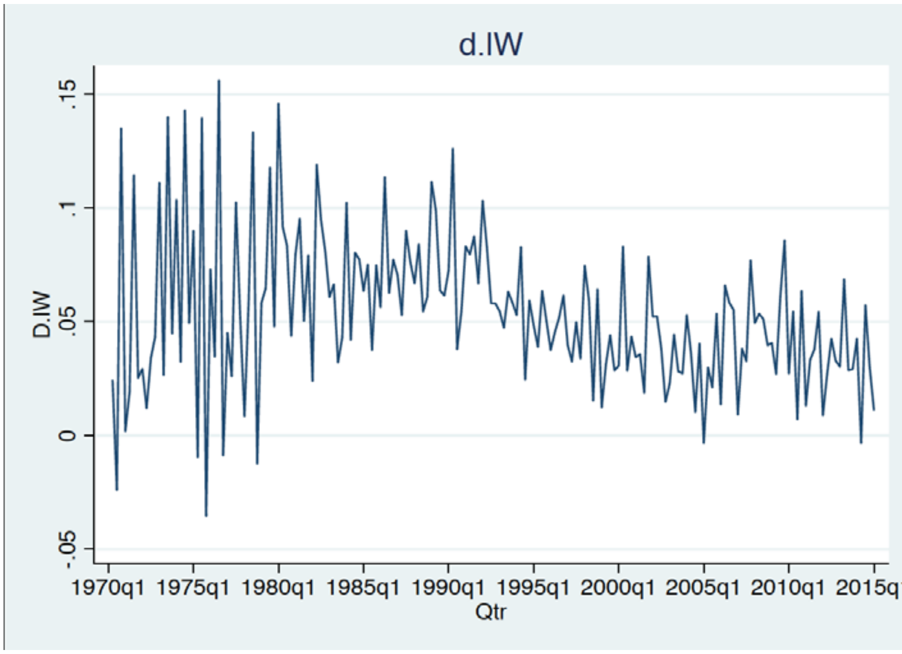

Figure 5: Growth Rate in Nominal Wage Rate

in an unalloyed sense. Throughout, inclusion of lagged values of inflation in our specifications dramatically improves fit and forecast performance. But given our interest in the relative contributions of the alternative theoretical structures to inflation, we focus on the narrow independent variables exclusively.

Throughout, we allow for higher order lags in all variables, and utilize a general-to-specific modelling strategy in model reduction.

Finally, we evaluate models in terms of standard goodness of fit test statistics, as well as the forecast performance of models over 12 quarters at the end of our sample period (estimation excludes the forecast period).

5 Data

The data used in all models are from the SARB historical time series data base, in quarterly format ranging from 1970Q1 to 2015Q1. Specific descriptions for each are specified in Table 1.

Stationarity tests for our variables are reported in Table 2. The tests confirm an $\sim I(1)$ structure for all variables, with the exception of the output gap, the change in the real money supply, government expenditure as a percentage of GDP, the government surplus/deficit as a percentage of GDP, the change in the nominal wage rate, which are $\sim I(0)$. In all subsequent empirical specifications, variables are employed in appropriate transform to ensure time series balance for the specification being estimated.

6 Estimation and Results

6.1 Benchmark Model: The Time Series Model

We begin with our benchmark case, as specified by equation (1). To reiterate, our interest is to provide a standard against which strictly behavioural and structural models are to be compared, in order to establish the relative capacity of competing structural explanations of inflation in South Africa to account for its empirical evolution.

Variable:	**Label:**	**Measure:**
Price level (p_t):	P	Price index of CPI or GDP deflator
Inflation rate (π_t):	π	CPI or GDP deflator based
Excess demand (D_t):	gY	Output gap = deviation of output from trend output (Hodrick-Prescott filter)
Unit labor cost (c_t):	$LULC$	Log of nominal unit labour cost
Change nominal wage rate	$d.lW$	$ULC \times RY/L \times P$
Real Labour Productivity	RY/L	Real GDP / Employment
Exchange rate (e_t):	$Exchange$	Nominal rand dollar exchange rate
Real wage (w_t):	w_t^{pub}, w_t^{pri}	Public $\left(w_t^{pub}\right)$ and private sector $\left(w_t^{pri}\right)$ real wage
Supply-side shock 1 (SS_t):	SS_t	eDviation of terms of trade from trend (Hodrick-Prescott filter)
Supply-side shock 2 (S)	$RExchange$	Real exchange rate
Money balances (M_t)	$d.M2$	Change in log of M2 balances
Government Expenditure (G_t)	$GovExp$	Government expenditure as a % of GDP
Government Surplus/Deficit	$S\&D$	Government Surplus/deficit as a % of GDP

Table 1: Variables Employed in Study

	$\sim I(0)$	$\sim I(1)$
CPI	1.110 [0.995]	-15.21^{***} [0.000]
$GDP\ Deflator$	12.648 [1.000]	-9.05^{***} [0.000]
gY	-5.54^{***} [0.00]	-6.79^{***} [0.00]
$LULC$	-1.93 [0.32]	-8.43^{***} [0.00]
SS	-4.60^{***} [0.00]	-9.93^{***} [0.00]
$Exchange$	0.43 [0.98]	-6.16^{***} [0.00]
$RExchange$	-2.24 [0.19]	-6.58^{***} [0.00]
$d.M2$	-4.27^{***} [0.00]	-6.65^{***} [0.00]
$GovExp$	-5.10^{***} [0.00]	-10.54^{***} [0.00]
$S\&D$	-6.74^{***} [0.00]	-29.17^{***} [0.00]
$d.lW$	-19.18^{***} [0.00]	-31.22^{***} [0.00]
RY/L	-1.59 [0.49]	-8.30^{***} [0.00]
Figures in square parentheses denote p-values.		

Table 2: Univariate Time Series Characteristics of the Data

	Time Series			
	(1)	(2)	(3)	(4)
π_t:	CPI	CPI	GDP	GDP
π_{t-i}	0.48^{***} (0.07){1}	0.49^{***} (0.07){1}	0.94^{***} (0.05){1}	0.95^{***} (0.06){1}
	0.27^{***} (0.07){3}	0.25^{***} (0.08){3}	-0.42^{***} (0.08){4}	-0.46^{***} (0.09){4}
	-0.15^{*} (0.09){4}	-0.16^{**} (0.08){4}	0.43^{***} (0.08){5}	0.48^{***} (0.08){5}
	0.14^{**} (0.07){5}	0.15^{**} (0.07){5}	-0.16^{**} (0.08){7}	-0.01 (0.10){7}
	0.14^{**} (0.07){7}	0.15^{**} (0.07){7}	0.12^{**} (0.07){8}	-0.02 (0.08){8}
$Arch.L1$	–	0.16 (0.14)	–	0.13^{***} (0.05)
$Garch.L1$	–		–	0.85^{***} (0.06)
$adj-R^2$	0.52		0.78	
MAE	1.74	1.78	1.01	0.80
MAPE	0.48	0.50	0.21	0.17
MSE	4.52	4.64	1.64	1.06
RMSE	2.13	2.15	1.28	1.03
***, **, *, denotes significance at the 1, 5 and 10% levels. Figures in round parentheses denote standard errors. Figures in curly parentheses denote lag length i in π_{t-i}. MAE denotes mean absolute error; MAPE denotes MA percentage error MSE denotes mean square error; RMSE denotes root MSE				

Table 3: Time Series Model Estimation Results

Estimation results for the time series model are reported in Table 3 - here and in what follows we report only the parameters that prove statistically significant under statistical model reduction. As is conventional in inflation studies, time series models report both a non-trivial amount of inertia in inflation, with lags up to 8 quarters (reported in the curly parentheses for each coefficient) proving statistically significant (reported by teh conventional asterisk notation and as evident from the standard erros in round parentheses), and the resultant time series models report strong goodness of fit test statistics - though the goodness of fit is markedly higher for the GDP deflator series than the CPI measure.[19] See columns (1) and (3) of Table 3.

For both CPI and the GDP deflator we also considered estimation of the time series model under the assumption of an ARCH/GARCH error structure. See columns (2) and (4) of Table 3. While surprisingly there is no statistical confirmation of ARCH structure for the CPI series (the ARCH coefficient is statistically insignificant), the GDP deflator series does confirm the presence of ARCH and GARCH structure in the error.[20]

We also report summary statistics of the forecast performance of the time series models considered (see the MAE, MAPE, MSE and RMSE statistics, for which higher is worse). For forecast purposes, estimation was restricted to the period 1970Q1 - 2012Q1, with the 2012Q2 - 2015Q3 observations reserved for forecast purposes.

The fit and forecast performance of the time series model is illustrated in Figure 6, with the figures in the left column reporting in-sample fit, and the right column forecast performance over the 2012Q2-2015Q3 period. We draw readers' attention to the stickiness of the inflation forecasts at the 6% level for both CPI and GDP deflator measures - a feature that will prove pervasive across the models that are to follow, and which accord well with the inflationary expectations literature in South Africa (see Kabundi et al, 2014).

Symmetrically to the model fit statistics, GDP deflator forecasts prove more precise than the CPI forecasts across all model specifications. Moreover, for the GDP deflator series exploitation of the ARCH error structure improves the accuracy of forecasts - unlike for the CPI series.

[19] Note: the standard adj-R^2 goodness-of-fit test statistic is not defined for ARCH specifications.

[20] Results from standard test diagnostics for the presence of ARCH/GARCH confirm the presence or absence of ARCH effects as reported throughout. We suppress these for the sake of parsimony.

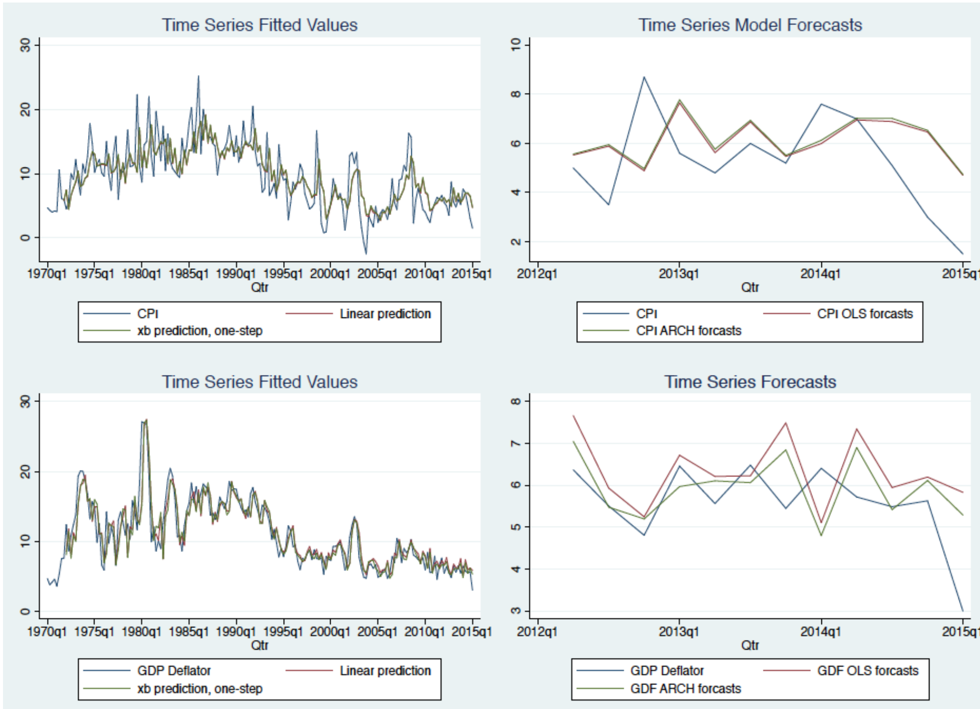

Figure 6: Time Series Models: Fit and Forecast.

We turn now to models of inflation that are purely behavioural or structural, in the sense that we preclude any lagged values of inflation from the models. The purpose is to establish the ability of the behavioural and structural explanatory variables to account for inflation, relative to the benchmark established by the atheoretical time series model. Of course, all of the following models improve their fit characteristics markedly on inclusion of a time series structure in inflation. But that is not our objective: instead we wish to establish whether, and to what extent the various structural variables identified under the models add to our understanding of inflation in South Africa.

6.2 Phillips Curve Type Models

The second set of results relates to Phillips curve type models, either under the Gordon-type structure of equation (2), under the Ghali-type structure of equations (3) and (4), or the New Keynesian Phillips curve model of (5).

6.2.1 The Gordon Model

As the first Phillips curve type model, we consider the Gordon model that has been used repeatedly in the South African context. We also consider some variants of the Gordon model, by expanding the set of variables that might shock inflation in the economy.

Table 4 offers the estimation results based on the base-line Gordon model, as given by equation (2) once the autoregressive structure in inflation is suppressed. Thus inflation depends on a demand shock, which we proxy by means of the output gap, gY_{t-i}, as measured by the deviation of actual GDP from trend GDP as measured by the Hodrick-Prescott filter. We also include a supply-side shock, SS_{t-i}, measured by the percentage deviation of actual terms of trade from trend estimated by the HP filter.[21] This is interpreted

[21] For supply shocks this study employs the terms of trade and real exchange rate, depending on the model being tested. A further supply shock that may be of particular importance to South Africa may be commodities prices: both the oil price and the gold price are of particular importance. Both would of course be implicitly included in the terms of trade and real exchange rate. However, further extension of this work may want to include these prices in the modeling explicitly.

	Gordon Model 1			
	(1)	(2)	(3)	(4)
π_t:	CPI	CPI	GDP	GDP
gY_{t-i}	3.51^{***} (1.28){1}	4.81^{***} (0.91){1}	-1.19 (1.18){1}	-3.22^{***} (0.74){1}
$d.LULC_{t-i}$	32.51^{***} (9.47){0}	39.28^{***} (9.37){0}	31.04^{***} (8.74){0}	27.33^{***} (4.05){0}
	42.28^{***} (9.70){1}	56.73^{***} (9.98){1}	31.56^{***} (8.88){1}	32.19^{***} (4.90){1}
	22.89^{**} (9.41){2}	29.23^{***} (7.93){2}	25.25^{***} (8.83){2}	37.61^{***} (6.96){2}
			17.98^{**} (8.62){3}	10.98^{*} (6.69){3}
SS_{t-i}	4.95 (6.69){0}	6.27 (5.51){0}	27.81^{***} (6.12){0}	12.25^{***} (4.06){0}
$Arch.L1$		0.62^{***} (0.21){1}		1.08^{***} (0.24){1}
$Garch.L1$		10.33^{***} (2.28){1}		2.57^{***} (0.99){1}
$adj-R^2$	0.18		0.21	
MAE	3.76	1.78	4.53	5.06
MAPE	1.06	0.92	0.87	0.97
MSE	18.81	15.10	22.22	27.32
RMSE	4.24	3.89	4.71	5.23

***, **, *, denotes significance at the 1, 5 and 10% levels.
Figures in round parentheses denote standard errors.
Figures in curly parentheses denote lag length i in X_{t-i}.
MAE denotes mean absolute error; MAPE denotes MA percentage error
MSE denotes mean square error; RMSE denotes root MSE

Table 4: Estimation Results of Gordon Model

as a supply shock, since it provides a measure of the relative competitiveness of domestic to international producers. This follows the specification of Burger and Marinkov (2006). Finally, we include measures of the unit labor cost, here given by the first differenced unit labor cost in log scale, $d.LULC_{t-i}$.[22]

Our results show that demand-side shocks, as measured by the output gap are statistically significantly and theoretically coherently associated with inflation only for the CPI inflation measure, not for the GDP deflator for which the output gap proves either insignificant or negatively associated with the inflation measure. Moreover, the impact of the output gap is very short-lived even for the CPI measure, with higher order lags in the output gap being consistently statistically insignificant. Indeed, the only association we find is from the immediately preceding quarter for the CPI measure.

By contrast, the impact of unit labor cost is not only substantively strong and positive on inflation, but it proves to be persistent over almost a full calendar year (we find consistent significance up to 3 quarters).

Our measure of supply-side shocks proves to be statistically significant only for the GDP deflator, not for CPI. Moreover, the impact of supply side shocks is not very persistent, in the sense that lagged values of the supply-side shock measure never prove to be statistically significant.

Finally, we note that the fit of the baseline Gordon model is significantly lower than the comparable time series models (0.18 vs 0.52 for CPI, 0.21 vs 0.78 for the GDP deflator). However, we now find strong support for the presence ARCH effects in the error structure of both the CPI and GDP deflator models. Inclusion of the ARCH structure in estimation, significantly improves the forecasting accuracy of the resultant model for the CPI measure. While not giving the full accuracy of the time series model, nonetheless the finding suggests that the autoregressive structure in inflation may be capturing persistence in error volatility.

We report the goodness of fit and forecast performance of the Gordon Type 1 models in Figure 7. We

[22] It is worth noting that since unit labour cost and output gap measures may be correlated, multicollinearity may bias the standard errors of the estimator sampling distributions upward. Statistical insignificance of the output gap may thus be a statistical artefact. However, in the results reported here, the problem with the output gap measure is not simply insignificance: in the case of the GDP deflator the output gap often returns the theoretically incoherent (negative) sign.

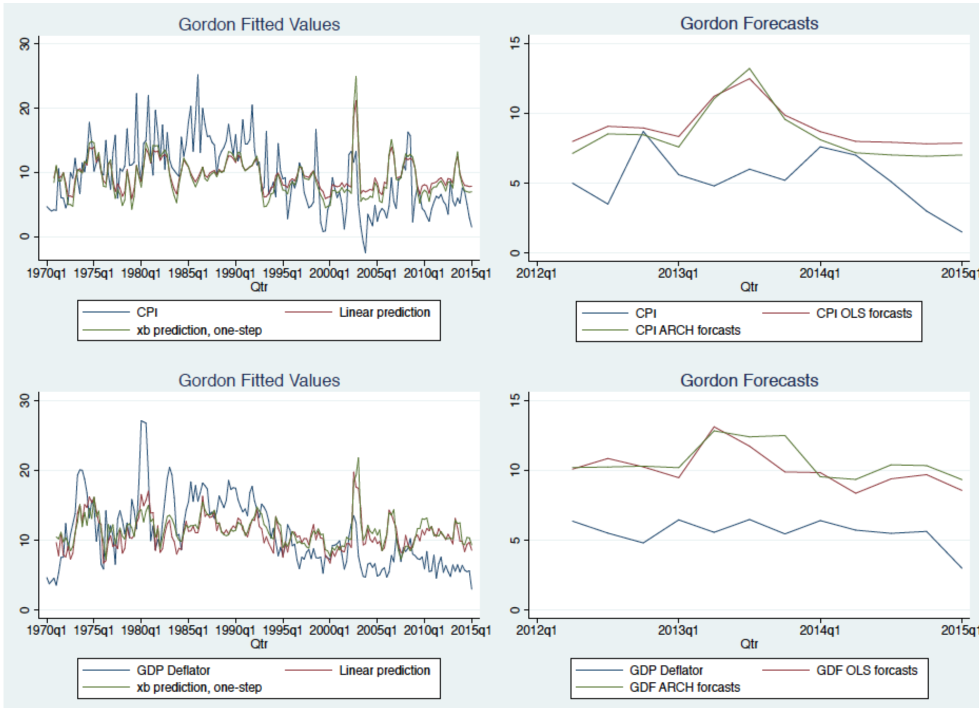

Figure 7: Gordon Model 1: Goodness of Fit and Forecast Performance.

note that the inflation forecasts under the Gordon structure settles on an inflation well in excess of 6%.

We consider two extensions of the Gordon model for the South African case. First, given persistent concerns in South Africa surrounding the volatility of the nominal (as opposed to the real) exchange rate, and the possibility of pass-through from exchange rate depreciation to domestic prices, we consider the possibility of the nominal exchange rate impacting on the inflation rate directly. Second, thus far we have controlled for changes in the nominal unit labour cost. But unit labour costs reflect changes in the cost of labour net of productivity changes, (given $NULC = (W.L/Y)$). As such, nominal unit labour costs may understate the impact of labour cost on inflation, since our prior is that nominal wage increases should be positively associated with inflation, while productivity gains should manifest a negative association. As a second extension of the Gordon model we therefore consider the separate impacts of changes in the average nominal wage rate, and changes in labour productivity.

Table 5 reports the results for the Gordon model controlling for the association of the nominal exchange rate. We continue to find a short-lived association of demand-side shocks as measured by the output gap, and for the GDP deflator measure of inflation the sign of the output gap is theoretically inconsistent (negative). By contrast, once again it is changes in the nominal unit labour cost that continue to report a strong, persistent, positive association with inflationary pressure for both the CPI and GDP deflator measures of inflation. Similarly, supply-side shocks continue to have a short-lived association with the GDP deflator.

There is some evidence of a pass-through of the nominal exchange rate to inflation. However, this is primarily restricted to the CPI measure, and once we control for the presence of ARCH structure in the error term, all statistical significance for an exchange rate impact dissipates. What is more, goodness of fit statistics show only marginal improvement over the Gordon 1 model of Table 4, while forecast accuracy summary statistics are generally worse than for the Gordon 1 model without nominal exchange rate impacts. At least within the Gordon model context, therefore, evidence for a strong nominal exchange rate impact on inflation is limited.

The reason for this may be that the impact of the exchange rate is already captured in the change in unit labour cost. Any residual effect that remains may simply be serving to capture the impact of volatility on the level of inflation, which is then eliminated once the ARCH error structure is accounted for.

	Gordon Model 2			
	(1)	(2)	(3)	(4)
π_t:	CPI	CPI	GDP	GDP
gY_{t-i}	2.24^{***} (1.31){1}	3.82^{***} (1.14){1}	-1.23 (1.22){1}	-2.48^{***} (0.91){1}
$d.LULC_{t-i}$	40.18^{***} (9.65){0}	37.75^{***} (7.73){0}	32.72^{***} (8.81){0}	29.57^{***} (5.27){0}
	45.70^{***} (9.71){1}	53.25^{***} (9.11){1}	37.61^{***} (8.84){1}	38.49^{***} (5.10){1}
	27.50^{***} (9.70){2}	37.12^{***} (9.63){2}	30.00^{***} (8.78){2}	52.15^{***} (7.44){2}
	17.90^{*} (9.57){3}	18.65^{*} (10.06){3}	30.27^{***} (8.90){3}	38.26^{***} (6.41){3}
			22.36^{**} (8.82){4}	34.06^{***} (8.80){4}
			19.88^{**} (8.77){5}	27.75^{***} (7.93){5}
			15.34^{*} (8.69){6}	13.93 (8.14){6}
SS_{t-i}	6.67 (6.58){1}	2.52 (6.23){1}	38.33^{***} (6.34){0}	20.85^{***} (5.29){0}
			-26.40^{***} (6.60){4}	-23.43^{***} (4.95){4}
$d.Exchange$	1.48^{*} (0.84){1}	1.15 (0.91){1}	1.22^{*} (0.77){1}	0.28 (0.51){1}
	1.78^{**} (0.83){2}	0.86 (0.84){2}	1.37^{*} (0.76){2}	0.01 (0.51){2}
$Arch.L1$		0.49^{***} (0.18)		0.97^{***} (0.27)
$adj - R^2$	0.21		0.29	
MAE	4.32	3.80	4.38	4.26
MAPE	1.17	1.04	0.85	0.82
MSE	24.79	20.47	21.67	20.37
RMSE	4.98	4.52	4.66	4.51

***, **, *, denotes significance at the 1, 5 and 10% levels.
Figures in round parentheses denote standard errors.
Figures in curly parentheses denote lag length i in X_{t-i}.
MAE denotes mean absolute error; MAPE denotes MA percentage error
MSE denotes mean square error; RMSE denotes root MSE

Table 5: The Gordon Model Controlling for the Nominal Exchange Rate

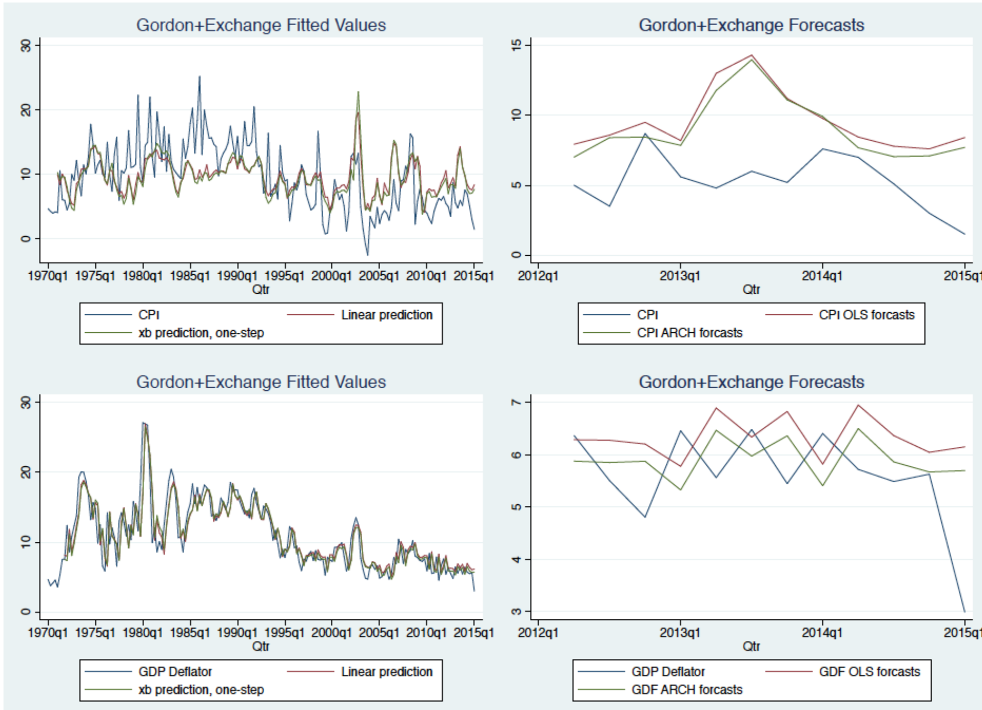

Figure 8: Gordon Model 2: Goodness of Fit and Forecast Performance.

We report the goodness of fit and forecast performance of the Gordon Type 2 models in Figure 8. The inclusion for the exchange rate improves fit over the simple Gordon model, and moves inflation forecasts closer to the 6% level.

In the second extension to the Gordon model, we separate the wage ($d.lW_{t-i}$) and labour productivity (RY/L_{t-i}) impacts that are conflated in the nominal unit labour cost variable of the standard specification. Our prior is that the impact of the nominal wage should be positive, while productivity growth should be negatively associated with inflation.

Our estimation results are reported in Table 6. Reassuringly, our priors are strongly confirmed. Changes in the nominal wage rate have a strong, statistically significant and persistent association with the inflation rate. Symmetrically, the net effect of changes in real labour productivity on inflation is negative.

What is startling, however, is that the fit of the Gordon model improves dramatically under the wage-productivity decomposition, relative to the Gordon model that simply controls for unit labour cost, rising from 0.18 to 0.59 for CPI, and 0.21 to 0.60 for the GDP deflator. Forecast accuracy for the CPI model is directly comparable to the baseline time series model for all summary statistics, while for the GDP deflator forecast accuracy is only marginally lower than for the time series model. For both definitions of inflation, therefore, the Gordon model under the wage-productivity decomposition is thus now comparable in fit and forecast accuracy to the baseline time series model. We emphasize that our modelling strategy does not include any autoregressive time series structure for inflation, loading purely on the structural variables. Inclusion of a time series structure on inflation readily allows the Gordon 3 model to surpass the time series model in performance.

Findings surrounding demand-side output gap shocks (positive, short lived, for CPI and in a number of cases the theoretically unsupported negative association for GDP deflator inflation), supply side shocks are symmetrical to those already noted for the Gordon 1 and 2 models. Similarly, we also consider the potential impact of the nominal exchange rate in Table 6. Again, the evidence supports an impact only on the CPI measure, and the impact is relatively weak and short-lived.

We report the goodness of fit and forecast performance of the Gordon Type 3 models in Figure 9. The unit labour cost decomposition clearly improves fit over the simple Gordon model, moves inflation forecasts

	Gordon Model 3							
π_t :	CPI	CPI	GDP	GDP	CPI	CPI	GDP	GDP
gY_{t-i}	2.68*** (1.12){1}	3.73*** (0.97){1}	0.10 (0.92){1}	−2.03*** (0.68){1}	3.49*** (1.11){1}	4.71*** (1.20){1}	4.08*** (2.15){1}	0.55*** (1.50){1}
							−6.13*** (2.60){2}	−4.23** (1.84){2}
							3.21** (1.36){4}	4.54** (0.84){4}
$d.lW$	41.23*** (12.22){0}	33.11*** (12.42){0}	21.58** (10.41){0}	22.00*** (6.93){0}	36.25*** (11.87){0}	30.37*** (11.34){0}	23.06** (10.64){0}	8.08 (7.85){0}
	54.38*** (13.24){1}	47.60*** (12.13){1}	33.89*** (11.18){1}	18.77** (7.70){1}	52.66*** (13.02){1}	43.31*** (10.26){1}	38.05*** (10.91){1}	21.45*** (7.16){1}
	42.26*** (12.99){2}	33.62** (13.55){2}	38.70*** (10.68){2}	26.18*** (7.53){2}	33.87*** (11.74){2}	21.25** (8.76){2}	39.50*** (10.72){2}	27.40*** (8.95){2}
	20.72* (11.86){3}	14.25 (11.13){3}	28.40*** (10.43){3}	13.83* (7.25){4}			31.20*** (10.59){3}	21.87*** (7.55){3}
			32.57*** (10.92){4}	21.72*** (6.69){4}			26.22** (10.65){4}	21.99*** (8.50){4}
			22.76** (10.04){5}	13.09* (7.35){5}				
$d.RY/L$	−0.88** (0.35){0}	−0.69 (0.75){0}	−0.97*** (0.28){0}	−1.07*** (0.18){0}	−1.03*** (0.35){0}	−0.78 (0.87){0}	−0.96*** (0.28){0}	−0.87*** (0.30){0}
	−1.77*** (0.35){1}	−1.02 (0.79){1}	−0.96*** (0.28){1}	−1.16*** (0.16){1}	−0.93** (0.36){1}	−0.68 (0.58){1}	−1.13*** (0.28){1}	−0.89* (0.46){1}
			−0.58** (0.28){2}	−1.01*** (0.22){2}			−0.67** (0.28){2}	−0.35 (0.30){2}
			−0.58** (0.28){3}	−1.41*** (0.29){3}			−0.62** (0.28){3}	−0.31** (0.15){3}
							−0.58* (0.31){4}	−0.24 (0.46){4}
SS_{t-i}	3.68 (5.69){0}	0.68 (6.46){0}	33.43*** (5.76){0}	19.54*** (4.27){0}	4.44 (5.63){0}	5.07 (4.93){0}	37.83*** (4.99){0}	24.70*** (4.51){0}
			10.30* (6.11){1}	6.57 (4.69){1}			−9.40* (5.77){3}	−4.27 (4.01){3}
			−12.01* (6.11){3}	−6.16* (3.49){3}			−19.40*** (5.74){4}	−4.48 (3.83){4}
			−20.64*** (5.81){4}	−7.29** (3.05){4}				
$d.Exchange_{t-i}$					−1.77*** (0.70){0}	−2.02** (0.93){0}	−1.17** (0.59){8}	−0.83** (0.55){8}
$Arch.L1$		0.29** (0.13)		1.11*** (0.27)		0.44*** (0.17)		0.86*** (0.27)
$Garch.L1$		0.47* (0.27)						
$adj-R^2$	0.42		0.59		0.43		0.60	
MAE	1.90	1.80	1.08	0.87	1.98	1.90	0.99	0.83
MAPE	0.46	0.45	0.22	0.18	0.44	0.43	0.20	0.17
MSE	4.71	4.21	1.67	1.19	4.94	4.47	1.42	1.00
RMSE	2.17	2.05	1.29	1.09	2.22	2.11	1.19	1.00

***, **, *, denotes significance at the 1, 5 and 10% levels.
Figures in round parentheses denote standard errors.
Figures in curly parentheses denote lag length i in X_{t-i}.
MAE denotes mean absolute error; MAPE denotes MA percentage error
MSE denotes mean square error; RMSE denotes root MSE

Table 6: The Gordon Model with Decomposed Unit Labour Cost

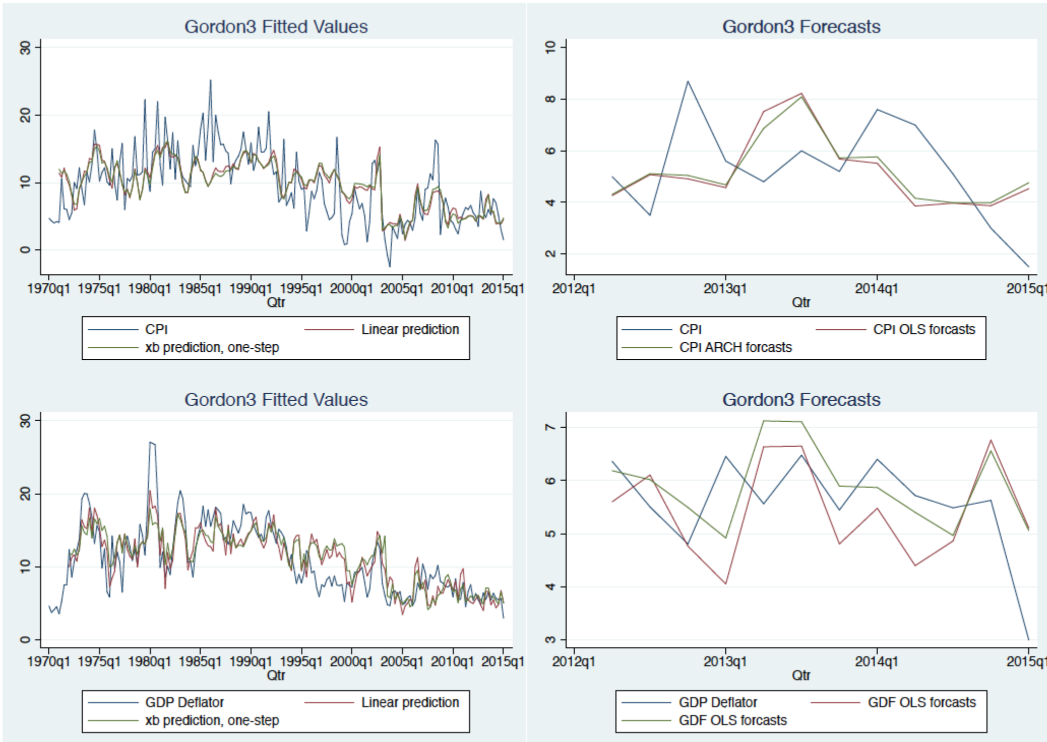

Figure 9: Gordon Model 3: Goodness of Fit and Forecast Performance.

below the 6% level for CPI, but leaves the forecast at approximately the 6% level for the GDP deflator.

The performance of the Gordon 3 model points to the analytical importance of the decomposition of the nominal unit labour cost variable into changes in the nominal wage, and changes in real labour productivity.

In summary, under the Gordon-model formulation of the Phillips curve, we find only weak evidence for any association between the output gap and inflation. It emerges only for the CPI inflation measure, but even there the impact is transitory, while for the GDP deflator measure the output gap generally has the theoretically unsupported negative sign. By contrast, it is nominal unit labour cost which reports a positive, and sustained association with inflation, with the principal channel of influence appearing to be changes in the nominal wage, rather than the real labour productivity channel. We reiterate the importance of the decomposition for an understanding of South African inflation dynamics. Supply side shocks and changes in the nominal exchange rate report only limited association with inflation under the Gordon framework.

6.2.2 The Ghali Model

The second class of Phillips curve model we consider is that based on Ghali (1999), previously estimated for South Africa by Fedderke and Schaling (2005). Estimation is of the system of equations given by (3, 4). We proceed by means of a standard VECM approach. The estimation technique is standard, so that our exposition is brief.[23] Consider the general VAR (Vector Autoregressive Estimation) specification given by:

$$z_t = A_1 z_{t-1} + ... + A_m z_{t-m} + \mu + \delta_t \tag{8}$$

where z_t is a $n \times 1$ matrix, m is the lag length, μ deterministic terms and δ a Gaussian error term. Reparametrization provides the VECM specification:

$$\Delta z_t = \sum_{i=1}^{k-1} \Gamma_i \Delta z_{t-i} + \Pi z_{t-k+1} + \mu + \delta_t \tag{9}$$

[23] See the more detailed discussion in Johansen (1991), Johansen and Juselius (1990, 1991, 1992).

Null:	CPI 1	CPI 2	CPI 3	GDP 1	GDP 2	GDP 3
$r = 0$	246.13^{**}	148.13^{**}	158.51^{**}	87.51^{**}	88.10^{**}	120.29^{**}
$r \leq 1$	31.21^{*}	33.76^{**}	32.05^{**}	31.07^{*}	33.40^{**}	36.55^{**}

Table 7: Trace Statistic on Number of Cointegrating Vectors

where $\Pi = \alpha\beta'$. The loading matrix, α, contains the short-run dynamics, while β is the matrix contains the long run equilibrium (cointegrating) relationships. The rank, r, of the matrix represents the number of cointegrating vectors and is tested for using the standard Trace and Maximal Eigenvalue test statistics. Where $r > 1$ issues of identification arise.[24] Identification can proceed by means of restrictions on α, β, or Γ, but is conventionally achieved via the β-matrix.

For our system of equations, since the output gap $(\widehat{y}_t)$ is $\sim I(0)$, we have the just-identified case of:

$$\beta' z_t = \begin{bmatrix} 1 & \beta_{12} & \beta_{13} & 0 \\ 0 & 1 & \beta_{23} & \beta_{24} \end{bmatrix} \begin{bmatrix} p \\ c \\ S \\ p^e \end{bmatrix}_t \tag{10}$$

while the output gap is included only in the short-run error correction specifications. For p_t we employ the log of CPI and GDP deflators, c_t is measured by the log of nominal unit labour cost, and the supply shock S_t by the real effective exchange rate.[25] For price expectations we employ the Hodrick-Prescott filter on the price series, and an alternative derived from the filtered inflation series to derive trend prices. Though our sample period is different from theirs (1970Q1 - 2015Q1, as opposed to 1963Q4 - 1998Q2), consistently with the earlier Fedderke and Schaling (2005) study, we also control for the possibility of a structural break over the 1970-1990 period in inflation.

Advantage of this estimation approach is that the system of equations can be estimated in price levels (ln-transformed), and explored for weak exogeneity restrictions, and above all be immune from concerns regarding endogeneity bias and inconsistency given the Engle and Granger (1987) superconsistency property of estimation under cointegration. Thus the loss of information under the differenced approach of Ghali (1999) is avoided.

In Table 7 we confirm that our data supports the presence of two cointegrating vectors, as required by our theoretical structure. Associated estimation results are reported in Table 8. For the sake of parsimony, we report only the price equation required for the focus of the present paper, and not the unit labour cost equation.

The core finding from the estimation results is that the finding of the Fedderke and Schaling (2005) paper, that the South African price level is significantly determined by the costs of production, and the unit labour cost in particular, is confirmed on our updated data. In the earlier study the unit labour cost coefficient was reported to be 1.31. In our new application of the modelling strategy, we find that on the GDP deflator price series the coefficient ranges from $1.22 - 1.37$, though we note that the specification that is the closest to the earlier study in controlling for the exceptional 1970-90 period, also generates the highest estimate of 1.37. For the CPI price series, the coefficient range is narrower, from $1.28 - 1.36$ (the earlier study did not explore CPI).

Unsurprisingly, since the forecasts for inflation have to be conducted on the basis of the short-run dynamic equation in the VECM for the price series, and the equation therefore contains an autoregressive specification of inflation, we find that the summary statistics for forecasts are considerably more favourable than those for any model reported in this study. But given the specification difference, the comparison does not provide a legitimate standard of evaluation. Goodness of fit and forecasts are reported in Figures 10 and 11.[26]

[24] See Wickens (1996), Johansen and Juselius (1990, 1992), Pesaran and Shin (1995a, 1995b), Pesaran, Shin and Smith (1996).

[25] We follow Fedderke and Schaling (2005) in computing the real effective exchange rate as:

$$S_t = \frac{P_t^* E_t}{P_t} = \frac{1}{\mu_t}\left[\frac{P_t^c}{P_t} - 1 + \mu_t\right]$$

where P_t^c denotes consumer prices, μ_t import penetration, P_t^* foreign prices, E_t the nominal Rand-Dollar exchange rate, and P_t the domestic price level.

[26] Note: the plotted changes are quarter-on-quarter changes - implied annualized changes are therefore larger by a factor of

	Ghali Model					
π_t:	CPI 1	CPI 2	CPI 3	GDP 1	GDP 2	GDP 3
$dep.Var$:	lnP	lnP	lnP	lnP	lnP	lnP
$lnULC$	1.28*** (0.16)	1.36*** (0.29)	1.29*** (0.20)	1.26*** (0.15)	1.37*** (0.34)	1.22*** (36.55)
$lnRExchange$	0.37** (0.19)	0.38 (0.28)	0.64** (0.27)	0.37 (0.57)	0.38 (0.58)	0.38** (0.15)
70-90 Break	No	Yes	No	No	Yes	No
adj-R^2 (price ecm)	0.88	0.89	0.91	0.22	0.23	0.42
Stable CV:	Yes	Yes	Yes	Yes	Yes	Yes
MAE	0.04	0.04	0.02	0.01	0.01	0.01
MAPE						
MSE	0.002	0.002	0.001	0.00012	0.00013	0.00007
RMSE	0.04	0.04	0.03	0.02	0.01	0.01

Table 8: The Ghali Model

In summary, under the Ghali-type structural model of inflation, we confirm again the primacy of a mark-up of price over the cost of production, as measured by unit labour cost. Specifically, we confirm not only the continued relevance of the variable, but the strength of the price-cost relationship, which suggests the presence of significant pricing power in the output markets of South Africa.

6.2.3 A New Keynesian Phillips Curve Model

Much as is the case for the prior literature on inflation in South Africa, Phillips curve frameworks in this paper thus struggle to reliably and robustly confirm any role for the output gap in inflation. Instead, it is consistently wage costs that show the strongest, most persistent, and robust association with inflation.

As noted in the discussion of the prior literature on inflation in South Africa, a more recent response has been to consider a New Keynesian Phillips curve formulation instead. For the sake of completeness, we considered this possibility also. In doing so, we follow the Nason and Smith (2008) use of real unit labour cost for the measure of marginal cost of production, rather than the Burger and Du Plessis (2013) deviation of labour share in total output from long run trend value, on the grounds of clearer theoretical justification for the variable specification.

We report our estimations of equation (5) in Table 9. Columns (1) and (2) report estimation results for CPI and GDP deflator inflation, estimated under OLS respectively. Results do not confirm the marginal cost specification of the impact of the output gap on inflation: the impact is insignificant (CPI, GDP deflator) and negative (CPI). What is more, the coefficient on the inflationary expectations implies a time rate of preference that is implausibly large, which is difficult to sustain on theoretical grounds.[27]

Estimation under the GMM, estimator, instrumenting on lagged values of all variables, is reported in columns (5) and (6). This generates a plausible positive time rate of preference through the coefficient on expected inflation. However, this comes at the cost of eliminating all statistical significance for the real unit cost of labour variable proxying for the output gap, while the coefficient on the unit labour cost remains negative.

In line with the NKPC literature, we also abandoned the theoretical purity of the approach, by allowing for habit formation in consumption, and controlling for a lagged inflation term. Results are reported in columns (3) and (4). Again, the result is a positive rate of time preference, but one which is now implausibly large. What is more, the real unit labour cost proxy for the output gap remains negative and in the case of CPI statistically insignificant. Estimation under GMM, reported in columns (7) and (8), is entirely symmetrical, with a rate of implied time preference which is implausibly large, and with a negative coefficient on the marginal cost of production proxy for the output gap.

What might account for the poor empirical performance of the New Keynesian model? We suggest that the reasons arise both from the underlying theoretical assumptions, and empirically. First, the specification

four.

[27] Note that we employed a range of alternative specifications of the expectations term - none of which reports results which improve on those reported in the manuscript.

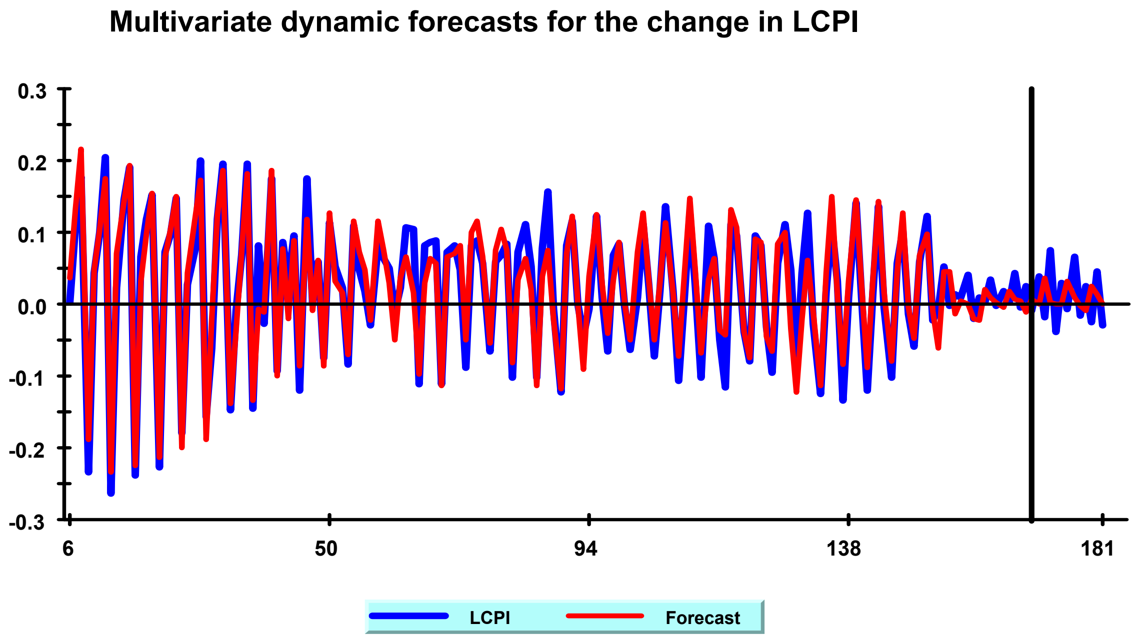

Figure 10: CPI Fit and Forecast: controlling for 1970-90 period.

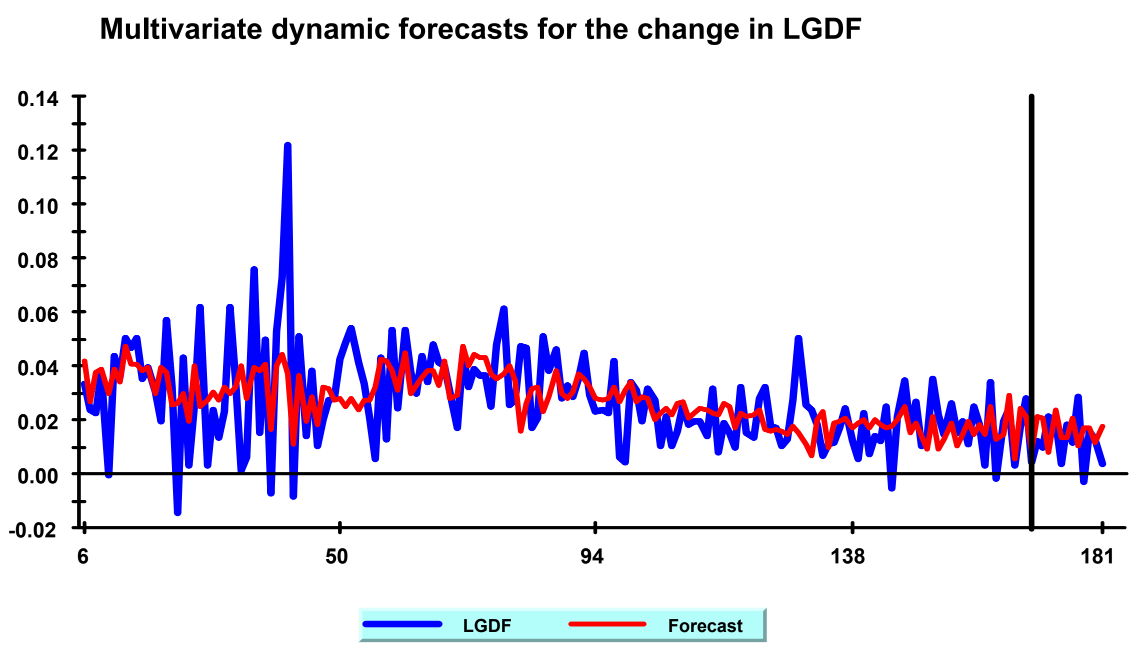

Figure 11: GDP Deflator Fit and Forecast: controlling for 1970-90 period.

	New Keynesian Phillips Curve							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	CPI	GDP	CPI	GDP	CPI	GDP	CPI	GDP
	OLS	OLS	OLS	OLS	GMM	GMM	GMM	GMM
$E(\pi_{t+1})$	0.68*** (0.06)	0.87*** (0.04)	0.44*** (0.06)	0.47*** (0.04)	0.99*** (0.08)	0.99** (0.04)	0.55*** (0.11)	0.40*** (0.07)
π_{t-1}			0.43*** (0.06)	0.52*** (0.04)			0.38*** (0.09)	0.59*** (0.06)
$d.RULC_{t-i}$	−5.86 (8.53)	0.08 (5.44)	−3.64 (7.47)	−9.83** (4.11)	−4.98 (30.52)	−7.34 (17.34)	−30.40 (26.20)	−35.93*** (11.89)
$adj-R^2$	0.45	0.75	0.58	0.86				
***, **, *, denotes significance at the 1, 5 and 10% levels.								
Figures in round parentheses denote standard errors.								
Figures in curly parentheses denote lag length i in X_{t-i}.								
MAE denotes mean absolute error; MAPE denotes MA percentage error								
MSE denotes mean square error; RMSE denotes root MSE								

Table 9: New Keynesian Phillips Curve Results

of the NKPC is derived under the assumption of no capital accumulation, and under clearing labour markets. Assuming away capital accumulation is perilous for any developing economy context, where invest in capital is a core driver of long run growth. Clearing labour market assumptions in South Africa are even more heroic. Finally, the model results in a very parsimonious specification of the drivers of inflation, which opens the possibility of bias and inconsistency due to omitted variables bias in estimation. What is more, the output gap may simply not be that important in the South African context as an inflation dirver, with other demand-side variables proving to be much more important (and omitted - see the discussion in the following subsection). Finding something that is'nt is likely difficult. Unfortunately it appears that the theoretical purity and elegance of the NKPC comes at the price of empirical irrelevance.

Perhaps it is possible to jolly the New Keynesian model along to the point where it might "work." But it also seems clear that such success would come at the cost of some violence to its theoretical coherence. It is difficult to see the point of engaging in such a trade off for a framework whose entire motivation is theoretical precision.

Given the weak empirical performance of the NKPC approach, we therefore do not consider it further in the present paper.

6.3 The Monetary Model

Under the Monetary models, demand-side shocks now do not emanate from a Phillips-curve mechanism of excess or deficient demand, but either from growth in the money supply, or the monetization of government debt. Thus monetary models are based on the specification given by equation (6).

The approach has a long provenance. Theoretically this is a direct implication of the quantity theory of money, in which changes in money supply growth trnaslate only into nominal pressure (inflation) in the economy, since there is no (lasting) supply response on the real side of the economy, i.e. no growth response. See for instance Lucas (1980, 1996), McCandles and Weber (1995), though this is of course a long-standing proposition in macroeconomics, reaching back to Friedman and Schwartz (1963) and beyond (at least to Hume). In effect, the absence of a supply-side response translates the upward shift in aggregate demand due to monetary expansion (or government expenditure) into pure inflationary pressure. Walsh (2003) provides a useful overview. In policy contexts, famously the Bundesbank utilized money supply growth as one of its principal forecast variables for inflation.

In the South African context, given the accumulated evidence of the pricing power of producers and the associated market concentration in output markets,[28] the implication is of supply-side rigidities in the economy. Under these conditions it is particularly apposite to explore the association between changes in money supply and government expenditure and inflationary pressure, since we might anticipate very muted supply-responses to changes in monetary and fiscal policy instruments.

[28] See Fedderke et al (2007), Aghion et al (2008, 2013), Fedderke and Szalontai (2009), and Fedderke et al (2016).

	Monetary							
π_t:	CPI	CPI	GDP	GDP	CPI	CPI	GDP	GDP
$d.M2_{t-i}$	0.20^{***} (0.05){2}	0.25^{***} (0.05){2}	0.14^{***} (0.04){1}	0.18^{***} (0.04){1}	0.13^{**} (0.06){0}	0.17^{***} (0.05){0}	0.24^{***} (0.04){1}	0.23^{***} (0.03){1}
	0.15^{***} (0.05){8}	0.13^{***} (0.04){8}	0.11^{***} (0.04){6}	0.13^{***} (0.04){6}	0.18^{***} (0.06){3}	0.16^{***} (0.05){3}	0.14^{***} (0.05){6}	0.12^{***} (0.04){6}
					0.21^{***} (0.05){8}	0.16^{***} (0.05){8}	0.13^{***} (0.05){10}	0.09^{***} (0.03){10}
$GovExp_{t-i}$	0.10^{**} (0.04){0}	0.07^{*} (0.04){0}	0.12^{***} (0.03){0}	0.07^{***} (0.02){0}				
	0.07^{*} (0.04){1}	0.05^{**} (0.03){1}	0.07^{**} (0.03){1}	0.09^{***} (0.03){1}				
	0.09^{**} (0.04){4}	0.07^{**} (0.03){4}	0.08^{***} (0.03){5}	0.05^{**} (0.02){5}				
			0.09^{***} (0.03){6}	0.04^{*} (0.03){6}				
$S\&D_{t-i}$					-0.20^{*} (0.10){6}	-0.11 (0.08){6}	-0.17^{*} (0.09){1}	-0.05 (0.05){1}
							-0.17^{*} (0.09){6}	-0.03 (0.05){6}
SS_{t-i}	13.58^{**} (6.37){1}	10.01^{*} (5.78){1}	40.21^{***} (5.58){0}	23.63^{***} (5.58){0}	9.75 (6.78){0}	5.43 (5.88){0}	43.14^{***} (6.11){0}	18.77^{***} (4.50){0}
			-26.23^{***} (5.62){4}	-15.96^{***} (4.52){4}			-22.66^{***} (5.93){4}	-10.20^{***} (3.59){4}
$Arch.L1$		0.36^{**} (0.15)		0.65^{***} (0.20)		0.62^{**} (0.19)		0.98^{***} (0.27)
$Garch.L1$		0.55^{***} (0.14)						
$adj-R^2$	0.32		0.44		0.25		0.36	
MAE	1.48	1.53	1.74	1.30	1.28	1.36	1.52	1.04
MAPE	0.44	0.47	0.36	0.28	0.47	0.48	0.34	0.24
MSE	3.63	3.80	4.08	2.87	3.87	4.08	5.16	2.44
RMSE	1.91	1.95	2.02	1.69	1.97	2.02	2.27	1.56

***, **, *, denotes significance at the 1, 5 and 10% levels.

Figures in round parentheses denote standard errors.

Figures in curly parentheses denote lag length i in X_{t-i}.

MAE denotes mean absolute error; MAPE denotes MA percentage error

MSE denotes mean square error; RMSE denotes root MSE

Table 10: The Monetary Model

In our empirical implementation we employ the change in $M2$ balances as a measure of changes in the money supply ($d.M2_{t-i}$), government expenditure as a percentage of GDP ($GovExp_{t-i}$) or alternatively the government surplus or deficit as a percentage of GDP ($S\&D_{t-i}$) as measures of demand-side shocks, while supply-side shocks (SS_{t-i}) continue to be measured by the percentage deviation of actual terms of trade from trend estimated by the HP filter.

Results are reported in Table 10.

We find that both changes in the money supply and government expenditure have a positive and persistent association with inflation, for both the CPI and the GDP deflator price measures. Both growth in the money supply and government expenditure appear to have particularly persistent inflationary consequences, in the case of money supply changes showing durations up to 10 quarters, and in the case of government expenditure 6 quarters. By contrast, the surplus/deficit on government accounts shows a much weaker, ambiguous, and non-persistent association with inflation.

We report the goodness of fit and forecast performance of the monetary models in Figure 12. For the monetary model we again see a clear forecast of a 6% inflation rate for the CPI inflation measure, and for the GDP deflator measure an increase in inflationary pressure to approximately 8%.

One potential implication to emerge from our consideration of the monetary model is therefore that demand-side pressure on South African inflation, may be most usefully represented not through an output gap measure, but through money supply growth and the expansionary or contractionary impact of government

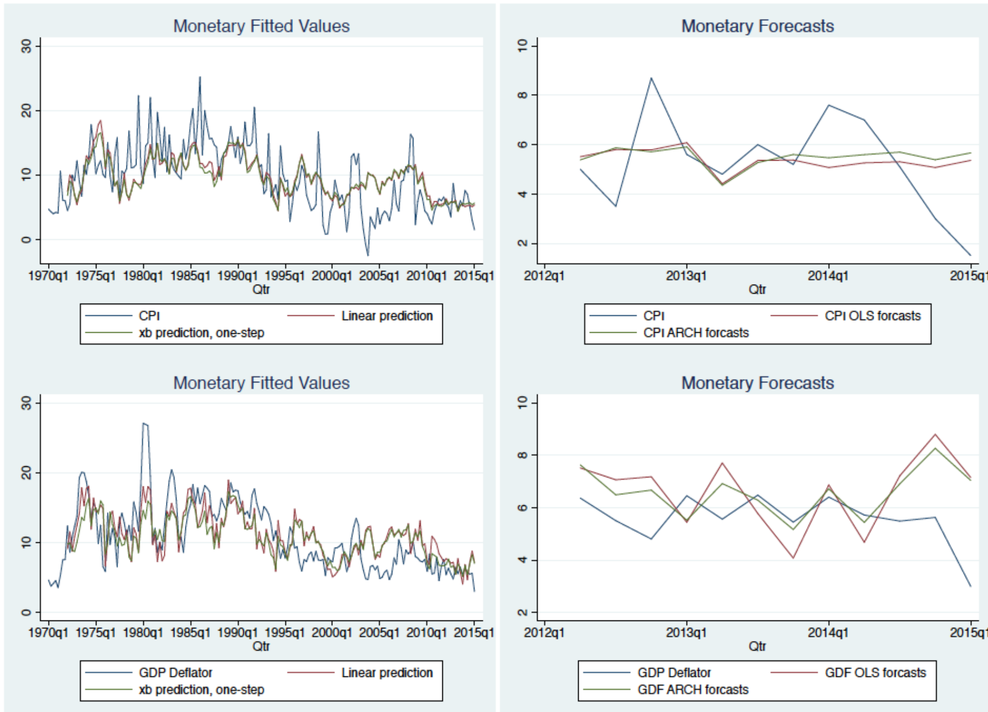

Figure 12: Monetary Model: Goodness of Fit and Forecast Performance.

expenditure.

6.4 A Hybrid Model

As a final step, we abandon theoretical purity. Instead of adopting rigidly a Phillips curve (of whatever type), a monetary, or a structural model of inflation, we employ a theoretically agnostic approach, in which we allow for all the variables identified in our preceding discussion as a possible covariate of inflation, to compete empirically in a general-to-specific modelling methodology.

Thus, we allow for the possibility that the output gap, unit labour costs or the alternative of decomposing unit labour cost into nominal wage changes and real labour productivity, supply shocks, changes in the nominal exchange rate, the growth rate in M2, and government expenditure as a percentage of GDP may all be associated with inflation.

We term this our hybrid model, since it does not prioritize any of the theoretical frameworks for inflation. In what follows we consider two alternative hybrid models. In the first we utilize the nominal unit labour cost specification. In the second, we utilize the decomposition of nominal unit labour cost into the change in nominal wage and change in real labour productivity specification of the cost push component of inflation.

For the specification with unit labour costs, Hybrid 1, we report results in Table 11. In the Hybrid 1 composite model, we continue to confirm significant and persistent inflationary impacts from changes in unit labour cost. By contrast, the output gap does not have a theoretically coherent impact on inflation (negative, rather than positive, now for both the CPI and the GDP deflator variables). Instead, and consistent with the findings already reported for the monetary model above, the demand side of the economy appears to exercising inflationary pressure through changes in the money supply and government expenditure. Such demand side effects are both positive, and persistent, lasting up to 8 lags. Supply side shocks continue to be relevant, and to a more moderate degree, so do changes in the exchange rate.

For both CPI and GDP deflator measures, we continue to find the presence of ARCH effects.

Goodness of fit shows dramatic improvement over all the underlying theoretical contributing models, as does forecast accuracy.

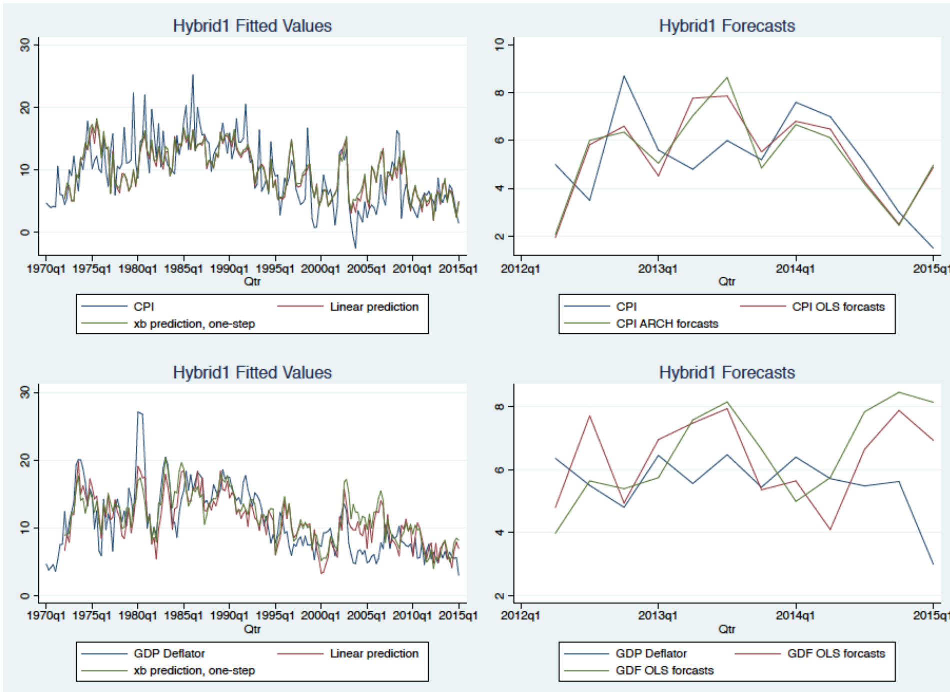

Figure 13: Hybrid Model 1: Goodness of Fit and Forecast Performance.

We report the goodness of fit and forecast performance of the Hybrid 1 models in Figure 13. The clear improvement in goodness of fit is evident for the Hybrid 1 model. What is more, for the Hybrid 1 model we do forecast the dramatic decrease in the official CPI-based inflation that is contained in the official SARB data series (post 2014Q1), rather than continuing to forecast a 6% inflation rate as was the case for all preceding models. By contrast, the Hybrid 1 model for the GDP deflator inflation measure again forecasts an increase in inflationary pressure to approximately 8%.

For the Hybrid 2 model specification, with unit labour cost decomposed into changes in the nominal wage and changes in real labour productivity, we report results in Table 12. Again, in the Hybrid 2 composite model, we continue to confirm significant and persistent inflationary impacts from changes in nominal wages, with growth in labour productivity having a negative impact on inflation. For this specification, the output gap continues to have the theoretically coherent positive impact on inflation for the CPI measure, and the theoretically inconsistent negative coefficient for the GDP deflator. Both growth in money balances and government expenditure as a per cent of GDP also exert a positive impact on inflation, in the case of government expenditure with some persistence. Supply side shocks continue to be relevant, and so do changes in the exchange rate.

While goodness of fit shows does not improve dramatically over the Gordon model with the d.lW & RY/L decomposition, forecast accuracy does show marginal improvement.

We report the goodness of fit and forecast performance of the monetary models in Figure 14. The high goodness of fit is evident for the Hybrid 2 model. As for the Hybrid 1 model, Hybrid 2 also forecasts the dramatic decrease in the official CPI-based inflation that is contained in the official SARB data series, rather than forecast a steady 6% inflation rate. In contrast to the Hybrid 1 model, Hybrid 2 does forecast a decreasing inflationary pressure for the GDP deflator, though it remains stable at a 6% inflation rate.

7 Conclusions and Evaluations

In this paper we have used different models to describe and forecast inflation in South Africa.

The paper presents a number of innovations to the South African literature on inflation. First, instead

	Hybrid 1			
π_t :	CPI	CPI	GDP	GDP
gY_{t-i}	-4.80^{*} (2.60){0}	-5.10^{**} (2.35){0}	-2.45^{*} (1.27){0}	
	5.88^{**} (2.76){1}	6.18^{***} (2.66){1}	-3.11^{**} (1.31){3}	-3.97^{***} (0.99){3}
	-5.53^{***} (1.54){4}	-4.72^{***} (1.54){4}		
$d.LULC_{t-i}$	27.78^{***} (8.24){0}	24.86^{***} (8.94){0}	12.92^{*} (7.56){0}	18.92^{***} (5.07){0}
	22.90^{**} (8.89){1}	25.93^{***} (9.23){1}	17.25^{***} (7.37){1}	23.98^{***} (5.68){1}
			20.06^{**} (7.23){2}	22.40^{***} (6.01){2}
SS_{t-i}	16.41^{***} (5.87){1}	17.78^{***} (5.46){1}	29.03^{***} (6.24){0}	15.46^{***} (4.56){0}
			16.46^{**} (6.77){1}	11.71^{**} (4.60){1}
			-12.50^{*} (6.79){3}	-23.48^{***} (4.34){3}
			-16.51^{***} (6.21){4}	-13.74^{***} (4.07){4}
$d.Exchange$	1.64^{**} (0.69){1}	1.76^{*} (0.94){1}	1.23^{**} (0.62){1}	0.44 (0.52){1}
	2.58^{***} (0.69){2}	2.10^{***} (0.80){2}	1.56^{**} (0.65){3}	0.24 (0.52){3}
	1.57^{**} (0.75){4}	0.99 (0.71){4}		
	1.51^{**} (0.67){6}	1.10^{*} (0.65){6}		
$d.M2_{t-i}$	0.19^{***} (0.06){2}	0.18^{***} (0.06){2}	0.16^{***} (0.05){0}	0.23^{***} (0.04){0}
	0.23 (0.05){8}	0.23^{***} (0.05){8}	0.19^{***} (0.05){5}	0.22^{***} (0.04){5}
$GovExp_{t-i}$	0.09^{**} (0.04){0}	0.10^{**} (0.04){0}	0.11^{***} (0.03){0}	0.07^{***} (0.02){0}
	0.08^{**} (0.03){1}	0.07^{**} (0.03){1}	0.07^{**} (0.03){4}	0.05^{***} (0.02){4}
	0.10^{***} (0.03){4}	0.10^{***} (0.03){4}	0.05^{*} (0.03){5}	0.02 (0.02){5}
	0.09^{***} (0.03){8}	0.08^{**} (0.04){8}	0.10^{***} (0.03){8}	0.05^{**} (0.02){8}
$Arch.L1$		0.32^{*} (0.18)		0.89^{***} (0.26)
$adj-R^2$	0.47		0.52	
MAE	1.64	1.69	1.47	1.71
MAPE	0.46	0.46	0.34	0.24
MSE	3.83	3.97	3.23	4.76
RMSE	1.96	1.99	1.80	2.18

***, **, *, denotes significance at the 1, 5 and 10% levels.
Figures in round parentheses denote standard errors.
Figures in curly parentheses denote lag length i in X_{t-i}.
MAE denotes mean absolute error; MAPE denotes MA percentage error
MSE denotes mean square error; RMSE denotes root MSE

Table 11: Hybrid Model 1

	Hybrid Model 2			
π_t :	CPI	CPI	GDP	GDP
gY_{t-i}	3.03^{***} (1.32){1}	4.74^{***} (1.29){1}	-2.05^{**} (1.03){2}	-1.99^{***} (0.83){2}
$d.lW$	36.49^{***} (11.68){0}	33.02^{***} (10.58){0}	17.41^{*} (9.81){1}	10.27 (6.49){1}
	41.66^{***} (13.08){1}	42.69^{***} (12.06){1}	22.37^{*} (9.35){2}	15.46^{***} (5.43){2}
	23.18^{**} (11.34){2}	21.16^{*} (10.96){2}	19.64^{**} (8.81){4}	19.61^{***} (7.20){4}
$d.RY/L$	-1.01^{***} (0.32){0}	-0.88 (0.80){0}	-0.80^{***} (0.26){0}	-0.68^{***} (0.41){0}
	-1.13^{***} (0.34){1}	-0.98 (0.66){1}	-0.73 (0.26){1}	-0.56^{***} (0.59){1}
SS_{t-i}	7.00 (5.46){0}	8.95 (5.41){0}	32.20^{***} (5.39){0}	23.52^{***} (4.51){0}
			11.80^{**} (5.84){1}	8.04^{**} (3.87){1}
			-11.33^{*} (5.82){3}	-8.40^{*} (4.48){3}
			-18.42^{***} (5.31){4}	-11.55^{**} (3.40){4}
$d.Exchange_{t-i}$	-1.27^{*} (0.67){0}	-1.49^{*} (0.79){0}		
	1.41^{**} (0.67){0}	0.92 (0.75){0}		
$d.M2_{t-i}$	0.14^{**} (0.07){3}	0.10 (0.07){3}	0.08^{**} (0.04){1}	0.09^{**} (0.03){1}
	-0.20^{***} (0.07){5}	-0.20^{***} (0.07){5}	0.09^{**} (0.04){5}	0.13^{***} (0.03){5}
	0.18^{***} (0.05){8}	0.19^{***} (0.05){8}		
$GovExp_{t-i}$	0.08^{**} (0.03){0}	0.05^{*} (0.04){0}	0.10^{***} (0.03){0}	0.06^{***} (0.02){0}
	0.06^{**} (0.03){4}	0.06^{**} (0.03){4}	0.05^{**} (0.02){4}	0.03^{*} (0.02){4}
	0.06 (0.03){8}	0.03 (0.03){0.03}	0.07^{***} (0.02){8}	0.06^{***} (0.02){8}
$Arch.L1$		0.31^{**} (0.13)		0.88^{***} (0.26)
$adj - R^2$	0.53		0.64	
MAE	1.83	1.87	1.57	1.14
MAPE	0.35	0.37	0.30	0.24
MSE	4.59	4.54	3.60	2.18
RMSE	2.14	2.13	1.90	1.48

***, **, *, denotes significance at the 1, 5 and 10% levels.
Figures in round parentheses denote standard errors.
Figures in curly parentheses denote lag length i in X_{t-i}.
MAE denotes mean absolute error; MAPE denotes MA percentage error
MSE denotes mean square error; RMSE denotes root MSE

Table 12: Hybrid Model 2

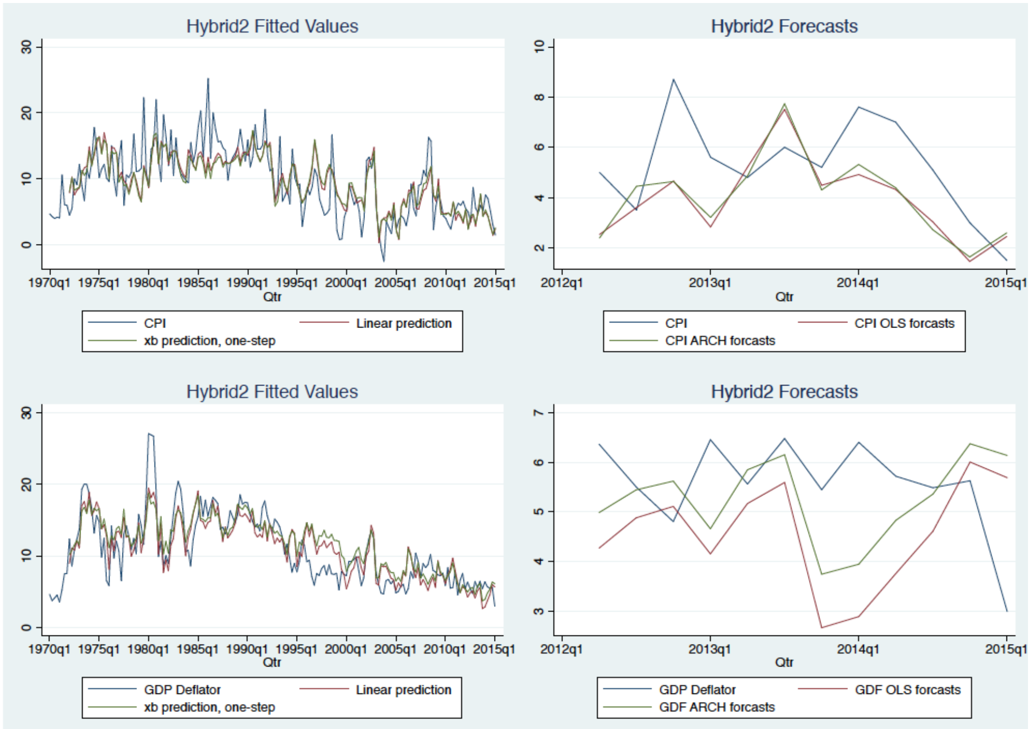

Figure 14: Hybrid Model 2: Goodness of Fit and Forecast Performance.

of rigidly considering only a single theoretical framework, we consider the relative performance of a range of competing inflation models. This covers Phillips curve type models, monetary models, structural models of inflation, as well as some hybrid models that are agnostic as to the theoretical foundations of inflationary pressure.

Second, we consider the utility of incorporating ARCH structure into the modelling in improving the performance of inflation models. An ARCH structure to inflation does find support, suggesting that exploiting the second moment of the inflation distribution is useful in the modelling of inflation in South Africa.

Our core findings are as follows.

First, the single most robust covariate of inflation is unit labour cost. We further decompose unit labour cost into changes in the nominal wage and real labour productivity. The principal association is a strong positive relationship between inflation and nominal wages, while improvements in real labour productivity report only a relatively weak negative association with inflation. The implication of this finding is that South African inflation has a strong cost-push structure, with the principal driver being increases in nominal wage costs, while productivity growth exercising only a very moderate restraint on inflationary pressure. This accords well with established empirical findings on the pricing power of South African producers.

Second, supply side shocks also consistently report an association with inflation.

As to demand-side shocks, the output gap does not return a robust statistical association with inflation. Instead, it is growth in the money supply and government expenditure which prove to return consistent associations with inflationary pressure, and these may prove to be more useful proxies for demand side shocks in inflation models than the output gap has proved to be.

The difficulty in finding a reliable impact of the output gap on inflation may well be due to the difficulties in developing reliable output gap measures - see Fedderke and Mengisteab (2016). But precisely given this limitation, it may be desirable to use alternative measures of demand side pressure instead, such as money supply growth and government expenditure stances.

In terms of forecast performance for inflation, the most successful models prove to be the structural model based on Ghali (1999), and our Hybrid 2 model, which loads nominal unit labour cost decomposed into the change in nominal wages and changes in real labour productivity, and incorporates demand-side shocks via money supply growth, government expenditure as well as the output gap.

References

[1] Aghion, P., Braun, M., and Fedderke, J.W., 2008, Competition and Productivity Growth in South Africa, *Economics of Transition*, 16(4), 741-68.

[2] Aghion, P., Fedderke, J.W., Howitt, P., and Viegi, N., 2013, Testing Creative Destruction in an Opening Economy: the Case of the South African Manufacturing Industries, *Economics of Transition*, 21(3),419-50.

[3] Aron, J. and J. Muellbauer, J.N.J., 2004, Are wage-setters forward-looking? Evidence from South Africa, Mimeo: Centre for the Study of African Economics, Oxford University.

[4] Aron, J. and J. Muellbauer, J.N.J., 2007, Trade Openness and Inflation, Mimeo: Centre for the Study of African Economics, Oxford University.

[5] Aron, J., Muellbauer, J.N.J., and Smit, B.W., 2004, A Structural Model of the Inflation Process in South Africa, Centre for the Study of African Economies, Working Paper No. CSAE WPS/2004-08.

[6] Ball, L., 1992, Why does high inflation raise inflation uncertainty, *Journal of Monetary Economics*, 29(), 371-388.

[7] Ben Nasr, A., Balcilar, M., Ajmi, A.N., Aye, G.C., Gupta, R., and Van Eyden, R., 2014, Causality between Inflation and Inflation Uncertainty in South Africa: Evidence from a Markov-Switching Vector Autoregressive Model, University of Pretoria Working Paper No. 2014-53.

[8] Burger P. and Du Plessis S., 2013, A New Keynesian Phillips curve for South Africa, in P. Schaeffer & E. Koussai (eds.), *Econometric methods for analyzing economic development*, Hershey, Pa.: IGI Global, 30-48.

[9] Burger, P. and Marinkov, M., The South African Phillips Curve: How Applicable is the Gordon Model?, *South African Journal of Economics*, 74 (2), 172-189.

[10] Calvo, G A., 1983, Staggered prices in a utility maximising framework, *Journal of Monetary Economics,* 12(3), 383-398.

[11] Cukierman, A. and Meltzer, A., 1986, A theory of ambiguity, credibility, and inflation under discretion and asymmetric information, *Econometrica*, 54(5), 1099-1128.

[12] Davidson, J.E.H., Hendry, D.F., Srba, F. and Yeo, S., Econometric Modelling of the Aggregate Time-Series Relationship Between Consumers' Expenditure and Income in the United Kingdom, *The Economic Journal*, 88(352), 661-691.

[13] Eliasson, A-C, 2001, Is the Short-run Phillips Curve Nonlinear? Empirical Evidence for Australia, Sweden and the United States, Sveriges Riksbank Working Paper Series No. 124.

[14] Engle, R.F., 1982, Autoregressive Conditional Heteroscedasticity with Estimates of the Variance of United Kingdom Inflation, *Econometrica*, 50(4), 987-1007.

[15] Engle, R.F., and Granger, C., 1987, Cointegration and Error Correction: Representation, Estimation and Testing, *Econometrica*, 55, 251-276.

[16] Fedderke, J., Kularatne, C., and Mariotti, M., 2007, Markup pricing in South African industry, *Journal of African Economies,* 16(1), 28-69.

[17] Fedderke, J.W., and Mengisteab, D.K., 2016, Estimating South Africa's output gap and potential growth rate, South African Reserve Bank Working Paper, WP/16/02.

[18] Fedderke, J.W., Obikili, N., and Viegi, N., 2016, Markups and Concentration in South African Manufacturing Sectors: an analysis with administrative data, UNU-WIDER Working Paper, forthcoming.

[19] Fedderke, J.W., and Schaling E., 2005, Modelling Inflation in South Africa: A Multivariate Cointegration Analysis, *South African Journal of Economics*, 73(1), 79-92.

[20] Fedderke J.W. and Szalontai, G.,2009, Industry Concentration in South African Manufacturing: Trends & Consequences, 1970-1996. *Economic Modelling*, 26(1), 241-50.

[21] Friedman, M., 1977, Inflation and unemployment, *Journal of Political Economy*, 85, 451-472.

[22] Friedman, M., and Schwarz, A., 1963, *A Monetary History of the United States, 1867-1960*, Princeton: University Press.

[23] Gali, J., and Gertler, M., 1999, Inflation dynamics: a structural econometric analysis, *Journal of Monetary Economics*, 44(2), 195-222.

[24] Ghali, K.H., 1999, Wage Growth and the Inflation Process: A Multivariate Cointegration Approach, *Journal of Money, Credit and Banking*, 31(3), 417-31.

[25] Glassman, J.E., and Stockton, D.J., 1983, An Evaluation of Alternative Price Forecasting Models: Theoretical Considerations, Working Paper No. 32, Board of Governors of the Federal Reserve System.

[26] Gordon, RJ., 1989, Hysteresis in history: Was There Ever a Phillips Curve?, *The American Economic Review*, 79(2), 220-225.

[27] Gordon, RJ., 1997, The Time-varying NAIRU and Its Implications for Economic Policy, *Journal of Economic Perspectives*, 11(1), 11-32.

[28] Hendry, D., 2001, Modelling U.K. Inflation, *Journal of Applied Econometrics*, 16(3), 255-75.

[29] Hodge, D., 2002, Inflation versus unemployment in South Africa: is there a trade-off? *South African Journal of Economics,* 70(3), 417-443.

[30] Holland, S., 1995, Inflation and uncertainty: tests for temporal ordering, *Journal of Money, Credit, and Banking*, 27(), 827-837.

[31] Johansen, S., 1991, Estimation and Hypothesis Testing of Cointegration Vectors in Gaussian Vector Autoregressive Models, *Econometrica*, 59(6), 1551-80.

[32] Johansen, S., and Juselius, K., 1990, Maximum Likelyhood Estimation and Inference on Cointegration - with applications to the demand for money, *Oxford Bulletin of Economics and Statistics*, 52(2), 169-210.

[33] Johansen, S., and Juselius, K., 1992, Testing structural hypotheses in a multivariate cointegrating analysis of the PPP and the UIP for UK, *Journal of Econometrics*, 53, 211-44.

[34] Kabundi, A. and Schaling, E. 2013, Inflation and Inflation Expectations in South Africa: An Attempt at Explanation, *South African Journal of Economics*, 81(3), 346-355.

[35] Kabundi, A., Schaling, E., and Some, M., 2014, Monetary Policy and Heterogeneous Inflation Expectations in South Africa, South African Reserve Bank Working Paper, WP/14/01.

[36] Kumo, W.L., 2015, Inflation Targeting Monetary Policy, Inflation Volatility and Economic Growth in South Africa, African Development Bank Working Paper No. 216.

[37] Lucas, R.E., jr., 1980, Two Illustrations of the Quantity Theory of Money, *American Economic Review*, 70(5), 1005-14.

[38] Lucas, R.E., jr., 1996, Nobel Lecture: Monetary Neutrality, *Journal of Political Economy*, 104(4), 661-82.

[39] Mankiw, N G., 2001, The inexorable and mysterious trade-off between inflation and unemployment, *Economic Journal*, 111(471), C45-C61.

[40] McCandles, G.T., jr., and Weber, W.E., 1995, Some Monetary Facts, Federal Reserve Bank of Minneapolis *Quarterly Review*, 19(3), 2-11.

[41] Moroke, N.D., and Luthuli, A., 2015, An Optimal Generalized Autoregressive Conditional Heteroscedasticity Model for Forecasting the South African Inflation Volatility, *Journal of Economics and Behavioral Studies,* 7(4), 134-149.

[42] Nason, J.M., and Smith, G.W., 2007, Identifying the New Keynesian Phillips Curve, *Journal of Applied Econometrics*, 23(5), 525-51.

[43] Phiri, A., 2015, Examining asymmetric effects in the South African Philips curve: Evidence from logistic smooth transition regression (LSTR) models, MPRA Paper No. 64487.

[44] Pesaran, M.H., and Y. Shin, 1995a, Long Run Structural Modelling, Mimeo, University of Cambridge.

[45] Pesaran, M.H., and Y. Shin, 1995b, An Autoregressive Distributed Lag Modelling Approach to Cointegration Analysis, *DAE Working Paper no 9514*, Department of Applied Economics, University of Cambridge.

[46] Pesaran, M.H. and Smith, R.P., 1995, Estimating Long-Run Relationships from Dynamic Heterogeneous Panels, *Journal of Econometrics*, 68, 79-113.

[47] Pesaran, M.H., Y. Shin, and R.J. Smith, 1996, Testing for the Existence of a Long Run Relationship, *DAE Working Paper No.9622*, Department of Applied Economics, University of Cambridge.

[48] Pesaran M.H., Shin, Y., and Smith, R.P., 1999, Pooled Mean Group Estimation of Dynamic Heterogenous Panels, *Journal of the American Statistical Association*, 94, pp. 621-634.

[49] Pourgerami, A. and Maskus, K., 1987, The effects of inflation on the predictability of price changes in Latin America: some estimates and policy implications, *World Development*, 15(), 287-290.

[50] Pretorious. C.J. and Janse van Rensburg. T.N., 1996, The Forecast Performance of Alternative Models of Inflation, South African Reserve Bank Occasional Paper No. 10.

[51] Schaling, E., 2004, The Nonlinear Phillips Curve and Inflation Forecast Targeting: Symmetric versus Asymmetric Monetary Policy Rules, *Journal of Money, Credit and Banking*, 36(3), 361-386.

[52] Stockton, D.J., and Glassman, J.E., 1987, An Evaluation of the Forecast Performance of Alternative Models of Inflation, *Review of Economics and Statistics*, 69(1), 108-17.

[53] Ungar, M., and Zilberfarb, B., 1993, Inflation and its unpredictability - theory and empirical evidence. *Journal of Money, Credit, and Banking*, 25(), 709-720.

[54] Walsh, C.E., 2003, *Monetary Theory and Policy*, 2'nd ed., MIT Press.

[55] Wickens, M.R., 1996, Interpreting cointegrating vectors and common stochastic trends, *Journal of Econometrics*, 74, 255-71.