A New Keynesian Phillips Curve for South Africa

S du Plessis and R Burger

Introduction

The time varying impact of a change in monetary conditions on real output and the aggregate price level is central to the challenge of monetary policy. Changes in the stance of monetary policy have their first impact on real variables in the economy (output and employment), sometimes summarised as a non-vertical short-run Phillips curve, but in the longer run the impact falls mainly on the aggregate price level. Awareness of this pattern is as old as economics' separate field of study and David Hume's remarkable mid-eighteenth century description thereof is frequently quoted (for example, Brunner and Meltzer, 1976; Lucas, 1995). However, despite this considerable attention and the importance of the issue for monetary policy, an agreed-upon model for the Phillips curve has not been reached (Mankiw, 2001). Indeed a mistaken view of this relationship – the idea of a permanent trade-off between inflation on the one side and real output and employment on the other – has been productive of much mischief in the design and implementation of monetary policy since the War (Friedman, 1968; Lucas, 1976; Romer and Romer, 2002).

A comparatively new model of the Phillips curve, often called the New Keynesian Phillips Curve (NKPC), has recently received considerable interest and support from monetary economists. It has become especially important in recent policy models where the NKPC has become a "standard specification" (for example, Clarida et al., 1999; McCallum, 2001; Woodford, 2003). The South African literature is exceptional in that these models have not yet been applied locally, despite their close association with forward-looking and rules-based monetary policy regimes such as the inflation targeting regime of the South African Reserve Bank. This paper takes a first step towards introducing the NKPC in the South African debate, by estimating a standard version of the model and comparing the results with international literature as well as South African precedents.

The first section of the paper provides a brief theoretical introduction to the NKPC. This is followed by a survey of the South African Phillips curve literature, as a benchmark for the results derived below. The data and method used in the empirical estimation are described in the following section and the results of this estimation in the section thereafter.

The New Keynesian Phillips curve

In the New Keynesian tradition nominal rigidities (which yield a non-vertical short-run aggregate supply curve and non-vertical short-run Phillips curve) are built on rational decision theoretic foundations (Mankiw, 2001). The NKPC is a linear approximation to a dynamic stochastic general equilibrium with nominal rigidities and rational expectations (Walsh, 2003). These features, the forward-looking and rational expectations and the general equilibrium and decision theoretical foundations, allow the NKPC a role in policy analysis which has been closed to more traditional specifications since Lucas's telling critique of econometric policy evaluation (Lucas, 1976).

While both labour and goods markets can give rise to nominal rigidities, NKPC derives nominal rigidities in goods markets, following the monopolistic competition framework – due to Dixit and Stiglitz (1977) – as applied later by Taylor (1980), Rotemburg (1982) and especially Calvo (1983). It is the latter's pricing model that has had the greatest influence on the NKPC literature. Following Calvo (1983) the typical NKPC derivation assumes forward-looking households and firms in a monopolistic setting and usually abstracts from capital accumulation. Price adjustments are time-contingent in the Calvo model with a fraction $(1 - \theta)$ of firms given the opportunity to change their output price every period, with the knowledge that this new price will be fixed over an uncertain horizon. The average firm's price is therefore fixed for $1/(1-\theta)$ periods. The aggregate price level in period *t*, p_t, is given by Equation 1:

$$p_t = \theta p_{t-1} + (1-\theta)p^* \qquad (1)$$

Where p* is the optimal price chosen by firms able to reset their prices. Because the firm's optimisation problem is dynamic and forward looking the optimal price can be shown to be a mark-up on a distributed lead of expected marginal costs as shown in Equation 2:

$$p^* = (1-\beta\theta)\sum_{i=0}^{\infty}(\beta\theta)^i E_t[\hat{\varphi}_{t+1}] \qquad (2)$$

where $\hat{\varphi}_t$ is the proportional variation of marginal costs from its flexible price level and β is the time discount factor. Equation 3 shows the resulting equation for current period inflation.

$$\pi_t = \beta E_t[\pi_{t+1}] + \frac{(1-\beta\theta)(1-\theta)}{\theta}\hat{\varphi}_t \qquad (3)$$

where $\pi_t = p_t - p_{t-1}$

The relationship between inflation, expected inflation and a measure of marginal cost in Equation 3 is a variant of the Phillips curve, though a less familiar expression than the more familiar models with output gaps or rates of unemployment. And the Phillips curve in (3) could be rewritten to resemble a traditional model more closely by following, *inter alia*, Gali and Gertler's (1999) observation that with reasonable assumptions the output gap is proportional to marginal cost, so no information is lost in a specification around marginal cost[1]. Given this proportionality it is possible to rewrite (3) with an output gap $\hat{y}_t$ that shows the gap between the actual level of output y_t and the flexible price level of output y_t^f. This yields a version of the NKPC with a more standard output gap, as shown in Equation 4.

$$\pi_t = \beta E_t[\pi_{t+1}] + \alpha\hat{y}_t \qquad (4)$$

However, the precise definition of the output gap used in this model has implications for the estimation strategy. Though (3) and (4) are formally equivalent it may be more difficult to estimate (4) given the difficulty of finding an empirical counterpart for the flexible price level of output. Conventionally used proxies – such as the Hodrick-Prescott (HP) filter or deterministic trends – are unlikely to reflect the flexible price output level accurately and using such poorly specified output gap measures may explain the problems of data adherence experience by models based on equation (4) (Henry and Pagan, 2004). Woodford (2003) has argued that attempted dismissals of the NKPC on empirical grounds often result from such poorly specified output gaps.

The hazard of using a poorly specified output gap is readily apparent from the following South African example. A common and somewhat arbitrary measure of the output gap $\{\hat{y}_t\}$ used in empirical work on the NKPC is a detrended output series, using the HP filter or some other smoothing function. Given the effect of productivity shocks on the flexible price output level, one would expect this variable to reveal some volatility. A smoothing of output will therefore discard economically relevant information, and yield a series that is subject to systematic measurement error.

This problem is particularly relevant in the current South African situation where output is presently above most statistically constructed long-term trends, apparently without leading to

[1] The assumption of no capital accumulation (mentioned above) is important for this result: Absent in this assumption, marginal cost is no longer proportional to the output gap with capital accumulation, though the relationship remains close to proportional (Gali and Gertler, 1999).

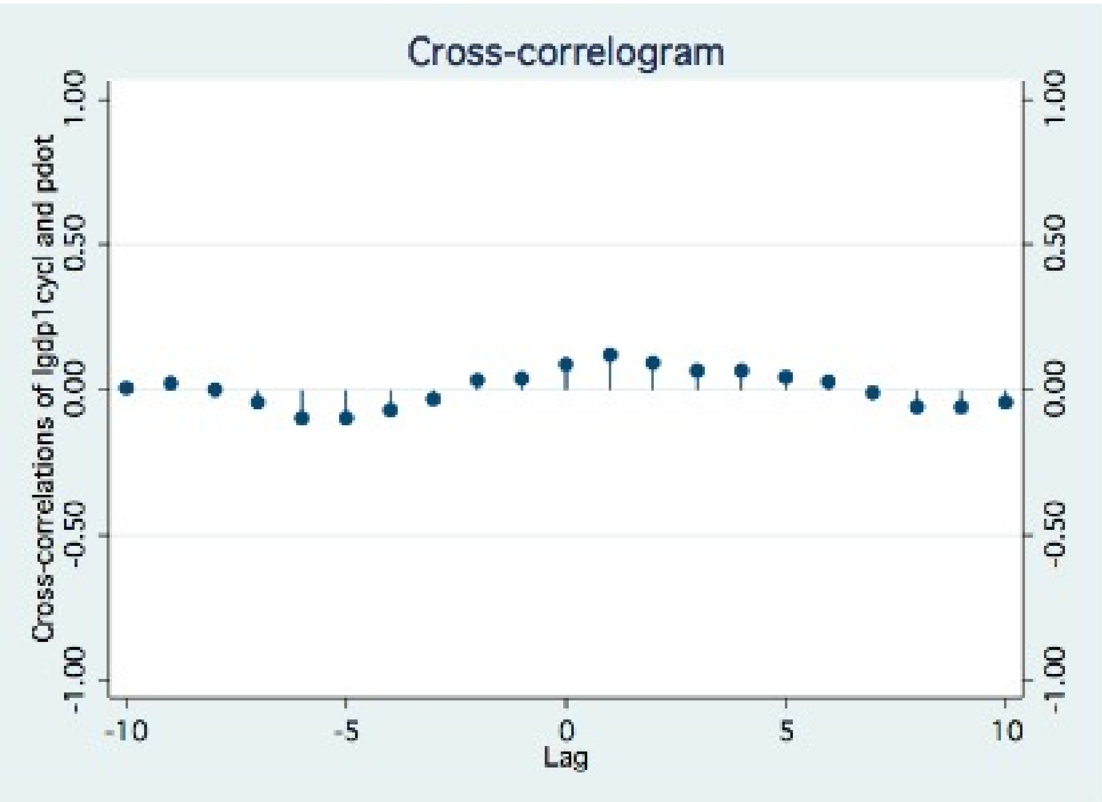
inflationary pressure. If the accelerating output growth has been the result of rising productivity, for instance, due to the opening up of the South African economy since the early 1990s, rather than being driven by aggregate demand, then this will have the effect of reducing marginal costs and therefore decreasing inflation. If such shocks are prevalent, then one would not expect a detrended output variable to be successful in explaining inflation. Indeed, estimating an NKPC for South Africa using detrended output as the measure of the output gap yields the model reported in Table 1.

Table 1: An NKPC for SA with an output gap

Dependent variable: Quarter on quarter consumer price inflation		
Variable	Coefficient	Standard deviation
Expected future inflation	0.979	0.011
Output gap	-0.047	0.028
Sample period:	1975Q1- 2003Q4	

The counterintuitive effect for the output gap using South African data, observed above, has been noted before (for example, Nell, 2000) and indicates the one potential drawback of using conventional definitions of the output gap in estimating a Phillips curve. A further potential drawback of the NKPC with a traditionally estimated output gap is that movements in inflation would anticipate movements in the output gap. This is an empirical prediction which has been found at odds with the data elsewhere (Gali and Gertler, 1999) and could also be tested in South Africa. Figure 1 shows a cross-correlogram between the output gap (estimated with an HP filter) and inflation in South Africa. The cross-correlogram shows a mild effect of the output gap on subsequent inflation, but no evidence of inflation leading the output gap as would be required by an NKPC with this output gap.

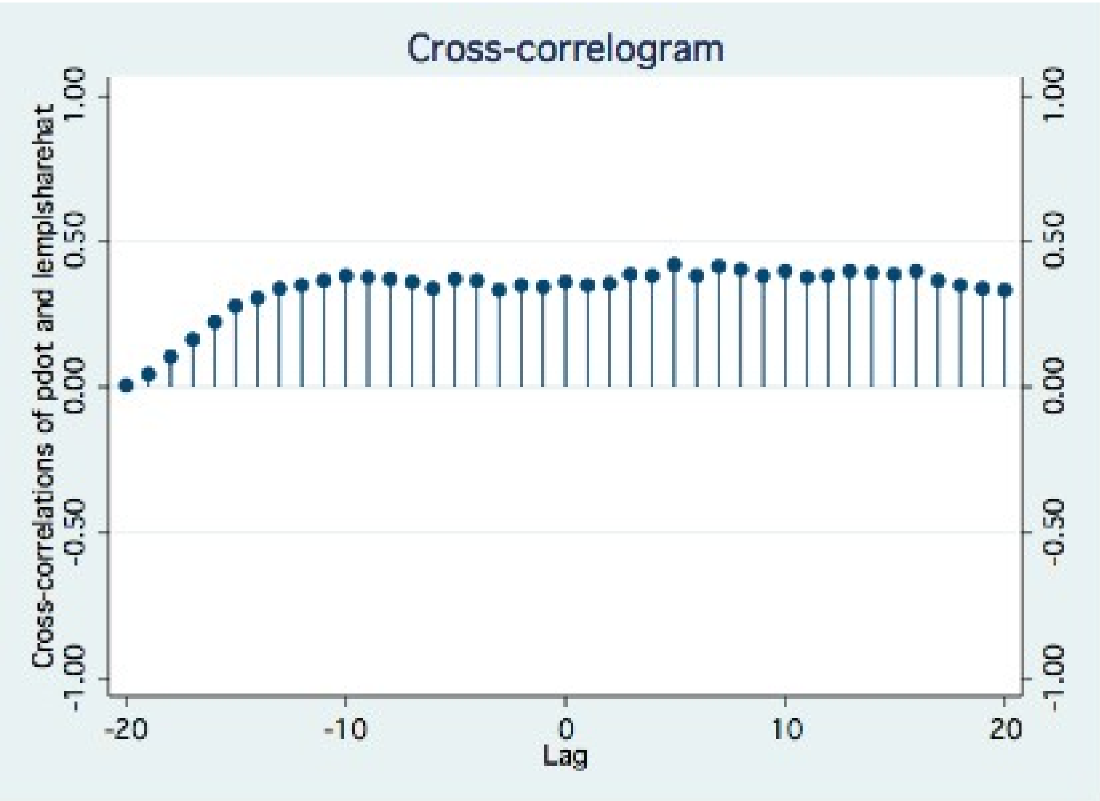
Figure 1: The output gap and inflation



Although marginal costs are a little easier to measure accurately than the output gap, it is proportional to the labour income share under certain mild conditions[2] (Walsh, 2003). If labour is the only variable input in a Cobb-Douglas production function $Y_t = A_t K_t^{\alpha_k} N_t^{\alpha_n}$, marginal cost will be $\varphi_t = \frac{W_t}{P_t} \frac{1}{\partial Y_t / \partial N_t} = \frac{W_t N_t}{P_t Y_t} = S_t$, where S_t is the share of income accruing to labour. In addition to avoiding problematic output gap measurements, using this variable (or the variation from its average) in Equation 3 rather than detrended output in equation 4 will, *inter alia*, allow accounting for the disinflationary effect of productivity increases in this model of inflation.

In contrast with Figure 1, the cross-correlogram in Figure 2 between the labour income share and inflation in South Africa shows that, empirically, inflation anticipates movements in the labour income share as required by the alternative specification of the NKPC.

Figure 2: Inflation and the labour income share



The estimated equation reported in Table 1 and the cross-correlograms provide evidence against an output-gap based specification and initial evidence in favour of the specification based on the labour income share.

In summary, whether Equations 3 or 4 are used, the resulting Phillips curve is fundamentally forward looking, with inflation depending on expected future inflation, not on lagged inflation as in more traditional specifications. The forward-looking aspect of the relationship, the foundation in dynamic stochastic general equilibrium theory, and the role for marginal cost as inflation driver are features that set the NKPC apart from earlier versions of the Phillips curve (Walsh, 2003).

Despite its theoretical elegance, the NKPC was initially found to be at odds with the data. Mankiw's (2001: C52) damning verdict was that "it cannot come even close to explaining the

[2] Specifically, that firms take wages as given, that labour productivity is exogenous and that labour adjustments are costless.

dynamic effects of monetary policy on inflation and unemployment". This criticism is closely related to two other shortcomings. Firstly, this model fails to account for inflation persistence: Simulations conducted by Fuhrer (1997) show that the NKPC cannot generate the degree of autocorrelation for inflation that is observed empirically. Since price-setters are expressly forward looking and perfect information exists in the model, any new information that is relevant for future price changes is immediately factored into new prices. In the NKPC model inflation therefore resembles a jump-variable, instead of the sluggish adjustment that the traditional Phillips curve described and which is observed in the data. The observed persistent effect of monetary policy on both output and inflation is, therefore, a problem for the NKPC.

Secondly, Ball (1994) showed that forward-looking agents would immediately reduce prices in response to the announcement of a credible disinflation. Prices will therefore immediately come down with expectations, which should precede the fall in nominal money growth, so that the effect on output is stimulatory (via faster real money growth). In reality disinflations are associated with recessions – even when launched by credible central banks like the Bundesbank – rendering Ball's explanation of widespread lack of credibility on the part of central banks implausible.

Recent work has shown that a small modification to the assumptions underlying the NKPC can account for the persistence in inflation. By specifying the representative consumer's utility function so as to allow for habit formation, individuals are assumed to have a preference for smoothing the level and changes in consumption over time. This assumption could be justified by the empirical evidence of "excess smoothness" in consumption behaviour which is hard to explain when assuming rational expectations and time-separable utility. The effect of allowing for habit formation is that real consumption expenditure is sluggish to change, and will show a delayed and hump-shaped response to monetary shocks (Fuhrer, 2000). The dampening effect of habit formation on expenditure and output can also feed through to inflation, so that it no longer acts like a jump variable. If inflation only responds gradually to the announcement of a disinflation, the impact of the latter could now be contractionary.

Christiano, Eichenbaum and Evans (2001) used impulse response functions to show that such a variation of the NKPC is able to generate the persistent effects of monetary shocks on inflation, output, consumption and investment that it is generally said to be incapable of. In addition to habit persistence they also allow for variable capital utilisation and adjustment costs in investment. None of these imply a violation of the individual rationality assumption.

Open economy extensions

While the early NKPC models were estimated for the United States where a closed economy model was perhaps plausible and for Europe, where the same assumption seems less plausible, it is rarely plausible to assume a closed economy setting for an emerging market economy such as South Africa. A number of recent papers offer open economy extensions for the NKPC and a widely used method is to extend the production function to include imported intermediate inputs. These extensions allow the specification of an augmented real marginal cost term which includes, in addition to the labour income share, the ratio of import prices to wages (Gali and Lopez-Salido, 2000; Balakrishnan and Lopez-Salido, 2002; Genberg and Pauwels, 2003; Cespedes et al., 2005).

The log-linearised version of this augmented real marginal cost variable is shown below:

$$
\begin{aligned}
mc_t &= S_t + \theta(pm_t - w_t) \\
\theta &= \left(\frac{1-\mu s}{\mu s}\right)(\sigma - 1)
\end{aligned}
\tag{5}
$$

where:
pmt: the log of import prices at t
wt: the log of remuneration per worker at t

s: 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.

The hybrid model

An important extension of the NKPC – the hybrid NKPC – nests both the traditional expectations augmented Phillips curve and the NKPC described above. Fuhrer (1997) suggested this hybrid model to test for the degree of forward-looking behaviour in price setting behaviour. Equation 6 below shows the reduced form inflation equation for Fuhrer's (1997) model which can also be derived from explicit microfoundations.

$$\pi_t = \beta_0 E_t\left[\pi_{t+1}\right] + \beta_1 \pi_{t-1} + \alpha \hat{y}_t \qquad (6)$$

Fuhrer's (1997) model economy is assumed to consist of two types of firms. A fraction, 1 – ω, of firms are forward looking, and set prices as described above. The remaining ω of firms are backward looking and set prices based on the recent inflation path. However, despite the model's microfoundations and despite its claim to be a realistic reflection of the way that prices are set in practice[3], it is not optimisation-based, and it is difficult to justify the suboptimal strategy followed by backward lookers without resorting to *ad hoc* features, the likes of which have often undermined Keynesian models.

Substituting the labour income share St for the output gap – as used by Fuhrer (1997) – yields a hybrid NKPC shown in Equation 7, which will be estimated with South African data below.

$$\pi_t = \gamma_f E_t\left[\pi_{t+1}\right] + \gamma_b \pi_{t+1} + \lambda \hat{S}_t$$

where

$$\lambda \equiv \frac{(1-\omega)(1-\beta\theta)(1-\theta)}{\theta} \qquad (7)$$

$$\gamma_f \equiv \frac{\beta\theta}{\phi}$$

$$\gamma_b \equiv \frac{\omega}{\phi}$$

$$\phi = \theta + \omega\left[1-\theta(1-\beta)\right]$$

The Phillips curve in the South African literature

South African literature on the Phillips curve stretches back some 40 years, the salient features of which are summarised in Table 2. The realisation that a model of the process of inflation is an indispensable input in the design and implementation of successful monetary policy is as old as this debate (for example, Samuels, 1967) and some of those policy implications are identified below.

Early South African contributions – Gallaway, Koshal and Chapin (1970), Hume (1971), Truu (1975), Strydom and Steenkamp (1976) and Strebel (1976) – followed closely in the steps of Phillips (1958) to investigate the potential trade-off between inflation (nominal wages) and the unemployment rate. The early evidence (for the sixties) suggested a statistically significant, though modest, trade-off between inflation and unemployment, a result which matched the then prevailing international experience (Friedman, 1977).

[3] Surveys have provided little support for "anticipatory pricing" by firms (Blinder et al., 1998).

The introduction of the natural rate hypothesis (Friedman, 1968; Phelps, 1968) internationally, combined with the increasing local unease with the accuracy of measured unemployment rates (especially for the black population) encouraged a move away from unemployment rates to variously defined output gaps in the Phillips curve. Krogh's (1967) conference paper – the seminal paper in this literature – is an example which preferred real GDP growth as a proxy for the demand effect in its Phillips curve relationship. As before, the earlier studies – Krogh (1967), Truu (1975) and Strydom and Steenkamp (1976) – found a significant trade-off between output and inflation, at least for the sixties.

Table 2A: Details of the existing literature on the SA Phillips curve

Paper	Sample perio	Measure of inflation	Measure of aggregate demand	Relevance of demand effect	Type of relationship
Krogh (1967)	1948 – 1965	GDP deflator	Real GDP growth	Small positive relationship at low levels of inflation which turns to a strong negative relationship at higher rates of inflation	Phillips curve gap
Gallaway, Koshal and Chapin (1970)	1948 – 1963	Nominal wage (private manufacturing construction)	Unemployment rate	Significant negative relationship, suggesting a mild trade-off	Distributed lag time series model with deter-ministic trend of Phillips curve
Hume (1971)	1946 – 1966	CPI	Unemployment rate	Significant negative relationship, suggesting a mild trade-off	9 equation wage-price model
Truu (1975)	1948 – 1975	CPI	Unemployment rate (non-agricultural)	Highly significant negative effect	Time series model Phillips curve
Strydom and Steenkamp (1976)	1960 – 1975	CPI and nominal wages	Output gap Unemployment	In a price equation the output gap is significant for 1960 - 1970, but not for 1971 – 1975. In a wage equation the unemployment rate significant over 1958 – 1975	Time series model of expectations augmented Phillips curve
Strebel (1976)	1954 – 1974	CPI	Unemployment rate	Unemployment is significant during periods of rising inflation, not during periods of disinflation	Time series regression and ANOVA analysis

Table 2B: Details of the existing literature on the SA Phillips curve

Levin and Horn (1987)	1969 – 1985	Nominal wages	Unemployment rate	Weaker since the seventies	Graphs of the Phillips curve
Pretorius and Smal (1994)	1970 – 1992	GDP deflator and CPI	Output gap	Output gap has an indirect effect via the wage equation	Time series model of the expectations augmented Phillips curve
Nell (2000)	1971 – 1993	CPI	Output gaps	Significant during period of accelerating inflation (1971-1985). Significant only during downswings between 1986-1993	Time series model of non-linear expectations augmented Phillips curve
Hodge (2002)	1970 – 2000	CPI	Various: Unemployment rate Employment growth Output gap	Relationships either perverse or insignificant, except for the output gap	Error correction model of the Phillips curve
Fedderke and Schaling (2005	1960 – 1999	GDP deflator	Output gap	No significant direct effect, but an indirect channel via the adjustment of unit labour costs to its long-run equilibrium	VECM model of the Phillips curve
Burger and Marinkov (200(	1976 – 2002	CPI (inflation gap)	Output gap	Little evidence of output gap effect	Gordon triangular model

There was less agreement on the policy implications of the evidence though, which was *the* major theme at the 1967 conference of the Economic Society of South Africa. Krogh (1967) argued strongly that the trade-off should not be used by policy-makers while Truu (1975) not only identified a strong trade-off for the sixties, but argued that the authorities had used this trade-off to ill effect, allowing inflation to accelerate in the pursuit of growth and employment. Strydom and Steenkamp (1976) interpreted their steeper long-run Phillips curve (relative to the short-run curve) as evidence that monetary and fiscal policies would be largely impotent in the fight against inflation. However, demand management could help control inflation through its impact on inflation expectations. This policy conclusion is practically identical to that which Burger and Marinkov (2006) reached thirty years later on the basis of weak demand effects in their estimated model.

Between Krogh (1967) at one end of the literature and Burger and Marinkov (2006) at the other, it became increasingly difficult to find a simple specification of the Phillips curve that matched both theory and the experience in South Africa. Two responses followed: One group of authors experimented with various non-linear specifications, hoping to identify phases of the business cycle of the inflationary process during which Phillips curve trade-offs might hold. In this group we find the work of Strebel (1976), Nell (2000) and Burger and Marinkov (2006). The alternative response was to abandon (implicitly or explicitly) the hope of including a demand effect directly in an inflation equation, in favour of an indirect effect via a wage equation determined jointly as a wage-and-inflation system. Pretorius and Small (1994) provide an explicit attempt in this tradition, while Fedderke and Schaling (2005) followed this route implicitly when they discovered that the output gap was only significant in the dynamic adjustment of their wage equation (and not in either of their equilibrium relationships).

To summarise this effort of four decades Hodge (2002) compared the sparse evidence of a Phillips curve at any horizon in South Africa with the consensus on the Phillips curve that had emerged in for example the USA, and which John Taylor (2000) included in his "five things we know for sure" about macroeconomics, i.e. that there is no long-run trade-off between inflation and growth (or employment) but that there is a short-run trade-off. Hodge (2002) found little evidence, either in *his* work or his fine summary of the South African literature, of even a short-run trade-off between inflation and growth (or employment).

And yet the pressure on the South African Reserve Bank (SARB) not to harm growth through an overly vigilant eye on inflation remains unrelenting and the SARB professes to implement its inflation target flexibly so as not to disrupt growth and employment unduly in the pursuit of its primary target. This implies a view at the SARB closer to the international consensus, despite the frustration of reduced form models of the Phillips curve. Some support for the SARB's position is offered below, by estimating an NKPC for South Africa where demand effects are statistically and economically significant.

Data and method

Method

Equation 8 is an estimable model based on Equation 3 above.

$$\pi_t = \beta\pi_{t+1} + \lambda\hat{\varphi}_t + \varepsilon_t \qquad (8)$$

Where $\varepsilon_t = \beta\{E_t[\pi_{t+1}] - \pi_{t+1}\}$ is an inflation shock which, under the assumption of rational expectations, will be orthogonal to the information set in period t. Given a set of instruments Z_t (such as lagged inflation, lagged labour income shares and production and commodity prices) with information about the future path of inflation the orthogonality condition stated in Equation 9 will hold and allows the estimation of the coefficients in Equation 8.

$$E[z_t\varepsilon_t] = E[z_t(\pi_t - \beta\pi_{t+1} - \lambda\hat{\varphi}_t)] = 0 \qquad (9)$$

This equation is estimated using GMM with the inverse of the Newey-West covariance matrix (with 4 truncation lags) as the weighting matrix. This procedure yields consistent estimates under heteroscedasticity and autocorrelation of unknown form. The kernel used to weight the autocovariances is based on the quadratic spectral kernel.

In order for the instrumental variables to be valid in GMM estimation, they are required to be both exogenous and relevant. Although the first criterion is required for identification and cannot be tested for, instrument relevance can and should be investigated. If the instruments are only weakly correlated to the identifying assumption, then the model's coefficients will be poorly identified (Stock and Wright, 2000: 1 055). In this case the sampling distribution of the GMM estimators can differ substantially from the normal distribution, yielding the standard battery of diagnostic tests invalid. In a survey of the weak identification problem in GMM estimation, Stock, Wright and Yogo (2002) suggest testing for this problem using the Anderson-Rubin (1949) and Kleibergen (2001) statistics. Both of these methods are fully robust to the presence of weak instruments. The tests are similar in that they test the null hypothesis that the estimated coefficients are the same as the parameters from the population model, $\beta = \beta_0$.

Moreira (2001) showed that both tests can be expressed in terms of the statistics:

$$\delta = \frac{(Z'Z)^{-1/2} Z'\underline{Y}b_0}{\sqrt{b_0'\Omega b_0}} \text{ and } \tau = \frac{(Z'Z)^{-1/2} Z'\underline{Y}\Omega^{-1}a_0}{\sqrt{a_0'\Omega a_0}} \qquad (10)$$

where *Z* is the set of instruments, $\underline{Y}$ contains the dependent variable and the set of endogenous explanatory variables, Ω is the covariance matrix of the errors of the variables in $\underline{Y}$ regressed on *Z*, b_0 = [1 - β_0]' and a_0 = [β_0 1]'.

The Anderson-Rubin (AR) statistic is

$$AR = \frac{(y - Y\beta_0)' P_Z (y - Y\beta_0)/K}{(y - Y\beta_0)' M_Z (y - Y\beta_0)/(T-K)} = \frac{\delta'\delta}{K} \qquad (11)$$

where $P_Z = Z(Z'Z)^{-1}Z'$, $M_Z = I - P_Z$ and T and K are the sample size and number of instruments, respectively. Under the null and in the presence of weak instruments, this statistic tends in distribution to a χ_K / K distribution.

The Kleibergen statistic is:

$$K = \frac{(\delta'\tau)^2}{\tau'\tau} \qquad (12)$$

which has a χ_1 limiting distribution, even in the presence of weak instruments. Stock, Wright and Yogo (2002) show that when *K* is large, the AR-statistic has low power. Ma (2002), and Yazgan and Yilmazkuday (2005) also consider the problem of weak identification in the context of estimating the New Keynesian Phillips curve.

Data

Data were drawn at a quarterly frequency from the South African Reserve Bank's *Quarterly Bulletin* for the period 1975 Q1 until 2003 Q4. The instrument set includes five lags of inflation, and two lags each of the log employment share, unit labour costs, detrended output and the long-short bond yield spread. A brief description of the data is given in Table 3 and the subsequent graphs plot inflation and the labour income share (Figure 3) and the relative import price (Figure 4) for South Africa.

Table 3: Data description

Variable	Description	SARB code
p_t	Consumer price index (logged)	RB7032N
π_t	$\pi_t = p_t - p_{t-1}$	
$\hat{S}_t$	Deviation of the log of the employment share of income from its long-run average as measure of the output gap	RB6295L
pm	The log of import prices	KBP5035L
w	The log of remuneration per worker	KBP7013L
MCO	The open economy version of real marginal cost	calculated
Output gap	Real output minus the Hodrick-Prescott trend of real output	RB6006D
Yield spread	Yield on gilts with maturity longer than 10 years minus the corresponding yield on gilts with maturity less than 3 years	RB2003M RB2000M

Figure 3: Inflation and the employment share

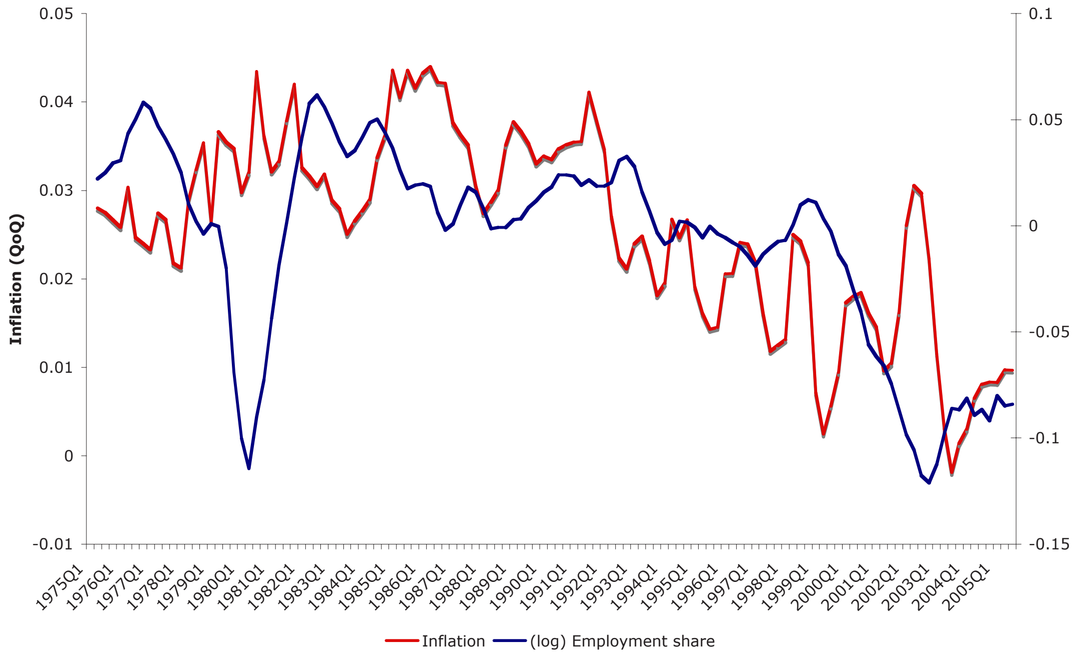
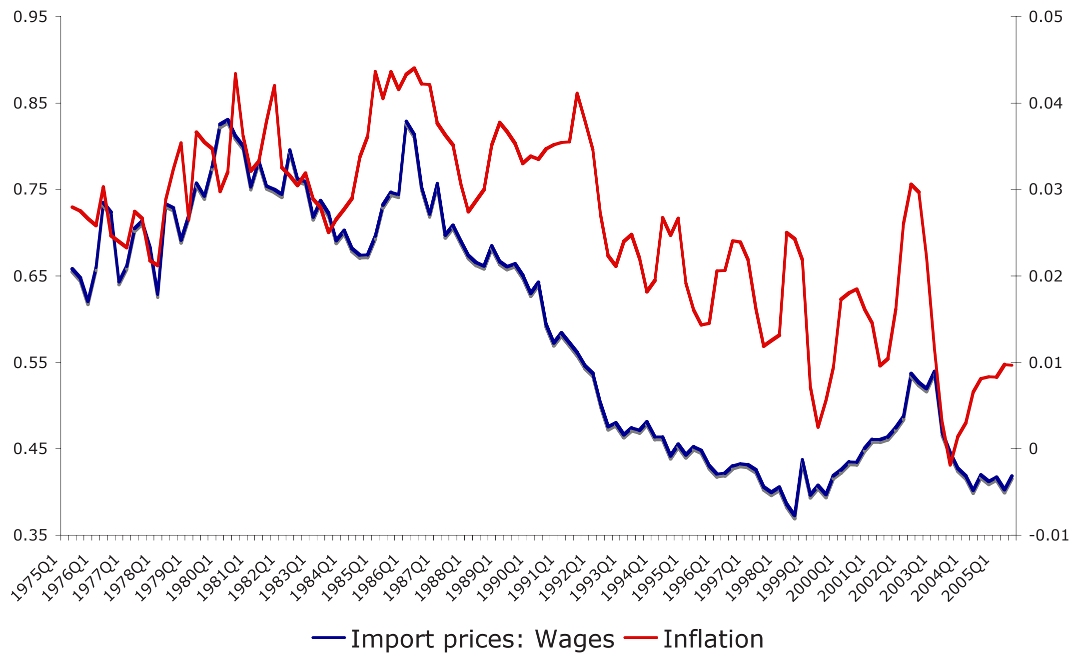


Figure 4: Inflation and relative import prices



The two components of the real marginal cost that will be the forcing variable in the NKPC estimated below have been combined by assuming an import elasticity of the domestic production greater than 1, which would entail disinflationary pressure in the domestic economy if import prices were to decline relative to local wages. Following Fedderke and Schaling's (2005) calculation, the open economy real marginal cost was calibrated with a mark-up of 30%.

Results

Closed economy

An estimate for the reduced form NKPC in Equation 7 is shown in Table 4, where the coefficient values are also contrasted with the estimated parameters from the same reduced form equation for the USA (Gali and Gertler, 1999) and the Euro area (Gali et al., 2001).

Table 4: Results of the reduced form closed economy Phillips curve estimation

Variable	Comparative models			
	South Africa[a]		USA[b]	Euro area[c]
	1975Q1-2003Q4	1985Q1-2003Q5		
$E_t[\pi_{t+1}]$	0.985 *(0.011)*	0.978 *(0.021)*	0.942 *(0.045)*	0.914 *(0.040)*
$\hat{S}_t$	0.018 *(0.011)*	0.091 *(0.026)*	0.023 *(0.012)*	0.088 *(0.041)*
J-statistic	4.116492 *(0.66)*[d]	8.10654 *(0.23)*[d]		8.21 *(0.51)*[d]
AR-statistic	0.7208 *(0.67)*[d]	1.4794 *(0.16)*[d]		
K-statistic	0.00007 *(0.99)*[d]	0.0519 *(0.82)*[d]		
$\hat{\theta}$	0.855	0.714	0.881	0.768
Implied average period between price changes	6.9 quarters	3.5 quarters	8.4 quarters	4.3 quarters

Standard errors in parenthesis
a) Instruments used: Inflation (lags 1 to 5), yield spread (1 lag) and labour income share (1 lag).
b) Instruments used: Inflation (lags 1 to 4), labour income share (lags 1 and 2), output gap (lags 1 and 2), wage inflation (lags 1 and 2).
c) Instruments used: Inflation (lags 1 to 5), labour income share (lags 1 and 2), output gap (lags 1 and 2), wage inflation (lags 1 and 2).
d) P-value.

The effect of labour income share is considerably higher when restricting the sample period to 1985-2003, which also implies a shorter average period between price changes. The J-statistics in Table 4 show that the null of overidentifying restrictions is not rejected, and the AR and K statistics are both less than the critical values for rejecting instrument relevance.

Using marginal cost as a proxy for the demand (or business cycle) effect yields a reduced form NKPC with a significant demand effect. This result contrasts sharply with the South African literature summarised above[4], but is comparable with estimates of the NKPC for the USA and the Euro area. The Hansens test for the overidentifying restrictions imposed on these reduced form equations is also reported, for which valid overidentifying restrictions are the null.

The reduced form results reported in Table 4 show estimated parameter values for the coefficient on real marginal cost which was $\lambda = \frac{(1-\beta\theta)(1-\theta)}{\theta}$ in Equation 3. The coefficient on expected inflation is the discount factor β, and it follows that the estimates of β and λ could be combined to retrieve the implied estimate of the structural parameter θ. The implied estimates of θ are also reported for each of the reduced form equations in Table 4 and were used to calculate the implied average period between price adjustments in the monopolistic competition model that underlies the reduced form.

All three reduced from equations have discount factors (β) that are within two standard deviations from 1, with the South African case closest to 0.99 which is a typical value for the discount factor in this literature (Gali and Gertler, 1999). This proximity of the discount factors to unity can now be exploited in a direct estimation of the structural parameters in Equation 3 using

[4] It may be worth noting that simply using the log labour income share in Equation (1) does not solve the problem. Specifically, it yields $\pi_t = \underset{(0.039)}{0.897}\,\pi_{t-1} + \underset{(0.023)}{0.005}\,\hat{S}_t$, where the output gap now enters the equation positively, but is still insignificant. Obtaining a workable inflation equation therefore requires using expected rather than lagged inflation, as well as the appropriate measure of the business cycle.

non-linear GMM. Gali and Gertler (1999) suggested two slightly different orthogonality conditions (with alternative normalisations) for this purpose, to guard against overly sensitive results due to the non-linear GMM method in a small sample. Equations 13 and 14 below show the two orthogonality conditions.

$$E\left[z_t\left(\pi_t - \beta\pi_{t+1} - \frac{(1-\beta\theta)(1-\theta)}{\theta}\hat{\varphi}_t\right)\right] = 0 \tag{13}$$

$$E\left[z_t\left(\theta\pi_t - \theta\beta\pi_{t+1} - (1-\beta\theta)(1-\theta)\hat{\varphi}_t\right)\right] = 0 \tag{14}$$

As a further robustness check both (13) and (14) are estimated twice: First as an unrestricted equation and second under the restriction that the discount factors (β) equal unity. The estimated values for the parameters β, θ and (the implicit value of) λ are reported in Table 5.

Table 5: Non-linear GMM estimates of the closed-economy NKPC structural parameters

	θ	β	λ	J-statistic	AR-statistic	K-statistic
Unrestricted (1)	0.747 (0.030)	0.978 (0.021)	0.091 (0.026)	8.108 (0.150)	2.902 (0.003)	3.607 (0.058)
(2)	0.729 (0.030)	0.976 (0.022)	0.108 (0.029)	7.790 (0.168)	3.432 (0.001)	5.213 (0.022)
Restricted β (1)	0.746 (0.029)	1.000	0.086 (0.023)	8.650 (0.194)	2.652 (0.007)	4.088 (0.043)
(2)	0.729 (0.028)	1.000	0.101 (0.025)	8.352 (0.213)	3.076 (0.002)	5.642 (0.018)

Standard errors in parenthesis

The model coefficients are not particularly sensitive to the choice of normalisation or the $\beta = 1$ parameter restriction. The J-statistics indicate that the overidentifying restrictions are not rejected, but the AR and K statistics both indicate problems of weak instruments. The estimates for θ reported in Table 5 imply between 3.7 and 4 quarters for the average period between price changes, which compares favourably with the point estimate of 3.5 quarters over the shorter sample period in Table 4.

Hybrid closed economy NKPC

The Hybrid NKPC model introduced in the first section implies the following two orthogonality conditions (given different normalisations):

$$E\left[z_t\left(\phi\pi_t - \theta\beta\pi_{t+1} - \omega\pi_{t-1} - (1-\omega)(1-\beta\theta)(1-\theta)\hat{S}_t\right)\right] = 0 \tag{15}$$

$$E\left[z_t\left(\pi_t - \frac{\theta\beta\pi_{t+1}}{\phi} - \frac{\omega\pi_{t-1}}{\phi} - \frac{(1-\omega)(1-\beta\theta)(1-\theta)}{\phi}\hat{S}_t\right)\right] = 0 \tag{16}$$

In his estimation, which uses detrended output as the measure of the output gap, Fuhrer (1997) finds that the coefficients for expected inflation differed significantly from zero. However, the magnitude is such as to suggest that forward-looking expectations play an unimportant role in inflation determination.

Gali and Gertler (1999) also estimate a hybrid Phillips curve which includes backward and forward-looking price-setting behaviour, but substitutes the labour income share for the output gap. This variation had a dramatic impact on the results: Forward-looking behaviour is now found to be very important – the coefficients suggest between 60 and 80 percent of firms use it to set prices – whereas backward looking is found to be comparatively unimportant. Gali, Gertler and Lopez-Salido (2001) replicated this methodology for the Euro area and, for some specifications, find that the proportion of firms that use backward-looking behaviour does not differ significantly from zero.

The parameter values of Equation 6 are estimated using non-linear GMM and the two sets of orthogonality conditions shown in Equations 15 and 16 and with the same instruments as above. Table 6 reports four sets of estimates: The unrestricted parameter values for orthogonality conditions (15) and (16) above, and the estimates where β is restricted to be 1, again for orthogonality conditions (15) and (16).

Table 6: Non-linear GMM estimates of the closed-economy hybrid NKPC structural parameters

	ω	Θ	β	γ_b	γ_f	λ	J-statistic	AR-statistic	K-statistic
Unrestricted (1)	-0.18 (0.133)	0.727 (0.035)	0.990 (0.024)	-0.321 (0.192)	1.306 (0.336)	0.164 (0.083)	7.087 (0.131)	5.283 (0.000)	3.229 (0.072)
(2)	0.54 (0.070)	1.016 (0.061)	0.444 (0.067)	0.431 (0.050)	0.361 (0.054)	-0.003 (0.012)	7.887 (0.096)	4.289 (0.000)	19.576 (0.000)
Restricted β (1)	-0.208 (0.122)	0.727 (0.035)	1.000	-0.401 (0.218)	1.401 (0.337)	0.173 (0.090)	7.046 (0.217)	5.408 (0.000)	2.732 (0.098)
(2)	0.255 (0.025)	0.725 (0.026)	1.000	0.260 (0.003)	0.740 (0.025)	0.057 (0.010)	8.588 (0.127)	1.835 (0.066)	0.009 (0.924)

Standard errors in parenthesis

Adding backward-looking expectations seems to have caused the results to become very sensitive to the choice of normalisation as well as the parameter restriction. In both the restricted or unrestricted cases, the model estimated under normalisation (1) yields negative values for the ω and γ_b-parameters, although they differ insignificantly from zero. Under normalisation 2, the model appears to do better after constraining the shares of backward and forward-looking price-setters to sum to one, since this is the only model in Table 6 for which the AR and K statistics do not strongly reject the hypothesis that $\beta = \beta_0$.

Open economy NKPC

Table 7 is comparable to Table 5 and shows the estimated coefficients for the open economy version of the NKPC.

Table 7: Results of the reduced form open-economy Phillips curve estimation

Variable	Comparative models: South Africa	
	1975Q1 – 2003Q4	1985Q1 – 2003Q5
$E_t[\pi_{t+1}]$	0.972 *(0.014)*	0.865 *(0.028)*
MCO	0.019 *(0.011)*	0.083 *(0.024)*
J-statistic	3.55 *(0.62)*[d]	10.28 *(0.11)*[d]
AR-statistic	0.6765 *(0.71)*[d]	2.8686 *(0.003)*[d]
K-statistic	0.1421 *(0.71)*[d]	4.0349 *(0.04)*[d]
	0.832	0.592
$\hat{\theta}$ Implied		
Average period between price changes	6.0 quarters	2.4 quarters

The table compares the linear GMM-estimates for the open-economy Phillips curve estimated over two periods: 1975 – 2003 and 1985 – 2003. Both models are estimated with the same set of instruments as the closed-economy Phillips curve: 5 lags of inflation as well as one lag each of the labour income share and the yield spread. The effect of the open-economy marginal cost driver on inflation is much stronger for the shorter time period, but the tests of data admissibility indicate that the shorter period may be plagued by problems of weaker instruments. The J-statistic shows that the null hypothesis of the validity of the overidentifying restrictions is not rejected in either period.

Table 8: Non-linear GMM estimates of the open-economy NKPC structural parameters

	Θ	β	λ	J-statistic	AR-statistic	K-statistic
Unrestricted (1)	0.791 (0.029)	0.865 (0.028)	0.083 (0.024)	10.276 (0.068)	2.918 (0.003)	4.078 (0.043)
(2)	0.768 (0.031)	0.846 (0.034)	0.106 (0.030)	10.168 (0.071)	3.410 (0.001)	3.709 (0.054)
Restricted β (1)	0.863 (0.031)	1.000	0.022 (0.011)	10.162 (0.118)	1.457 (0.167)	0.183 (0.669)
(2)	0.836 (0.028)	1.000	0.032 (0.012)	7.790 (0.254)	1.566 (0.129)	0.060 (0.806)

Surprisingly, the AR and K-statistics reveal that using non-linear GMM estimation helps to ameliorate the weak instrument problem in the case of the unrestricted parameters, and when the further restriction $\beta = 1$ is imposed there is no evidence of weak identification whatsoever. The J-statistics show that the overidentifying restrictions cannot be rejected with 95 per cent confidence in any of the models, and that they are more valid in the models that incorporate the parameter restriction.

Hybrid open-economy NKPC

Finally, Table 9 presents the estimation results for a hybrid open-economy NKPC.

Table 9: Non-linear GMM estimates of the open-economy hybrid NKPC structural parameters

	ω	θ	β	γ_b	γ_f	λ	J-statistic	AR-statistic	K-statistic
Unrestricted (1)	0.31 (0.147)	0.833 (0.050)	0.941 (0.043)	0.273 (0.022)	0.697 (0.103)	0.022 (0.017)	8.521 (0.074)	1.253 (0.264)	0.079 (0.779)
(2)	0.56 (0.041)	1.051 (0.041)	0.421 (0.037)	0.440 (0.031)	0.348 (0.031)	-0.010 (0.008)	7.499 (0.112)	4.647 (0.000)	21.650 (0.000)
Restricted β (1)	-0.046 (0.107)	0.847 (0.029)	1.000	-0.057 (0.033)	1.057 (0.142)	0.031 (0.015)	9.079 (0.106)	1.558 (0.132)	0.162 (0.688)
(2)	0.187 (0.027)	0.758 (0.038)	1.000	0.198 (0.003)	0.802 (0.029)	0.051 (0.016)	9.310 (0.097)	1.635 (0.109)	0.348 (0.555)

In estimating the open-economy hybrid NKPC it can be observed that the open-economy marginal cost driver only enters the model significantly after applying the restriction that $\gamma_b + \gamma_f = 1$. Under normalisation (1) the ω and γ_b-parameters are negative, although not significantly different from 0. The restricted model estimated under normalisation provides the most theoretically consistent version of the NKPC, and the AR and K statistics suggest that this is also the version that best fits the data. It is disconcerting, however, that the final parameter estimates and test statistics are so sensitive to the choice of normalisation and the parameter restriction.

Conclusion

In this paper it is shown that the NKPC merits consideration when studying inflation dynamics in South Africa. Apart from the theoretical merit of the approach, it addresses the long-standing problems of incorporating real output effects in inflation models that have troubled the local literature since the mid-seventies. The structural parameters that were derived from the NKPC suggest an inflation dynamic that is not fundamentally at odds with that found in the USA and Europe.

The paper has also indicated that such a structural model for inflation dynamics in South Africa could be estimated using the Generalized Method of Moments without necessarily falling prey to the problems of weak instruments. The positive message is that structural models of inflation dynamics in South Africa stand to gain from considering the content and structure of the NKPC models. However, it was also found that the estimated models were sensitive across different sub-samples and while the most encouraging results were obtained for the more recent sub-samples, (though they show evidence of the weak instrument problem) the fragility of structural parameters across sub-samples and with respect to different non-linear normalisations remains a concern.

References

Anderson, W T and Rubin, H. 1949. Estimation of the parameters of a single equation in a complete system of stochastic equations. *Annals of Mathematical Statistics* 20: 46-63.

Balakrishnan, R. and Lopez-Salido, D. 2002. Understanding UK inflation: the role of openness. London, *Bank of England Working Paper* 164.

Ball, L. 1994. Credible disinflations with staggered price setting. *American Economic Review* 84: 282-289.

Blinder, A S, Canetti, E R D, Lebow, D E and Rudd, J B. 1998. *Asking about prices.* New York: Russel Sage Foundation.

Brunner, K and Meltzer, A H. 1976. The Phillips Curve. *Carnegie-Rochester Conference Series on Public Policy 1*(1): 1-18.

Burger, P and Marinkov, M. 2006. The South African Phillips curve: how applicable is the Gordon model? *South African Journal of Economics* 74(2): 172-189.

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

Cespedes, L F, Ochoa, M and Soto, C. 2005. The New Keynesian Phillips curve in an emerging market economy: the case of Chile. Santiago, Central Bank of Chile *Working Paper No.* 355.

Christiano, L J, Eichenbaum, M, and Evans, C L. 2001. Nominal rigidities and the dynamic effects of a shock to monetary policy. Boston, Ma., *NBER Working Paper* No. 8403.

Clarida, R, Gali, J. and Gertler, M. 1999. The science of monetary policy: a New Keynesian perspective. *Journal of Economic Literature* 37(4): 1661-1707.

Dixit, A K and Stiglitz, J E. 1977. Monopolistic competition and optimum product diversity. *American Economic Review* 67(3): 297-308.

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.

Friedman, M. 1968. The role of monetary policy. *American Economic Review* 58(1): 1-17.

--- 1977. Nobel lecture: Inflation and unemployment. *Journal of Political Economy* 85(3): 451-472.

Fuhrer, J C. 1997. The (un)importance of forward-looking behaviour in price specifications. *Journal of Money, Credit and Banking* 29(3): 338-350.

--- 2000. Habit formation in consumption and its implications for monetary policy models. *American Economic Review* 90(3): 367-390.

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

Gali, J, Gertler, M and Lopez-Salido, D. 2001. European inflation dynamics. *European Economic Review* 45: 1237-1270.

Gali, J and Lopez-Salido, D. 2000. A new Phillips curve for Spain. London, *BIS Paper* No. 3.

Gallaway, L E, Koshal, R K and Chapin, G L. 1970. The relationship between the rate of change in money wage rates and unemployment levels in South Africa. *South African Journal of Economics* 38(4): 367-373.

Genberg, H and Pauwels, L L. 2003. An open economy New Keynesian Phillips curve: evidence from Hong Kong. Geneva, *HEI Working Paper* No. 03/2003.

Henry, S G B and Pagan, A R. 2004. The econometrics of the New Keynesian Policy Model: Introduction. *Oxford Bulletin of Economics and Statistics* 66 (Supplement): 581-607.

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

Hume, I M. 1971. A study of inflation in South Africa. *Oxford Bulletin of Economics and Statistics* 33(4): 223-244.

Kleibergen, F. 2001. Testing parameters in GMM without assuming that they are identified. Amsterdam, Tinbergen Institute, *Discussion Paper* TI 01-067/4.

Krogh D C. 1967. Growth and inflation. *South African Journal of Economics* 35(4): 294-310.

Levin, M and Horn, G S. 1987. Phillips curves for selected South African labour markets. *Journal for Studies in Economics and Econometrics* 11(3): 25-50.

Lucas, R J. 1976. Econometric policy evaluation: a critique. *The Phillips curve and labour markets.* K. Brunner and A. H. Meltzer. Amsterdam, North Holland.

--- 1995. Monetary neutrality. *Nobel Prize Lecture*. Stockholm.

Ma, A. 2002. GMM estimation of the New Phillips Curve. *Economic Letters* 76: 411-417.

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

McCallum, B T. 2001. Recent developments in analysis of monetary policy rules. *Federal Reserve Bank of St Louis Economic Review* (November/December): 3-11.

Moreira, M J. 2001. Test with correct size when instruments can be arbitrarily weak Cambridge, Ma., Department of Economics, *Harvard University Discussion Paper*.

Nell, K S. 2000. Is low inflation a precondition for faster growth? The case of South Africa. Mimeograph. Canterbury, University of Kent, *Department of Economics Working Paper* No. 00/11.

Phelps, E S. 1968. Money-wage dynamics and labour market equilibrium. *Journal of Political Economy* 76(4): 678-711.

Phillips, A W. 1958. The relation between unemployment and the rate of change of money wage rates in the United Kingdom, 1861-1957. *Economica* 25: 283-299.

Pretorius, C J and Smal, M M. 1994. A macro-economic examination of the price-formation process in the South African economy. South African Reserve Bank *Quarterly Bulletin* (March): 25-36.

Romer, C D and Romer, D H. 2002. The evolution of economic understanding and postwar stabilisation policy. Boston, Ma., *NBER Working Paper*, 9274.

Samuels, L H. 1967. Control of inflation. *South African Journal of Economics* 35(4): 341-356.

Stock, J H and Wright, H. 2000. GMM with weak identification. *Econometrica* 68(5): 1055-1069.

Stock, J H, Wright, J H and Yogo, M. 2002. A survey of weak instruments and identification in generalized methods of moments. *Journal of Business and Economic Statistics* 20(4): 518-529.

Strebel, P J. 1976. On built-in inflation, imported prices and the Phillips curve: a comment. *South African Journal of Economics* 44(4): 446-456.

Strydom, P D F and Steenkamp, L. 1976. Inflation in South Africa II: Aggregate demand and price expectations. *South African Journal of Economics* 44(4): 417-434.

Taylor, J B. 1980. Aggregate dynamics and staggered contracts. *Journal of Political Economy* 88: 1-22.

--- 2000. Five things we know for sure. *Hoover Digest* 1998(3).

Truu, M L. 1975. Inflation in the South African Economy. *South African Journal of Economics* 43(4): 446-470.

Walsh, C E. 2003. *Monetary theory and policy (second edition)*. Cambridge, Ma., The MIT Press.

Woodford, M. 2003. *Interest and prices: Foundations of a theory of monetary policy.* Princeton, Princeton University Press.

Yazgan, M E and Yilmazkuday, H. 2005. Inflation dynamics of Turkey: a structural estimation. *Studies in Nonlinear Dynamics and Econometrics* 9(1): 1-13.