THE SOUTH AFRICAN PHILLIPS CURVE: A TRIANGULAR PUZZLE?

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Abstract: *To create a higher employment rate, economic growth in South Africa needs to improve. However, recent improvements in the growth rate raise the fear that if this growth exceeds the natural growth of the economy, the country might again experience inflation instead of higher employment. Hence, there is a need to estimate the output gap and to establish whether or not that output gap impacts on inflation. Traditionally the method to establish whether or not there is a relationship between the output gap and the change in inflation is merely to regress the latter on the former. This yields the well-known augmented Phillips curve. However, Gordon has argued that this specification of the Phillips curve produces biased results. Instead, he puts forward and estimates successfully for several industrialised countries his so-called 'triangle' model that tests for hysteresis and inertia in the behaviour of inflation, as well as the impact on inflation of changes in the output level. This paper considers whether or not Gordon's triangle model is applicable to South Africa, i.e. is there hysteresis and inertia present in South Africa? In addition, in an attempt to find a better estimation of the output gap, the paper also experiments with alternative ways to estimate the long-run output level, thereby extending on the standard technique that uses the HP-filter.*

JEL codes: *E31; E37*

To create a higher employment rate, economic growth in South Africa needs to improve. However, recent improvements in the growth rate raise the fear that if this growth exceeds the natural growth of the economy, the country might again experience inflation instead of higher employment. Hence, there is a need to estimate the output gap and to establish whether or not that output gap impacts on inflation. Thus, a need exists to establish whether or not there is a Phillips curve relationship in South Africa. There are several variants of the Phillips curve. The first, as estimated by Phillips (1958) himself, measures the relationship between wage inflation and unemployment.[2] However, other versions consider the relationship between price inflation and unemployment or price inflation and output. This paper focuses on the latter, given the absence of quarterly unemployment data in South Africa, as well as the lack of a reliable and sufficiently long unemployment time series.

Traditionally the way to estimate the Phillips curve is merely to regress the change in the price level on a measure of the output gap (or the deviation of actual unemployment from the NAIRU). However, Gordon (1990:481-5) has argued that estimating the Phillips curve in this manner biases the estimated results. Instead Gordon (1997; 1989) puts forward his so-called triangular model that controls for inertia effects, output level effects and rates-of-change (in output) effects. He applies the model to several European countries, the US and Japan and finds meaningful results. The question this paper poses is whether or not the triangular model also applies to South Africa. In estimating the Phillips curve for South Africa the paper also experiments with three versions of the output gap, based on three different methods to estimate long run output. The paper first presents an overview of literature on the Phillips curve and its estimation for South Africa and other countries. This is followed by the second section that considers the model to be estimated as well as the discussion of the alternative measures of the output gap. The third section presents the estimated results followed by section four that contains the conclusion and a discussion of the policy implications.

1. WHAT DOES THE LITERATURE SAY?

In addition to his own estimates of the Phillips curve for South Africa, Hodge (2002:424-9) provides an overview of earlier attempts to estimate the Phillips curve for South Africa. These include early studies by Krogh (1967), Gallaway, Koshal and Chapin (1970), Hume (1971), Truu (1975), Levin and Horn (1987).

Hodge (2002:431) then presents his own estimate of a Phillips curve for South Africa:

$$p_t = \beta_1 + \beta_2 p_{t-n} + \beta_3 U_{t-n} + \beta_4 m_{t-n} + e_t \tag{1}$$

where: p = inflation
U = the actual unemployment rate
m = SA import price index (to control for supply shocks)

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[2] However, Phillips was not the first to consider the relationship between employment and a price measure. Solow (1997: 433-5) shows that Irving Fisher considered the relationship between the wholesale price index and factor employment.

Because in South Africa unemployment data only exists on an annual basis, Hodge estimated the relationship with annual data for the period 1983-98. In addition to estimating equation (1) with unemployment data, Hodge also estimated the equation by substituting in turn the annual percentage change in employment, the jobless rate and economic growth rate for the unemployment rate. Note that he did not estimate a long run trend for unemployment, arguing that the long run rate could merely be derived by equating p_t to zero and assuming that the constant, β_1, contains an unchanged long run component so that $\beta_1 = \beta_0 - \beta_3\overline{U}$ where $\overline{U}$ represents an unchanging long run unemployment. He also did not estimate a long run trend for employment, the jobless rate or the economic growth rate. Thus, Hodge did not use a time-varying estimate of the NAIRU or any of the other variables that he used to substitute for the unemployment rate. He found no evidence of a relationship between inflation and either unemployment, employment or the jobless rate. However, he found evidence of a relationship between the first differences of inflation and growth.

Nell (2000) also estimated a Phillips curve for South Africa. However, unlike Hodge, Nell (2000:12-3) estimated potential or long-run output growth (and thus, not the level of long run output) and substituted it into the following Phillips curve relationship:

$$p_t = \beta_1 + \sum_{i=1}^{k} \beta_2 p_{t-i} + \sum_{i=1}^{m} \beta_3 (\Delta y - \Delta\bar{y})_{t-i} + e_t \qquad (2)$$

where: Δy = actual output growth rate
$\Delta \bar{y}$ = potential output growth rate

In order to allow for a non-linear, convex, Phillips curve, Nell (2000) also estimated a model where he separates the output gap variable into positive and negative values:[3]

$$p_t = \beta_1 + \sum_{i=1}^{k} \beta_2 p_{t-i} + \sum_{i=1}^{j} \beta_3 (\Delta y - \Delta\bar{y})_{t-i}^{overh} + \sum_{i=1}^{z} \beta_4 (\Delta y - \Delta\bar{y})_{t-i}^{weak} + e_t \qquad (3)$$

where: $(\Delta y - \Delta\bar{y})_{t-i}^{overh}$ = negative output gap (i.e. actual output growth exceeds potential output growth)[4]; periods with positive output values take on a value of zero
$(\Delta y - \Delta\bar{y})_{t-i}^{weak}$ = positive output gap; periods with negative output values take on a value of zero

Furthermore, Nell estimated the Phillips curve relationship for South Africa for two distinct periods: the accelerating inflation period (1971Q1-1985Q4) and the deflationary period (1986Q1-1997Q2). Nell (2000:16-17) found that the overall output gap is statistically significant for the accelerating inflation period, but not for the deflationary period. In addition, he found that the negative output gap is statistically significant in the accelerating inflation period, while the positive output gap is statistically *in*significant. Thus, during the accelerating inflation period the Phillips curve trade off only holds for when the economy overheats. In the deflationary period this result is reversed, with the negative output gap (i.e. the one for the overheated economy) being statistically *in*significant, while the positive output gap is statistically significant. The overall output gap for this period, however, is statistically *in*significant. When using the split output gap procedure, instead of a convex Phillips curve, Nell (2000:17, 28) found concavity when the economy overheats for the accelerating inflation period and non-convexity (and non-concavity) when the economy is weak for the decelerating inflation period. This finding of Nell can be compared with that of Stiglitz (1997:9) who mentions that there is some evidence in the US of a concave Phillips curve.

In a recent estimation of the Phillips curve Fedderke and Schaling (2005) use the Johansen technique to examine the determinants of inflation in South Africa. The dependent variable in the long run relationship is the price level. (Note that Phillips curves are usually considered to be short run relationships, which explain why it is inflation, and not the price level, which is the dependent variable in the short run models.) The authors considered price expectations, unit labour cost, the output gap and the real exchange rate as possible explanatory variables. All variables with the exception of the output gap were found to be I(1) and therefore, to be non-stationary (Fedderke and Schaling 2005:87). This meant that since the standard Johansen cointegration technique can usually only be

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[3] Convexity implies that when the economy is overheating, a 1 percentage point increase in the output gap is associated with an increase in inflation in excess of 1 percentage point, while if the economy is weak, a 1 percentage point increase in the output gap is associated with a less than 1 percentage point increase in inflation. Concavity implies the opposite.

[4] Some sources (cf. Bannock *et al.* 1998:308) define a positive output gap the other way round, namely when actual output (or output growth) exceeds potential output (or potential output growth).

estimated with I(1) data,[5] the output gap, being an I(0) variable, could not be included in the long run regression that explained the price level. Only unit labour cost and the exchange rate were found to be statistically significant as explanatory variables. The output gap was included in the short run dynamics of the model, where it was found that it is not statistically significant as an explanatory variable of inflation (Fedderke and Schaling 2005:89).

With regard to international studies, a clear preference seems to exist for models where the long run component of either output or unemployment (i.e. the NAIRU) is a time-varying variable (Gordon 1998, 1997, 1990, 1989; Ball and Mankiw 2002; Staiger, Stock and Watson 1997).[6] This is in contrast to earlier models that used a constant output growth or a constant NAIRU (though such models are still estimated, cf. Hodge (2002) and Malinov and Sommers (1997)). Furthermore, whereas the earliest Phillips curves did not include inflation in previous periods as explanatory variables (equation (4) below), the crude augmented Phillips curve merely assumes that inflation in the previous period has a parameter value equal to one (equation (5) below)(cf. Staiger *et al.* 1997:35-6).

$$p_t = \beta_1 + \beta_2 D_t + e_t \qquad (4)$$

$$p_t = \beta_1 + p_{t-n} + \beta_2 D_t + e_t$$

so that:

$$p_t - p_{t-1} = \partial p_t = \beta_1 + \beta_2 D_t + e_t \qquad (5)$$

where D is the excess demand variable that equals either the unemployment gap, $(U - \overline{U})$, where U and $\overline{U}$ represent the actual unemployment rate and the NAIRU respectively, or the output gap, $(y - \bar{y})$, where y and $\bar{y}$ represent the natural log of actual and long run output respectively.

However, less crude versions of the augmented model allow for inflationary inertia by not limiting the value of the parameters of the past values of inflation (equation (6) below).

$$p_t = \beta_1 + \sum_{i=1}^{k} \beta_2 p_{t-n} + \beta_3 D_t + e_t \qquad (6)$$

In addition to the inclusion of the inertia effects, Gordon (1997:16) has also argued that not only should the output (or unemployment) gap in the current period be included to take account of possible level effects, but one should also either include lags of the output gap (equation (7)) or the change in the output gap over time (equation (8)) to take account of rate-of-change effects.[7] The rate-of-change effect is included because the economy may, for instance, be growing at its long run growth rate (or even higher) while the level of output is below its long run level. The rate-of-change and the output level may then exert opposite effects on inflation. Gordon (1997:16; 1990:483) furthermore argues for the inclusion of a proxy for possible supply shocks (z in both equations (7) and (8)). The exclusion of such a proxy might bias the parameter of the output gap towards zero because a supply shock may cause an extraneous positive correlation between inflation and unemployment or the output gap (when defined as $(\bar{y} - y)$). Equations (7) and (8) also include unit labour cost, w. Mehra (2004:69) has shown that once one controls for the influence of lagged inflation and the output gap, the exclusion of unit labour costs implies the implicit assumption that current inflation does not depend directly on productivity adjusted wages. Furthermore, one assumes implicitly that wages adjust one-for-one with productivity in each period and that they depend on lagged inflation and the output gap. However, in the short run it is not uncommon for wage and price adjustments to diverge, in which case unit labour cost may exert an influence on inflation independent of past inflation. For instance, Mehra (2004:69) argues that faster productivity growth and slow nominal wage growth may lead to lower inflation if firms pass the effect of lower unit labour cost onto prices. The inclusion of unit labour cost represents a supply side, cost push factor in the equation in addition to the excess demand factor and the inertia effect. This suggests that prices are set on a mark-up basis, given the effect of demand.

$$p_t = \sum_{i=1}^{k} \beta_1 p_{t-i} + \sum_{i=1}^{m} \beta_2 D_{t-i} + \beta_3 w_t + \beta_4 z_t + e_t \qquad (7)$$

[5] Note that two series of I(2) data can also be included as explanatory variables in a long run relationship estimated with the Johansen technique, provided that the combination of the two series is integrated of order one, I(1).

[6] Though there are authors such as Galbraith (1997) who argue that the NAIRU and similar concepts related to long run output should be abandoned.

[7] This is similar to Phillips' (1958) original formulation where money-wage inflation was defined as being dependent on unemployment and the proportionate change in unemployment (cf. Wulwick 1989:176).

$$p_t = \sum_{i=1}^{k} \beta_1 p_{t-i} + \beta_2 D_t + \beta_3 \Delta D_t + \beta_4 w_t + \beta_5 z_t + e_t \quad (8)$$

Note that in equation (8), the larger β_1 is, the larger the inertia effect will be, thereby prolonging the duration of inflation once it exists (Gordon 1990:488). If β_3 in equation (8) equals zero while $\beta_2 > 0$, equation (8) reverts back to the simple Phillips curve relation where only the output level matters, while if β_2 equals zero there is no level effect, which means that the economy suffers from full-blown hysteresis. In this case, the smaller β_2 is, the more pronounced hysteresis will be and hence, the longer the economy will take to adjust back to some long run level. With full-blown hysteresis the economy will not at any time stabilise at its long run level and may come to rest at a level of output different from the long run level, while experiencing a constant rate of inflation, with no tendency of self correction (Gordon 1990:488). Thus "…full hysteresis implies that changes in both inflation and output are completely independent of the level of detrended output, and that an economy in the depth of a Great Depression can experience an acceleration of inflation, no matter how high the level of unemployment or low the level of detrended output, if excess nominal GNP growth exceeds last period's inflation rate." (Gordon 1989:222). In such a case, excess demand will only impact on inflation through the rate-of-change effect and then only if $\beta_3 > 0$. If β_2, β_3 and β_4 equal zero, while β_1 and $\beta_5 > 0$, inflation becomes merely a function of inflationary expectations (a random walk with drift) and supply shocks, whereas if $\beta_4 > 0$ inflation is a cost-push and not a demand-pull phenomenon.

Equation (8) represents Gordon's *triangular model* given that it accommodates inertia, level and rate-of-change effects (Gordon 1997). The model has come to be widely accepted, with several authors using a similar framework to specify the Phillips curve (cf. Mehra 2004; Duca and VanHoose 2000:732; Alogoskoufis and Smith 1991:1256), though many still do not include all the elements of the triangular model (cf. Niskanen 2002:197; Blanchard and Katz 1997:60-1; Roberts 1995:979). For instance Roberts (1995:979) excludes the rate-of-change variables because, he argues, the unemployment rate is strongly serially correlated, which means that the current unemployment rate is an adequate proxy for current, lagged and future unemployment.

2. MODEL AND METHOD

Based on the above, this paper estimates the general triangular model of Gordon as contained in equation (8), restated here as equation (9), where all parameters are expected to have positive signs:

$$p_t = \beta_1 p_{t-1} + \beta_2 (y - \bar{y})_t + \beta_3 \Delta (y - \bar{y})_t + \beta_4 w + \beta_5 z_t + e_t \quad (9)$$

In addition, to allow for a non-linear Phillips curve the paper also follows Nell (2000) and splits the output gap into two variables, one, $(y - \bar{y})_t^{overh}$, named the negative output gap, but containing positive values (with the years that contained negative values set to zero), and one, $(y - \bar{y})_t^{weak}$, named the positive output gap, but containing negative values (with the years containing the positive values set to zero). Both split gaps are expected to have parameters with positive signs.[8] The general triangular model of Gordon with a split output gap as contained in equation (10):

$$p_t = \beta_1 p_{t-1} + \beta_2 (y - \bar{y})_t^{overh} + \beta_3 (y - \bar{y})_t^{weak} + \beta_4 \Delta (y - \bar{y})_t^{overh} + \beta_5 \Delta (y - \bar{y})_t^{weak} + \beta_6 w + \beta_7 z_t + e_t \quad (10)$$

This paper uses three methods to estimate the long run output trend. All three methods result in a time varying output trend. The first is the standard Hodrick-Prescott (HP) filter. It is "…a generalisation of a linear trend that allows the slope of the trend to change gradually over time. Formally, the HP filter minimizes the sum of the squared deviations between the trend and the actual series, with a penalty for the curvature that keeps the trend smooth. If there were no penalty, the filter would yield the original series; if the penalty were very high, it would yield a linear time trend." (Ball and Mankiw 2002:122). The function minimises y_{HP} in the following objective function:

$$\sum_{t=1}^{T} (y_t - \bar{y}_{HP,t})^2 + \theta \sum_{t=2}^{T-1} (\partial \bar{y}_{HP,t+1} - \partial \bar{y}_{HP,t})^2 \quad (11)$$

[8] Note that the negative value obtained by multiplying the positive parameter with the negative value of the positive output gap, $(y - \bar{y})_t^{weak}$, implies downward pressure of the positive gap on inflation.

where according to convention θ takes on a value of 100 for annual data, 1600 for quarterly data and 44000 for monthly data. Given the use of quarterly data in this study, θ is set to 1600.

The second method, based on the method developed by Ball and Mankiw (2002:122-3) for Phillips curves using the NAIRU, is based on the idea that one should distinguish between long run changes in the relationship between inflation and output (i.e. changes in $\bar{y}$ in equation (12)) and short run fluctuations in inflation as captured by the error term in equation (5), recalled here as equation (12), but without the intercept:

$$\Delta p_t = \beta_1 (y - \bar{y})_t + e_t = \beta_1 y_t - \beta_1 \bar{y}_t + e_t \tag{12}$$

Lagging equation (12) with one period and subtracting the lagged version from equation (12) yields equation (13):

$$\Delta\Delta p_t = \beta_1 \Delta y_t - \beta_1 \Delta\bar{y}_t + \Delta e_t \tag{13}$$

Next, following Ball and Mankiw one assumes that the long run growth rate is constant, meaning that one could regress $\Delta\Delta p_t$ on Δy_t and treat $\beta_1 \Delta\bar{y}_t$ as a constant. This yields a value for β_1, which is substituted into equation (14) below, where equation (14) is derived by rearranging equation (12).

$$-\bar{y}_t + e_t / \beta_1 = -y_t + \partial p_t / \beta_1 \tag{14}$$

The right-hand side of equation (14) can be computed with the given β_1. Following the computation of the right-hand side value, the HP filter is applied to that value so as to extract the value of $\bar{y}$. This value of $\bar{y}$ then constitutes the time varying long run output used to calculate the output gap that will enter the actual Phillips curve estimation using Gordon's triangular model.

The third method applies a centred-moving average (CMA) filter to the actual long run output level. (Nell (2000:12-3) applies the method to the long run output growth level.) The long run output level calculated with the CMA filter is then given by:

$$\bar{y} = \frac{1}{2k+1}\left(y_t + \sum_{i=1}^{k} (y_{t+i} + y_{t-i}) \right) \tag{15}$$

where k = 8 (Nell (2000:13) argues that eight is the value most consistent with a Phillips curve relationship).

Using these three methods to calculate the long run output level and subsequently the output gap yields three versions of the triangular model of Gordon (equation (9.1; 9.2 and 9.3)) and three versions of the triangular model with a split output gap (equation (10.1; 10.2 and 10.3)).

The triangular model of Gordon estimated with the standard HP filter:

$$p_t = \beta_1 p_{t-1} + \beta_2 (y - \bar{y}_{HP})_t + \beta_3 \Delta(y - \bar{y}_{HP})_t + \beta_4 w + \beta_5 z_t + e_t \tag{9.1}$$

The triangular model of Gordon estimated with the Ball and Mankiw method:

$$p_t = \beta_1 p_{t-1} + \beta_2 (y - \bar{y}_{BM})_t + \beta_3 \Delta(y - \bar{y}_{BM})_t + \beta_4 w + \beta_5 z_t + e_t \tag{9.2}$$

The triangular model of Gordon estimated with the CMA filter:

$$p_t = \beta_1 p_{t-1} + \beta_2 (y - \bar{y}_{CMA})_t + \beta_3 \Delta(y - \bar{y}_{CMS})_t + \beta_4 w + \beta_5 z_t + e_t \tag{9.3}$$

The triangular model of Gordon with a split output gap estimated with the standard HP filter:

$$\begin{aligned} p_t = {} & \beta_1 p_{t-1} + \beta_2 (y - \bar{y}_{HP})_t^{overh} + \beta_3 (y - \bar{y}_{HP})_t^{weak} + \beta_4 \Delta(y - \bar{y}_{HP})_t^{overh} + \beta_5 \Delta(y - \bar{y}_{HP})_t^{weak} \\ & + \beta_6 w + \beta_7 z_t + e_t \end{aligned} \tag{10.1}$$

The triangular model of Gordon with a split output gap estimated with the Ball and Mankiw method:

$$p_t = \beta_1 p_{t-1} + \beta_2 (y - \bar{y}_{BM})_t^{overh} + \beta_3 (y - \bar{y}_{BM})_t^{weak} + \beta_4 \Delta (y - \bar{y}_{BM})_t^{overh} + \beta_5 \Delta (y - \bar{y}_{BM})_t^{weak} + \beta_6 w + \beta_7 z_{,t} + e_t \tag{10.2}$$

The triangular model of Gordon with a split output gap estimated with the CMA filter:

$$p_t = \beta_1 p_{t-1} + \beta_2 (y - \bar{y}_{CMA})_t^{overh} + \beta_3 (y - \bar{y}_{CMA})_t^{weak} + \beta_4 \Delta (y - \bar{y}_{CMA})_t^{overh} + \beta_5 \Delta (y - \bar{y}_{CMA})_t^{weak} + \beta_6 w + \beta_7 z_{,t} + e_t \tag{10.3}$$

3. EMPIRICAL RESULTS

The data for the variables used in equations 9.1 through to 10.3 are presented in Figure 1 to 6 below. The total period for which data was used stretches from just post the 1973 oil shock, thus from 1974Q1 to 2002Q2. However, change variables such as inflation and the change in the output gap are calculated as the percentage change of a quarter over the same quarter in the previous year, which moves the starting point of the sample period used for the regression on with one year to 1975Q1. The sample period moves on with another year to 1976Q1 given the use of the change-in-inflation variable in equation (13), which measures the change in inflation as the percentage change of a quarter over the same quarter in the previous year. Furthermore, data on unit labour cost up to 2002Q2 and data from 2002Q3 onwards are incomparable (see SARB: Online), which explains why the analysis runs only up until 2002Q2.

An ocular inspection of the inflation graph (Figure 1) indicates a possible structural break in 1991Q3. This possibility will be examined further below.

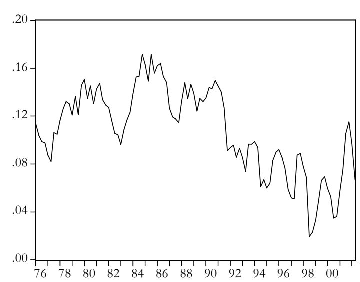


Figure 1. Inflation Rate (Source: SARB (2005))

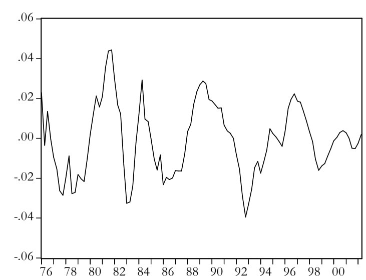


Figure 2. Output Gap: calculated using the HP Filter (Source: SARB (2005) and authors' own calculations)

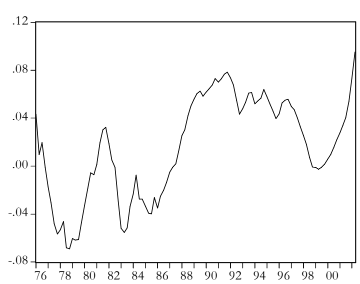


Figure 3. Output Gap: calculated using the Ball method (Source: SARB (2005) and authors' own calculations)

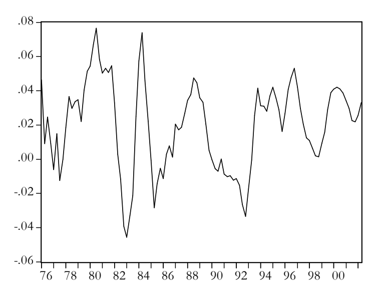


Figure 4. Output Gap: calculated using the CMA Filter and Mankiw (Source: SARB (2005) and authors' own calculations)

On first sight, the output gaps calculated using the HP filter and the CMA filter seem to yield similar figures (Figures 2 and 4), while the Ball and Mankiw method seems to yield a somewhat different picture of the output gap (Figure 3). This is borne out further by the correlation coefficient of 0.55 between y_{HP} and y_{CMA}, while the correlation coefficient between y_{HP} and y_{BM} equals 0.44 and that between y_{CMA} and y_{BM} equals 0.06.

As a measure of the supply shock, the analysis includes the change in the terms-of-trade. This is similar to Nell (2000) and Huh and Lee (2002:223-4). Huh and Lee (2002:223-4) argue that the terms-of-trade is the suitable variable to include to capture in particular the effect of external shocks to small open economies. One can then also assume that these shocks, as they register in the terms-of-trade, are independent of domestic shocks as contained in the error term (thus, ensuring the absence of heteroskedasticity).

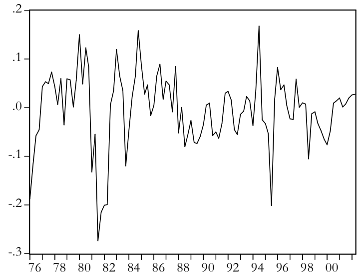


Figure 5. Differenced log of the Terms-of-trade: used as a proxy for supply shock (Source: SARB)

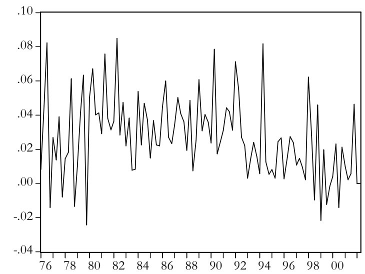


Figure 6. Differenced log of the Unit Labour Cost

To establish the univariate characteristics of the variables the Augmented Dickey Fuller (ADF) test was performed on all of the time series. In addition, because further ocular inspection of the inflation graph (Figure 1) indicated a possible structural break in 1991Q3 a Perron test was also performed on the inflation time series. The ADF test tests for possible changes in the mean, variance and covariance of a time series. The ADF test is given by:

$$\Delta y_t = \mu + \beta t + \delta y_{t-1} + \sum_{i=1}^{k} a_i \Delta y_{t-k} + \varepsilon_t \qquad (13)$$

where k is the number of lagged differences of Δy_t that renders the error term ε_t free of serial correlation (i.e. ε_t becomes white noise). This number of lagged differences, k, was chosen by general-to-specific testing at the 5% and 10% significance levels, with a maximum permitted value of 12. The alternative hypothesis of the ADF test assumes that no structural breaks occur within the sample – thus, if the series is stationary, all shocks are assumed to be temporary and the null hypothesis of a unit root is rejected. On the other hand, if the null hypothesis is not rejected, then it is assumed that the series has a permanent component of unknown size, i.e. the shocks permanently displace the series. (For more on the ADF test, see Gujarati (2003:817-8).)

To allow for the possibility of structural breaks in the data the Perron test is used under an alternative hypothesis that allows for a one-time break in both the mean and a trend at a pre-specified point in time. This test was proposed by Perron who argues that most macroeconomic time series are stationary fluctuations around a deterministic trend if allowance is made for the possibility of a shift in the intercept of the trend function as well as a shift in the slope.

The Perron unit root test is specified as:

$$y_t = \mu + \beta t + \gamma_1 DU_t + \gamma_2 DT_t + \delta y_{t-1} + \sum_{i=1}^{k} a_i \Delta y_{t-k} + \varepsilon_t \qquad (14)$$

where DU and DT are dummy variables, DU = 1 if t > TB , 0 otherwise and DT = t – TB if t > TB, 0 otherwise (TB denotes the time of the break). The differences of inflation are included to correct for the serial correlation in the error term (Perron, 1989: pp.1373). The t-statistic, $t(\delta)$, equals -5.328 and exceeds the critical value of -4.24 at the 5% level of significance. Thus, the test confirms the result of the ocular inspection, meaning we accept that a structural break occurred in 1991Q3 and that inflation is a series with stationary fluctuations around a deterministic trend. Historically speaking, this break makes sense, as the first sub-period represents a high inflation period during which the South African Reserve Bank did not combat inflation persistently (with real interest rates even being negative in the mid-1980s), while the second represents a period during which the South African Reserve Bank pursued a strong anti-inflationary policy.

The ADF test was conducted on all the variables for the period 1976Q1 to 2002Q2. Subsequent to establishing the breakpoint through the use of the Perron test, the ADF test was again performed on all the series for the two sub-periods. The results indicate that all time-series are I(0), i.e. they are stationary at least at the 10% level of significance. For more detail, see Appendix I, Table A.

With the properties of the time-series established, equations (9.1) to (10.3) were run for the overall period 1976Q1 to 2002Q2. Table 1 contains the results.[9]

[9] Note that the Phillips curve was also estimated using the business cycle (more specifically the ratio of the lagged to the leading indicator index) and business confidence indicators. However, the results did not differ significantly from those estimated with the output gaps reported in Tables 1 to 3.

Table 1. Total Period: 1976Q1 to 2002Q2

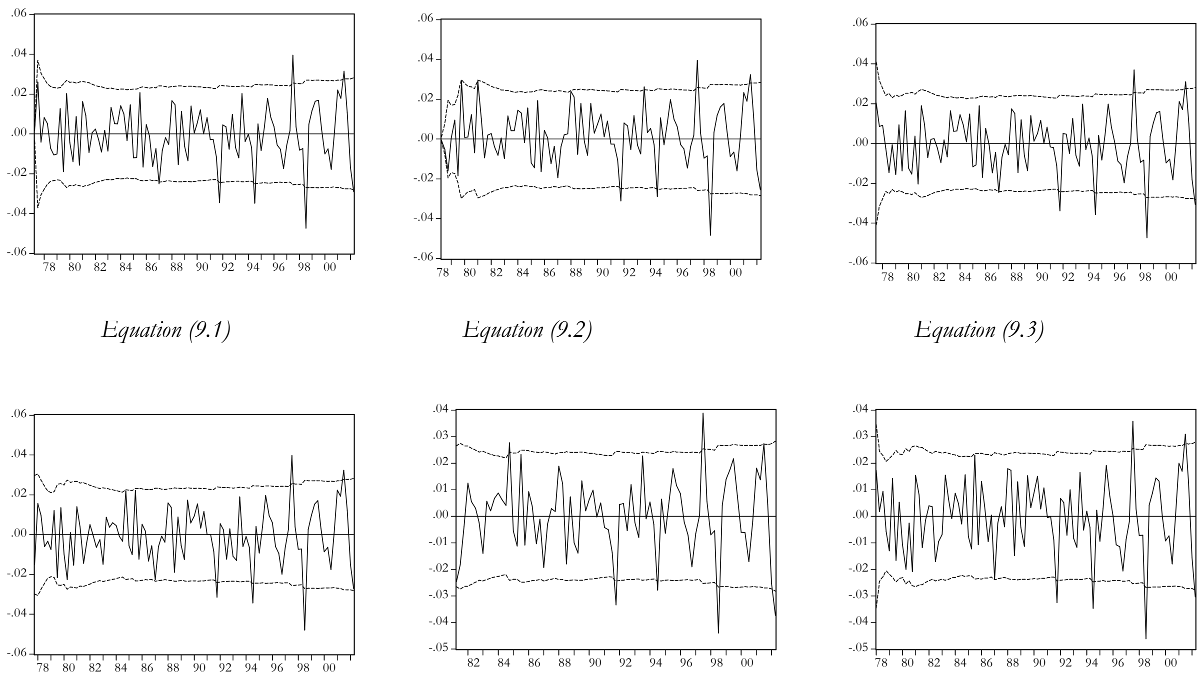
Variable	Equation (9.1)	Equation (9.2)	Equation (9.3)	Equation (10.1)	Equation (10.2)	Equation (10.3)
p_{t-1}	0.9802**	0.9828**	0.9706**	0.9549**	0.9288**	0.9325**
	(51.281)	(52.016)	(48.932)	(37.404)	(23.354)	(31.743)
$(y-\bar{y}_{HP})_t$	-0.1006	-	-	-	-	-
	(-1.122)					
$\Delta(y-\bar{y}_{HP})_t$	0.0941	-	-	-	-	-
	(1.444)					
$(y-\bar{y}_{BM})_t$	-	-0.0541*	-	-	-	-
		(-1.694)				
$\Delta(y-\bar{y}_{BM})_t$	-	0.0095	-	-	-	-
		(0.186)				
$(y-\bar{y}_{CMA})_t$	-	-	0.0575	-	-	-
			(1.235)			
$\Delta(y-\bar{y}_{CMA})_t$	-	-	0.0522	-	-	-
			(0.526)			
$(y-\bar{y}_{HP})_t^{overh}$	-	-	-	0.0745	-	-
				(0.354)		
$(y-\bar{y}_{HP})_t^{weak}$	-	-	-	-0.2486*	-	-
				(-1.759)		
$\Delta(y-\bar{y}_{HP})_t^{overh}$	-	-	-	0.1465	-	-
				(1.037)		
$\Delta(y-\bar{y}_{HP})_t^{weak}$	-	-	-	0.0561	-	-
				(0.528)		
$(y-\bar{y}_{BM})_t^{overh}$	-	-	-	-	0.0254	-
					(0.372)	
$(y-\bar{y}_{BM})_t^{weak}$	-	-	-	-	-0.2325**	-
					(-2.039)	
$\Delta(y-\bar{y}_{BM})_t^{overh}$	-	-	-	-	0.1079	-
					(0.759)	
$\Delta(y-\bar{y}_{BM})_t^{weak}$	-	-	-	-	0.0173	-
					(0.214)	
$(y-\bar{y}_{CMA})_t^{overh}$	-	-	-	-	-	0.0914
						(1.350)
$(y-\bar{y}_{CMA})_t^{weak}$	-	-	-	-	-	-0.0507
						(-0.546)
$\Delta(y-\bar{y}_{CMA})_t^{overh}$	-	-	-	-	-	0.3555**
						(2.492)
$\Delta(y-\bar{y}_{CMA})_t^{weak}$	-	-	-	-	-	-0.026
						(-1.542)
w_t	0.0378	0.0499	0.0391	0.0287	0.0699	0.0385
	(0.653)	(0.777)	(0.662)	(0.504)	(1.045)	(0.626)
z_t	0.0016	-0.0014	0.0113	0.0079	-0.0097	0.0125
	(0.071)	(-0.059)	(0.539)	(0.292)	(-0.431)	(0.614)
Adjusted R^2	0.8464	0.8487	0.8472	0.8463	0.8505	0.8512
Breusch-Godfrey test	39.215	37.875	39.292	38.565	39.941	40.076
p (Breusch-Godfrey test)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
White test	22.439	19.438	22.223	36.827	41.837	33.491
p (White test)	0.3171	0.4935	0.3285	0.2961	0.1292	0.4435
ADF of residual	-9.6386	-9.8252	-9.8039	-9.5583	-10.136	-9.8163

1. Estimated t-statistics are in parentheses. Significance at the 5% level is denoted by ** and * at the 10% level.
2. When testing for the stationarity of the residual series, critical ADF statistic of -2.890 was used.

The White test indicates the absence of heteroskedasticity, however, as shown by the Breusch-Godfrey test, every regression suffered from autocorrelation. Hence the Newey-West correction was applied to correct the standard errors for autocorrelation. (For more detail on this method consult Gujarati (2003:484-5)). Furthermore, the residual series were all found to be stationary at the 5% significance level, thus indicating cointegration.

With regard to the parameters, in all of the equations lagged inflation was particularly significant at even the 1% level of significance. This result points towards the presence of inertia in South African inflation. The output gap estimated with the Ball and Mankiw long run output level was found to be significant at the 10% level in equation (9.2), but the estimated coefficient has the wrong sign on *a priori* grounds and was hence rejected. In neither of the other two equations ((9.1) and (9.3)) estimated with the total output gap, was the output gap statistically significant. In equation (10.1), the positive gap, $(y-\bar{y}_{HP})_t^{weak}$, was found to be statistically significant at the 10% significance level, but has the incorrect sign on *a priori* grounds. In equation (10.2), the positive gap, $(y-\bar{y}_{BM})_t^{weak}$, was also found to be significant, but at the 5% level, and also has the incorrect sign. Lastly, in equation (10.3), the difference of the negative gap, $\Delta(y-\bar{y}_{CMA})_t^{overh}$, was found to be statistically significant at the 5% level and has the correct sign. Unit labour costs and the terms-of-trade variables were not found to be significant in any of the six equations for the total period under consideration. Thus, in conclusion, there is no evidence that the output gap can serve as an explanatory variable for inflation.

Subsequent to running the regressions, a stability test in the form of a recursive residual plot was performed on all the regressions. The results are displayed in Figure 7.



Equation (9.1) *Equation (9.2)* *Equation (9.3)*

Equation (10.1) *Equation (10.2)* *Equation (10.3)*

Figure 7. Recursive residual plots for the total period 1976Q1 to 2002Q2

Most of the plots suggest that the relationship was stable up to round about 1991, where after the presence of several spikes outside the two-standard error bands indicates possible instability in the estimated regressions. This finding corresponds closely to the findings of both the ocular inspection as well as the Perron test that indicate the presence of a structural break in 1991Q3. Hence, the regressions were run for the two sub-periods, i.e. 1976Q1 to 1991Q2 and 1991Q3 to 2002Q2. The results are presented in Tables 2 and 3 below.

Table 2. First Sub- period: 1976Q1 to 1991Q2

Variable	Equation (9.1)	Equation (9.2)	Equation (9.3)	Equation (10.1)	Equation (10.2)	Equation (10.3)
p_{t-1}	1.0072**	1.0029**	0.9982**	0.9782**	0.9208**	0.9787**
	(51.972)	(43.330)	(51.887)	(39.782)	(26.928)	(41.455)
$(y-\bar{y}_{HP})_t$	-0.0351	-	-	-	-	-
	(-0.333)					
$\Delta(y-\bar{y}_{HP})_t$	0.0749	-	-	-	-	-
	(1.159)					
$(y-\bar{y}_{BM})_t$	-	-0.0254	-	-	-	-
		(-0.699)				
$\Delta(y-\bar{y}_{BM})_t$	-	0.0092	-	-	-	-
		(0.178)				
$(y-\bar{y}_{CMA})_t$	-	-	0.0469	-	-	-
			(1.073)			
$\Delta(y-\bar{y}_{CMA})_t$	-	-	0.0741	-	-	-
			(0.723)			
$(y-\bar{y}_{HP})_t^{overh}$	-	-	-	0.0123	-	-
				(0.066)		
$(y-\bar{y}_{HP})_t^{weak}$	-	-	-	-0.1502	-	-
				(-1.031)		
$\Delta(y-\bar{y}_{HP})_t^{overh}$	-	-	-	0.2347*	-	-
				(1.753)		
$\Delta(y-\bar{y}_{HP})_t^{weak}$	-	-	-	-0.0305	-	-
				(-0.293)		
$(y-\bar{y}_{BM})_t^{overh}$	-	-	-	-	0.1315**	-
					(2.332)	
$(y-\bar{y}_{BM})_t^{weak}$	-	-	-	-	-0.2584**	-
					(-2.6011)	
$\Delta(y-\bar{y}_{BM})_t^{overh}$	-	-	-	-	0.1988**	-
					(2.429)	
$\Delta(y-\bar{y}_{BM})_t^{weak}$	-	-	-	-	0.0263	-
					(0.353)	
$(y-\bar{y}_{CMA})_t^{overh}$	-	-	-	-	-	0.0904
						(1.416)
$(y-\bar{y}_{CMA})_t^{weak}$	-	-	-	-	-	-0.0730
						(-0.608)
$\Delta(y-\bar{y}_{CMA})_t^{overh}$	-	-	-	-	-	0.1972
						(1.549)
$\Delta(y-\bar{y}_{CMA})_t^{weak}$	-	-	-	-	-	-0.049
						(-0.311)
w_t	-0.0264	-0.0116	-0.0174	-0.0312	0.0161	-0.0303
	(-0.362)	(-0.132)	(-0.232)	(-0.431)	(0.175)	(-0.400)
z_t	0.0171	0.0125	0.0217	0.0141	0.0115	0.0201
	(1.164)	(0.769)	(1.635)	(0.669)	(0.691)	(1.407)
Adjusted R^2	0.6845	0.6329	0.6865	0.6886	0.6614	0.6837
Breusch-Godfrey test	16.472	15.545	15.923	14.049	15.139	17.096
p (Breusch-Godfrey test)	0.0025	0.0037	0.0031	0.0071	0.0044	0.0019
White test	15.598	20.401	24.426	28.777	20.336	40.344
p (White test)	0.7412	0.4331	0.2242	0.6774	0.9586	0.1774
ADF of residual	-4.4023	-4.3009	-4.3050	-4.4907	-4.5751	-4.6192

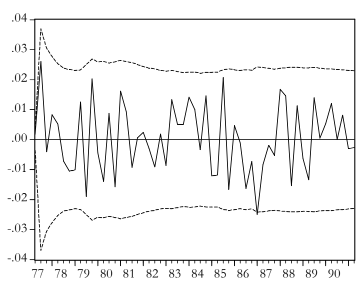
1. Estimated t-statistics are in parentheses. Significance at the 5% level is denoted by ** and * at the 10% level.
2. When testing for the stationarity of the residual series, critical ADF statistic of -2.910 was used.

As with the overall period the White test showed no heteroskedasticity for the first sub-period, while every equation for this period suffered from autocorrelation. Thus, the Newey-West correction of the standard errors was again applied. The residual series were found to be stationary at the 5% significance level, thus indicating cointegration.

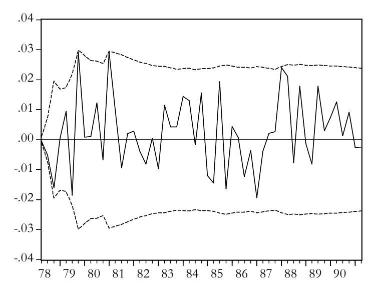
For the first sub-period lagged inflation was particularly significant in all of the equations at the 1% level of significance. This again points towards inertia in South African inflation. Note that in equations (9.1) through to (9.3), none of the gaps or any of the changes in the gaps were found to be statistically significant. This suggests that there was no effect of the output gap on inflation during this period. In equation (10.1), the change in the negative gap, $\Delta(y-\bar{y}_{HP})_t^{overb}$, was found to be statistically significant at the 10% significance level and has a correct sign. In equation (10.2), the negative and the positive gaps, thus both $(y-\bar{y}_{BM})_t^{overb}$ and $(y-\bar{y}_{BM})_t^{weak}$, were found to be significant at the 5% level. However, only the negative gap has the correct sign, while the positive gap has an incorrect sign (given that the minus of the estimated parameter suggests that the larger the gap (which has values with negative signs) is, the higher inflation will be). Furthermore, the difference of the negative gap, $\Delta(y-\bar{y}_{BM})_t^{overb}$, was significant at the 5% level and has a correct sign. These results with regard to the inflation-output gap relationship are ambiguous and points towards the non-existence of such a relationship in South Africa during the period under consideration.

Unit labour cost and the terms-of-trade variables were not found to be significant in any of the six equations for the first sub-period. Furthermore, the *in*significance of the unit labour costs indicates no wage pressure on inflation during the period under consideration.

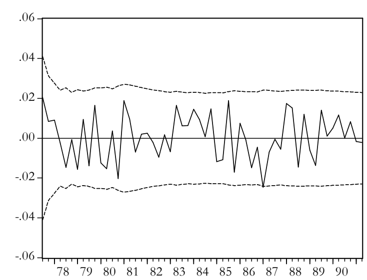
Stability tests were again performed through a residual series plot (Figure 8). Most of the plots point toward stability, except the plot of equation (10.2), which shows some instability in 1984.



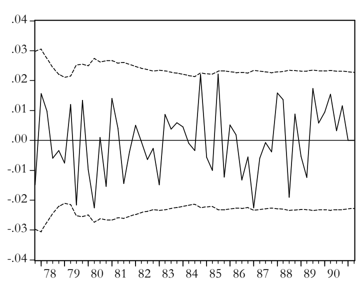
Equation (9.1)



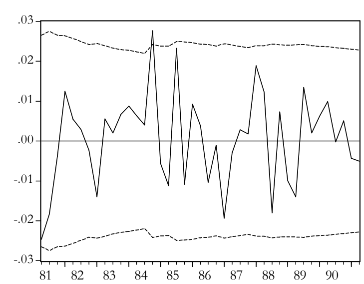
Equation (9.2)



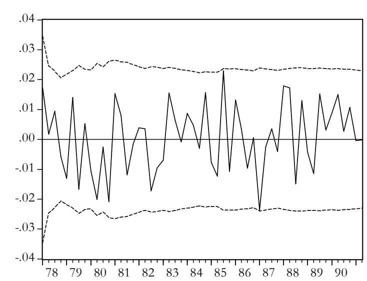
Equation (9.3)



Equation (10.1)



Equation (10.2)



Equation (10.3)

Figure 8. Recursive residual plots for the first sub-period 1976Q1 to 1991Q2

With regard to the second sub-period (i.e. 1991Q3 to 2002Q2), the White test found no heteroskedasticity, while autocorrelation seems to be present in all the regressions. Hence, the Newey-West correction was again applied. Again the residual series were found to be stationary at the 5% significance level, thus indicating cointegration.

Table 3. Second Sub- period: 1991Q3 to 2002Q2

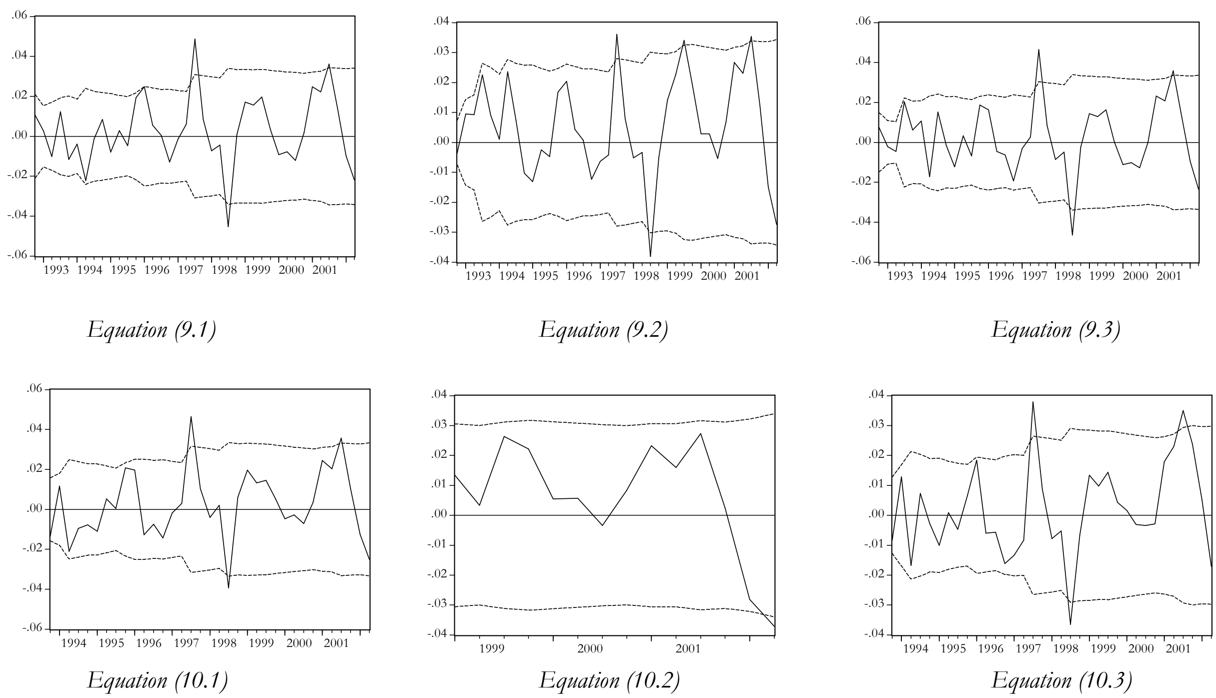
Variable	Equation (9.1)	Equation (9.2)	Equation (9.3)	Equation (10.1)	Equation (10.2)	Equation (10.3)
p_{t-1}	0.9114**	0.8699**	0.8768**	0.9451**	0.8365**	0.7129**
	(16.907)	(7.560)	(15.666)	(13.128)	(7.287)	(7.788)
$(y - \bar{y}_{HP})_t$	-0.1729	-	-	-	-	-
	(-0.712)					
$\Delta(y - \bar{y}_{HP})_t$	0.1270	-	-	-	-	-
	(0.594)					
$(y - \bar{y}_{BM})_t$	-	0.0924	-	-	-	-
		(0.530)				
$\Delta(y - \bar{y}_{BM})_t$	-	-0.0364	-	-	-	-
		(-0.215)				
$(y - \bar{y}_{CMA})_t$	-	-	0.1456	-	-	-
			(1.417)			
$\Delta(y - \bar{y}_{CMA})_t$	-	-	0.0233	-	-	-
			(0.068)			
$(y - \bar{y}_{HP})_t^{overb}$	-	-	-	0.5037	-	-
				(1.113)		
$(y - \bar{y}_{HP})_t^{weak}$	-	-	-	-0.7906**	-	-
				(-2.246)		
$\Delta(y - \bar{y}_{HP})_t^{overb}$	-	-	-	-0.5646	-	-
				(-1.379)		
$\Delta(y - \bar{y}_{HP})_t^{weak}$	-	-	-	0.8619**	-	-
				(2.330)		
$(y - \bar{y}_{BM})_t^{overb}$	-	-	-	-	0.1509	-
					(0.889)	
$(y - \bar{y}_{BM})_t^{weak}$	-	-	-	-	-9.1807**	-
					(-2.864)	
$\Delta(y - \bar{y}_{BM})_t^{overb}$	-	-	-	-	-0.0223	-
					(-0.069)	
$\Delta(y - \bar{y}_{BM})_t^{weak}$	-	-	-	-	0.0250	-
					(0.084)	
$(y - \bar{y}_{CMA})_t^{overb}$	-	-	-	-	-	0.1473
						(0.866)
$(y - \bar{y}_{CMA})_t^{weak}$	-	-	-	-	-	-0.0853
						(-0.241)
$\Delta(y - \bar{y}_{CMA})_t^{overb}$	-	-	-	-	-	1.2022**
						(3.564)
$\Delta(y - \bar{y}_{CMA})_t^{weak}$	-	-	-	-	-	-1.9172**
						(-4.124)
w_t	0.1367	0.1163	0.1691**	0.1786**	0.1086	0.2793**
	(1.409)	(1.247)	(1.706)	(1.769)	(1.277)	(3.433)
z_t	-0.0305	-0.0387	-0.0361	-0.0531	-0.035	-0.0081
	(-0.503)	(-0.719)	(-0.619)	(-0.999)	(-0.645)	(-0.143)
Adjusted R^2	0.5410	0.4897	0.5086	0.5172	0.4989	0.6154
Breusch-Godfrey test	21.851	21.263	25.408	13.113	22.804	14.652
p (Breusch-Godfrey test)	0.0002	0.0002	0.0000	0.0107	0.0001	0.0055
White test	26.736	22.999	25.477	33.967	35.253	37.339
p (White test)	0.1428	0.2888	0.1837	0.4207	0.2335	0.2763
ADF of residual	-7.5065	-7.0784	-8.2873	-5.6590	-6.6797	-4.6934

1. Estimated t-statistics are in parentheses. Significance at the 5% level is denoted by ** and * at the 10% level.
2. When testing for the stationarity of the residual series, critical ADF statistic of -2.936 was used.

Again lagged inflation was particularly significant in all the equations at the 1% level of significance. Thus, inertia continues to remain a significant phenomenon in the second sub-period. Furthermore, as with the first sub-period, none of the gaps or any of the changes in the gaps were found to be statistically significant in equations (9.1) through to (9.3). This suggests again that there was no effect of the output gap on inflation during this period. In equation (10.1), the positive gap, $(y-\bar{y}_{HP})_t^{weak}$, was found to be statistically significant at the 5% significance level, but has an incorrect sign and was thus rejected. The difference of the positive gap, $\Delta(y-\bar{y}_{HP})_t^{weak}$, was also significant at the 5% level, but has the correct sign. In equation (10.2), the positive gap, $(y-\bar{y}_{BM})_t^{weak}$, was also found to be significant at the 5% level, but again has an incorrect sign and is thus also rejected. Lastly, in equation (10.3), the differences of the positive and the negative gaps, $\Delta(y-\bar{y}_{CMA})_t^{weak}$ and $\Delta(y-\bar{y}_{CMA})_t^{overh}$, were found to be statistically significant at the 5% level, but only the difference of the negative gap has a correct sign. As with the first period, the results with regard to the inflation-output gap relationship are very ambiguous, again pointing to the non-existence of such a relationship.

Unit labour cost, *w*, was found to be significant at the 5% level in equations (9.3), (10.1) and (10.3). Thus, unit labour cost and the mark-up behaviour that may accompany it, might explain the behaviour of inflation during the second sub-period. Upon inspection of the graphs, something of this can be seen in the reduction of both inflation and unit labour costs during the late 1990s and their stabilization from round about 1998 (see Figures 1 and 6). The terms-of-trade variable was insignificant in all six equations for the second sub-period.

The recursive residual plots for the second sub-period indicate instability especially in 1997, 1998 and 2001.[10] This might be ascribed to the effects of the Asian crisis and the currency instability in 2001. However, for the remainder of the period the relationship seems stable.



Equation (9.1) *Equation (9.2)* *Equation (9.3)*

Equation (10.1) *Equation (10.2)* *Equation (10.3)*

Figure 9. Recursive residual plots for the second sub-period 1991Q3 to 2002Q2

3. CONCLUSION

Thus, is there a triangular Phillips curve present in South Africa? As discussed above, the presence of a triangular Phillips curve implies the existence of inflation inertia, output level effects and rates-of-change (in output) effects. Inertia effects are clearly present. However, there is almost no evidence of output level effects, suggesting the presence of hysteresis in output. Evidence to support the rates-of-change effect seems just as limited. Thus, the

[10] Note that 1999 and 2002 also occur as spikes, but only in one equation out of the six, namely equation (9.2) in the case of 1999 and equation (10.2) in the case of 2002.

triangular model seems not to apply to South Africa. In addition to the standard components of the triangular model, unit labour costs and terms-of-trade were also included. The latter were not statistically significant in both sub-periods, while unit labour costs were statistically significant in the second sub-period. Thus, unit labour cost can play a role in the reduction of inflation and the maintenance of low inflation in deflationary and stable inflationary periods.

With regard to policy, the insignificance of the output gaps in both sub-periods suggests that the anti-inflationary policy, in so far as it affected the demand side of the economy, does not really influence inflation. Thus, the conclusion is not that monetary policy does not influence the output gap, but that any such policy does not seem to influence inflation via the output gap. However, it seems as if monetary policy does work through inflationary expectations, given the presence of inertia and given that the strong anti-inflationary policy period (second sub-period) coincides with the decrease in inflation. Furthermore, the *in*significance of the overheating gaps in the deflationary period also bodes well for the economy, as it suggests that if actual output exceeds potential output, the output gap does not put upward pressure on inflation.

3. APPENDIX I

Table A. Unit root tests

Variable	Total period (1976Q1 to 2002Q2)	First sub-period (1976Q1 to 1991Q2)	Second sub-period (1991Q3 to 2002Q2)
p_t	I(0)# **	I(0)**	I(0)**
$(y - \bar{y}_{HP})_t$	I(0)**	I(0)*	I(0)*
$(y - \bar{y}_{BM})_t$	I(0)*	I(0)*	I(0)*
$(y - \bar{y}_{CMA})_t$	I(0)*	I(0)**	I(0)*
w_t	I(0)**	I(0)**	I(0)**
z_t	I(0)**	I(0)**	I(0)*

1. Significance at the 5% and 10% levels is denoted by ** and * respectively.
2. Due to the p_t series undergoing a structural break in 1991Q3, a Perron unit root test was performed on this series for the total period (this is denoted by #).

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