Inflation, inflation uncertainty, and output growth: Are they related in South Africa?

Prepared by Eliphas Ndou and Thabo M Mokoena
Research Department, South African Reserve Bank

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Abstract

This paper uses univariate GARCH-in-mean models to investigate the welfare costs of inflation operating indirectly through the inflation uncertainty channel. The study assesses four relationships, namely, (i) the effect of inflation uncertainty on inflation as suggested by Holland (1995) or Cuikerman Meltzer (1986); (ii) the effect of inflation on inflation uncertainty as suggested by Friedman (1977); (iii) the impact of inflation uncertainty on real output growth uncertainty according to the Taylor-curve principle or Logue-Sweeney hypothesis; and (iv) the impact of inflation uncertainty on real output growth as suggested by Friedman (1977). Overall, we provide evidence that the welfare costs of inflation in the economy work indirectly through the inflation-uncertainty channel. The six main results with regard to South Africa are as follows: Empirical evidence supports the stabilisation hypothesis advanced by Holland (1995), in which a conservative monetary authority prefers an anti-inflation stance to reduce inflation and inflation uncertainty. Secondly, the findings support Friedman's hypothesis that higher inflation leads to more inflation uncertainty. Thirdly, we find that higher inflation uncertainty is detrimental to output growth. Fourthly, the findings indicate that the adoption of the inflation-targeting framework has had a significant positive effect on real output growth and has reduced the variability of both inflation and output growth. Lastly, we find evidence of the Logue-Sweeney effect that high inflation uncertainty under inflation targeting leads to higher output growth uncertainty. In policy terms, under inflation targeting, the reduction of inflation uncertainty would be consistent with a decline in output growth uncertainty. We conclude that, with the implementation of inflation targeting, a central bank can stabilise the volatilities of both inflation and output growth rates, indicating that price stability should be a priority for monetary authorities.

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Corresponding authors' e-mail addresses: Thabo.Mokoena@resbank.co.za; Eliphas.Nodu@resbank.co.za

1 Introduction

This paper searches for evidence of welfare costs of higher inflation operating indirectly through the higher inflation uncertainty channel in South Africa. Friedman, in his 1977 Nobel Prize Lecture, argued that increased inflation uncertainty reduces the information function of price movements and hinders long-term contracting, thus potentially reducing real output growth. Friedman also argued that high inflation leads to higher inflation uncertainty. In this context, the paper focuses on four of the twelve hypotheses advanced by Fountas and Karansos (2007) by assessing any significant relationships among inflation, inflation uncertainty, output growth uncertainty and output growth in South Africa.

In several recent studies researchers have found positive, negative or no relationships between inflation and output growth in various countries. Despite the conflicting empirical results, researchers agree that the cost of higher inflation and inflation uncertainty on output growth and the associated welfare costs are significant. Moreover, in the literature, the link between the inflation process and economic performance has remained unresolved. We fill the gap in South Africa by analysing the relationship in the areas of inflation uncertainty, output growth uncertainty and output growth to learn more about the degree of their interrelationships.

The four hypotheses we test are as follows: (i) Firstly, we test for the impact of inflation on inflation uncertainty, which is expected to be positive according to Friedman (1977). Secondly, we analyse the impact of inflation uncertainty on inflation to determine whether the central bank pursues stabilisation policies (as suggested by Holland 1995) or goes out of its way to surprise with higher inflation, hoping for output gains (Cuikerman and Meltzer 1986). The third hypothesis is to test the impact of inflation uncertainty on real output growth, which is expected to be negative as argued by Friedman (1977). The fourth hypothesis is to test for the impact of inflation uncertainty on real output growth uncertainty, which, according to Taylor (1979), is expected to be negative or positive according to Logue and Sweeney (1981). In this context, following the recent studies, we measure inflation uncertainty by the conditional variance of the inflation rate in a Generalized Autoregressive Conditional Heteroskedasticity (GARCH) framework to capture the time-varying nature of inflation variability. We estimate a generalised autoregressive conditional heteroskedasticy in mean (GARCH-M) model of inflation aimed at producing a measure of inflation uncertainty.

The main results are as follows: Firstly, there is evidence supporting Holland's "stabilisation hypothesis" in which a conservative monetary authority prefers an anti-inflation stance to reduce inflation and inflation uncertainty, suggesting that there is a significant negative effect of inflation uncertainty on the inflation rate. Secondly, the results are consistent with Friedman's hypothesis that higher inflation leads to more inflation uncertainty. Thirdly, we find that inflation uncertainty is detrimental to output growth. This is consistent with Friedman's argument regarding the negative real effects of inflation uncertainty on output growth.

One of the shortcomings in this empirical literature is that most studies do not deal with the issue of the time lag of the transmission effects and the magnitudes of the effects as carried out in the VAR monetary analysis. Instead, the literature focuses mainly on the significance, causality and signs of the impacts. In this study we are guided by the recent literature's precedence in order to focus on explaining the channels through which inflation uncertainty effects are transmitted into the economy, either contemporaneously or with some lags.

According to Fountas and Karanasos (2007), the transmission of shocks indicates that the higher unanticipated costs due to the impact of inflation uncertainty could be working through the intertemporal and intratemporal allocation of resources. Inflation uncertainty affects interest rates (inflation premium) and consequently all decisions relating to intertemporal allocation of resources. Assuming nominal rigidities, inflation uncertainty affects the real cost of factors of production and relative prices of final goods, which is the intratemporal allocation of resources. Moreover, Levi and Makin (1980) show that inflation uncertainty lowers employment due to institutional rigidities, reducing the efficiency of price system in guiding economic activity and consequently leading to a reduction in output. The link between inflation uncertainty and employment takes place when higher inflation uncertainty leads to the postponement or cancellation of long-term spending plans.

The other transmission mechanism possibly works through the Phillips-curve relationship. Holland (1986) argues that increased wage indexation in contracts indicates the responsiveness of nominal wages to inflation surprises. The degree of wage indexation spreads to sectors beyond the labour market covered by bargaining agreements to smaller union contracts and non-unionised labour. Thus, high wage indexation leading to higher mark-ups through the Phillips relationships is associated with a high unemployment rate. Higher mark-ups lead to higher inflation, hence the Phillips-curve relationship suggests that higher inflation reduces output. Furthermore, high wage indexation increases the responsiveness of inflation towards unemployment, hence more wage indexations will be ultimately be passed through to higher inflation from increased demand for goods, a phenomenon that negatively impacts on output. Moreover, Ratti (1985) discusses that the rise in inflation uncertainty increases actual and expected real wages and depresses the level of employment. According to the aggregate-supply–aggregate-demand relationship higher expected wages lead to higher expected inflation, which negatively affects output.

In addition, the study finds that the adoption of the inflation-targeting framework has increased real output growth significantly but lowered the variability of both inflation and output growth considerably. Our specification of the mean equation enables the calculation of both the long-run quarterly output growth rates and the long-run impact of inflation uncertainty. The study finds that the long-run quarterly output growth rates are higher without accounting for the costs of inflation uncertainty. However, in the long run higher inflation uncertainty reduces the quarterly real output growth rates. It is inferred that, in the long run, the welfare costs in terms of real output growth reduction due to higher inflation uncertainty as a fraction of long-run real output growth rates are about 30 to 33 per cent.[1] Despite the quantitatively high value and the uncertainty of such magnitudes, we conclude that there are significant welfare costs working through the indirect inflation uncertainty channel.

[1] Literature surveyed has not done such quantification but tends to focus on causality. This makes it difficult to compare the magnitudes against other studies. Moreover, the estimations were done in Eviews 7 which is unable to use the Delta approach to calculate the significance hence it is difficult to justify whether this reduction is highly significant or not.

Over and above the above-mentioned results, there is evidence of the Logue-Sweeney effect that high inflation uncertainty, under inflation targeting, leads to higher output growth uncertainty. In policy term, this suggests that lowering inflation uncertainty would be associated with lowering output growth uncertainty. This implies that, with the implementation of inflation targeting, a central bank can achieve the objective of stabilising the volatility of both inflation and output growth. Broadly, these findings suggest that an anti-inflation stance by a central bank can successfully reduce inflation uncertainty and that a clear focus on long-run price stability helps to anchor medium- to long-term inflation expectations, thus reducing inflation uncertainty and minimising the welfare costs of inflation.

The rest of the paper is organised as follows: Section 2 presents the theory. Sections 3 and 4 present literature review and econometric methodology used in this study. Section 5 presents the data and the empirical results. Section 6 concludes and discusses the policy implications of the findings.

2 Theory

2.1 The Friedman hypothesis

Friedman (1977) argued that increased uncertainty distorts the price system in allocating resources efficiently, thereby reducing the informativeness of price movements associated with long-term contracting, hence, potentially reducing output growth and investment. This happens because inflation uncertainty hinders the settlement of contracts of hard-to-reverse long-term investment projects. In addition, since inflation uncertainty increases relative price variation in the economy, it hinders the efficiency of the price system from allocating resources (Elder. 2004). Thus, Friedman (1977) postulates that higher average inflation rate leads to more inflation uncertainty. This hypothesis suggests a positive relationship. This happens when an increase in inflation induces an erratic policy response by a monetary policy authority and, therefore, leads to more uncertainty about the future of an inflation rate.

2.2 The impact of inflation uncertainty on inflation

Milton Friedman (1977) was the first to suggest that higher inflation uncertainty could result in higher inflation. Various theories formulated to explain this outcome suggest that the impact of inflation uncertainty on inflation can be either positive or negative. Based on the sign of the preceding stated possible outcome, we can glean the behaviour of the central bank on how it deals with inflation uncertainty and, consequently, the inflation outcome. Cukierman and Meltzer (1986) were the first to provide a theoretical framework explaining such a causal effect. The authors hypothesised that, when inflation uncertainty is high, a less conservative central bank, instead of disinflation, has an incentive to surprise the public by generating unanticipated inflation, hoping for output gains. A view pointing to similar causality was advanced by Demetriades (1988), who suggested that a positive correlation between inflation and inflation variance arose from asymmetric information between policy-makers, the public, and the asymmetric stabilisation polices, in which there were greater policy responses to negative shocks than to positive shocks. Furthermore, Ball (1992) uses a game-theoretic asymmetric framework to show that uncertainty about the policy-makers' preferences only affects inflation uncertainty when inflation is high. In the model, economic agents do not know the preferences of the policy-maker. Thus, at a high level of inflation, one type of policy-maker may initiate a stabilisation programme and the other type may not. However, at a low level of inflation, both types of policy-makers accept the existing inflation rate. The above views suggest a positive relationship between inflation uncertainty and inflation.

There are views which argue that the relationship can be negative. Such hypothesis regarding inflation and inflation uncertainty was advanced by Holland (1995). He argued that higher inflation uncertainty could be associated with lower average inflation when a conservative central bank, in an effort to minimise the welfare losses emanating from inflation uncertainty, takes a strong anti-inflation stance by contracting the money supply, thereby reducing inflation. By contrast, Pourgerami and Maskus (1987) argued that higher inflation would lead to lower inflation uncertainty when agents invested resources into forecasting.

2.3 Inflation uncertainty, real output growth, and output growth uncertainty

Friedman (1977) suggested that there was a negative impact of inflation uncertainty on output operating through inefficiency of price system in allocating resources. Thus, increased uncertainty about the inflation distorts the effectiveness of the price mechanism in allocating resources efficiently, leading to negative output effects. In this context, the Taylor-curve principle refers to a second-order Phillips curve in which there is a non-vertical long-run trade-off between fluctuations in output and fluctuations in inflation. Fountas and Karanasos (2007) suggest that this arises when increases in the average inflation rate lead to more inflation uncertainty as hypothesised by Friedman, whereas higher inflation uncertainty leads to lower output uncertainty according to Taylor (1979). These hypotheses suggest a negative relationship.

By contrast, there are hypotheses suggesting a positive relationship between higher inflation uncertainty and higher output growth uncertainty. The positive relation between inflation uncertainty and growth uncertainty in the absence of inflation targeting is explained by Logue and Sweeney (1981) as follows: A higher inflation rate makes it more difficult for producers to distinguish between nominal and real demand shifts, thus leading to more relative price variation. Since relative price variation leads to inefficient allocation of resources, there is likely to be generalised uncertainty among producers, leading to increased variability in real investment and economic activity. In the context of inflation targeting, the Logue-Sweeney effect suggests that a central bank can achieve the objective of stabilising the volatility of both inflation and output growth.

Dotsey and Sarte (2000) showed in a cash-in-advance model that inflation variability has a positive effect on economic growth through increased savings. In this context, increased savings from risk-averse agents increase the pool of savings during periods of inflation uncertainty. The pool of savings then translates into higher investment and output growth.

Another alternative view concerning inflation uncertainty and output growth operating through the investment channel was advanced by Caballero (1991), who suggested that the structure of the model determined whether the effect of uncertainty would be negative or positive. For example, in Craine (1989) the effect of uncertainty is negative in risk-averse firms, whereas in Hartman (1972) the effect of inflation uncertainty is positive in the competitive firms with symmetric adjustment costs. Under irreversible investment with asymmetric adjustment costs, there will be a negative link between inflation uncertainty and investment. These models view the decision to invest as an option in which the firms can exercise their option by either investing or delaying the investment but continuing to hold the option. Greater uncertainty raises the option value of waiting, thereby increasing the required rate of return on investment projects, leading to cancellations or postponements.

3 Literature review

Some of the recent studies concerning the relationship between inflation and inflation uncertainty include Caporale, Onorante, and Paesani (2010), Thornton (2007), Fountas, Ioannidis, and Karanasos (2004), Elder (2004), and Davis and Kanago (2000). Most of these studies rely on GARCH models in the spirit of the seminal contributions by Engle (1982) and Bollerslev (1986) to estimate the relationship between inflation and inflation uncertainty.[2] As indicated above, GARCH-based analyses have often revealed a positive relation between inflation and inflation uncertainty.

Some of the recent studies regarding the relationship between inflation uncertainty and output growth include Bhar and Mallik (2010), Chang and He (2010), Fountas (2010), Fountas and Karanasos (2007), and Fountas, Karanasos and Kim (2006). The studies generally find a negative relationship between inflation uncertainty and real output growth. For instance, Bhar and Mallik (2010) use a multivariate exponential GARCH-in-mean model to investigate the effects of inflation uncertainty and output growth uncertainty on inflation and output growth. They find that inflation uncertainty has a positive and significant effect on the level of inflation and a negative and significant effect on output growth. Grier and Grier (2006) rely on the same methodology to establish that inflation uncertainty has a negative and significant

[2] Engle (1995) provides an extensive survey of the various uses of the ARCH models.

effect on output growth in Mexico during the period 1972–2001. In addition, Grier et al. (2004) and Shields et al. (2005) find that inflation uncertainty decreases inflation and output growth for the United States. Furthermore, Chang and He (2010) rely on a bivariate Markov regime-switching GARCH model to establish that the relationships between inflation and inflation uncertainty and inflation and output growth change with the level of inflation. They find that the harmful effects of inflation on output growth are greater during high-inflation periods than during low-inflation periods.

4 Econometric methodology

GARCH models are commonly used in the analysis of the relationships among inflation, inflation uncertainty, output growth uncertainty and output growth. In this context, inflation uncertainty is proxied by the conditional variance of the unpredictable shocks to the inflation rate. Fountas and Karanasos (2007) argue that most studies do not distinguish between anticipated and unanticipated changes (the source of uncertainty) in inflation. We do not proxy inflation uncertainty by a moving standard deviation or variance of the inflation series because the latter measures inflation variability and not uncertainty. We focus on the unanticipated uncertainty because anticipated inflation uncertainty makes up a small total proportion of total inflation uncertainty and the fact that it can be hedged makes it not to be relevant for investment-type decisions. We use a GARCH-in-mean model consisting of a mean equation and a conditional variance equation. The GARCH technique allows for the measurement of inflation uncertainty by the conditional variance of inflation series and allows for the more accurate testing of the two parts of the Friedman hypothesis. Most literature investigates causality; we similarly add more lags to test the robustness of the findings to different lag-length choices. In addition, we use vector autoregression (VAR) analysis as an extra robustness test of the findings.

4.1 The relationship between inflation and inflation uncertainty

We estimate the relationship between inflation and associated uncertainty simultaneously to increase the efficiency in the estimation procedure. We estimate models from general form to more specific form. Thus, we start with the exponential

GARCH which includes asymmetry effects, after which failure to identify any asymmetry effects implies using a model without asymmetry effects. The GARCH model presented below is in specific form after rejecting the more general form. The mean and variance equations are of the form:

$$\pi_t = \alpha_0 + \sum_{i=1}^{5} \alpha_i \pi_{t-i} + \sum_{i=1}^{2} \chi_i \varepsilon_{t-i} + \gamma \sigma^2{}_{\pi t} + \varepsilon_t \qquad [1]$$

$$\varepsilon_t = v_t \sqrt{\sigma_{\pi t}} \qquad [2]$$

$$\sigma^2{}_{\pi t} = \beta_0 + \beta_1 \varepsilon^2{}_{\pi t-1} + \beta_2 \sigma^2{}_{\pi t-1} + \beta_3 \pi_{t-1} + \beta_4 D_t \pi_{t-1} + \beta_5 D_t + \varepsilon_t \qquad [3]$$

$$\beta_0 > 0, \quad \beta_1 > 0, \quad \beta_2 > 0; \quad \beta_1 + \beta_2 < 1$$

where π_t denotes the inflation rate at time t. The error process is given by equation [2] and the conditional variance of ε_t is given by equation [3].

4.1.1 The effect of inflation uncertainty on inflation

The mean equation [1] tests the impact of inflation uncertainty on the inflation rate. The sign of the in-mean coefficient (γ) in equation [1] differentiates the behaviour of a central bank regarding how it deals with inflation uncertainty to control inflation. The sign can be either positive or negative. Firstly, a positive sign is consistent with the Cuikerman-Meltzer hypothesis, whereas a negative sign is consistent with the stabilisation hypothesis advanced by Holland (1995).

4.1.2 The effect of inflation rate on inflation uncertainty

In the inflation conditional variance equation [2], we test the effect of the inflation rate on inflation uncertainty. We estimate the conditional variance equation mainly to test the Friedman hypothesis that inflation has a positive effect on inflation uncertainty. In the variance equation [3] the D_t is a dummy variable equalling 1 during the inflation-targeting era and zero otherwise. The inflation-targeting period is from the first quarter of 2000 to the end of the sample period in 2009. We include the inflation targeting dummy the coefficient of which is denoted (β_5) to examine its effect on mean conditional variance. A significant and positive sign on (β_5) implies that the adoption of an inflation-targeting framework has increased the mean conditional variance. A significant and negative sign on (β_5) implies a decline in the mean conditional variance.

According to GARCH-M model, the conditional variance of inflation can affect inflation contemporaneously. Fountas (2010) argues that this is restrictive since a central banker adjusts the money supply growth rate to a change in inflation uncertainty with a time lag. Hence, inflation being highly correlated with money growth is also affected with a time lag following a change in inflation uncertainty. Secondly we use the interactive variable between inflation targeting dummy and inflation rate (β_4) to assess whether adoption of inflation targeting changed the effect of inflation rate on conditional variance. A significant positive sign on (β_4) indicates that high inflation under inflation targeting increased the conditional variance by a magnitude of (β_4). However, the overall effect would be ($\beta_4 \pm \beta_3$), if the (β_3) is significant and positive or positive. Moreover, finding a significant positive impact of inflation on inflation uncertainty would support the Friedman hypothesis. The strength of effect can be separated between the pre-inflation-targeting and post-inflation-targeting period as specified in the equation.

We assess and report the model adequacy statistics to ensure that the GARCH model estimated satisfies both theoretical conditions and model diagnostics.

4.2 The effect of inflation uncertainty on real output growth

The equations to test for the effects of inflation uncertainty on output growth and the impact of inflation uncertainty on output growth uncertainty are given by both the mean equation [4] and variance equations [5a] and [5b] for output growth rate, which are of the following form:

$$Y_{gt} = \kappa_0 + \kappa_1 Y_{g_{t-1}} + \kappa_2 Y_{gt-2} + \kappa_3 \sigma^2{}_{\pi t} + \varepsilon_t \qquad [4]$$

$$\log \sigma_{yt}^{\ 2} = \lambda_0 + \lambda_1 \tfrac{|\varepsilon_{t-1}|}{\sigma_{yt-1}} + \lambda_2 \frac{\varepsilon_{t-1}}{\sigma_{y_{t-1}}} + \lambda_3 \log \sigma^2{}_{y_{t-1}} . \qquad [5a]$$

$$\log \sigma_{yt}^{\ 2} = \lambda_0 + \lambda_1 \tfrac{|\varepsilon_{t-1}|}{\sigma_{yt-1}} + \lambda_2 \frac{\varepsilon_{t-1}}{\sigma_{y_{t-1}}} + \lambda_3 \log \sigma^2{}_{y_{t-1}} + \lambda_4 \sigma^2{}_{\pi t} . \qquad [5b]$$

where Y_{g_t} denotes real output growth. Equation [5a] is a baseline conditional variance equation and equation [5b] is the extended conditional variance equation that tests the Taylor-curve principle. In mean equation [4] the sign on the coefficient (κ_3) determines whether inflation uncertainty has a positive or negative effect on output growth rate. A significant negative sign would be consistent with the real effects of inflation uncertainty predicted by Friedman. Finding a significant negative sign implies that higher inflation uncertainty is detrimental to output growth as suggested by Friedman, implying that the central bank's commitment to maintaining price stability is justified.

We model the conditional variance using an Exponential GARCH (EGARCH) specification, which is intended to capture the asymmetric effect of positive and negative shocks on volatility. It has the advantage that non-negativity restrictions on certain coefficients are not required. Moreover, we start modelling from the general form to specific form. [3] We continue to use the conditional variance of the inflation rate from the previous estimation.

We estimate two mean equations with the same variables. We report the results of the variance equation in both cases to show the estimates. However, in the extended version of the variance equation, we include the inflation uncertainty variable to test the Taylor-curve principle. The difference between the baseline and the extended model is that the extended model includes inflation uncertainty as an additional variable.

In the conditional variance equation [5b] the coefficient (λ_4) tests the impact of inflation uncertainty on real output growth uncertainty, which is predicted to be negative by Taylor (1979). According to Fountas, Karanasos and Kim (2002), the Taylor-curve principle implies a trade-off between inflation uncertainty and output

[3] The lags of this equation are selected based on the model having the lowest Akaike Information Criterion (AIC) and Schwarz Criterion (SC) and expected theoretical signs.

growth uncertainty in the long run. In general, the Taylor-curve principle suggests that an elevated level of inflation leads to more inflation uncertainty, finally resulting in lower output uncertainty.[4]

Our distributed lag mean-equation specification allows calculating the quarterly long run effects. Following Edwards (2006), Campa and Goldberg (2002), as well as Gagnon and Ihrig (2004), we derive from equation [4] the quarterly long-run output growth rate and the quarterly long-run effect of inflation uncertainty on output growth as follows.

Table 1 Long-run output growth and the welfare cost of inflation uncertainty

Long-run growth rate	$\frac{\kappa_0}{(1-\kappa_1-\kappa_2)}$ =A
Long-run effect of inflation uncertainty on growth	$\frac{\kappa_3}{(1-\kappa_1-\kappa_2)}$ =B
Percentage of welfare cost of inflation uncertainty on real growth	$\frac{B}{A}$

Furthermore, we modify the preceding equation to include the inflation-targeting dummy and to assess the inflation uncertainty impact on both output growth and output growth uncertainty under inflation targeting.

$$Y_{gt} = \varphi_0 + \varphi_1 Y_{g\,t-1} + \varphi_2 Y_{gt-2} + \varphi_3 D_t + \varphi_4 D_t * \sigma^2{}_{\pi t} + \varepsilon_t \qquad [6]$$

$$\log \sigma_{yt}{}^2 = \phi_0 + \phi_1 \frac{|\varepsilon_{t-1}|}{\sigma_{y_{t-1}}} + \phi_2 \frac{\varepsilon_{t-1}}{\sigma_{y_{t-1}}} + \phi_3 \log \sigma^2{}_{y_{t-1}} \qquad [7a]$$

$$\log \sigma_{yt}{}^2 = \phi_0 + \phi_1 \frac{|\varepsilon_{t-1}|}{\sigma_{y_{t-1}}} + \phi_2 \frac{\varepsilon_{t-1}}{\sigma_{y\,t-1}} + \phi_3 \log \sigma^2{}_{y\,t-1} + \phi_4 D_t + \phi_5 \sigma^2{}_{\pi t} + \phi_6 D_t * \sigma^2{}_{\pi} \qquad [7b]$$

The coefficient (φ_3) in equation [6] measures the impact of the inflation-targeting dummy on mean output growth rate. A positive sign indicates that the inflation-targeting framework increased mean output growth rate by (φ_3). Moreover, the coefficient on the interaction between the inflation-targeting dummy and inflation uncertainty (φ_4) measures the effect of inflation uncertainty under inflation targeting.

[4]Fountas (2010) explains the sequence in Taylor curve principle. The increase in average inflation rate leads to more inflation uncertainty according to Friedman hypothesis. In addition, more inflation uncertainty will be accompanied by less output growth

A negative sign implies that inflation uncertainty under inflation targeting lowers output growth. Similarly, we report mean-equation results together with their EGARCH variance results. However, in the extended conditional variance equation [7b] we assess simultaneously the effect of inflation uncertainty and inflation-targeting effect on the conditional variance of output growth rate. We estimate a conditional variance equation [7a]. This is the simple baseline EGARCH model.

In the extended conditional variance equation [7b] the sign on the coefficient (ϕ_4) determines the impact of inflation targeting on output growth uncertainty. A positive sign implies that the adoption of inflation targeting increased the mean conditional output growth uncertainty. A negative sign implies a decrease in mean conditional output growth uncertainty. Similarly the coefficient (ϕ_5) investigates the Taylor-curve principle, which is expected to be negative. The sign on the coefficient (ϕ_6) assesses the Logue-Sweeney effect. Under inflation targeting the latter coefficient is expected to be positive. This implies that stabilising inflation volatility would stabilise output volatility under inflation targeting. Alternatively, it means that under inflation targeting failure to control inflation uncertainty would lead to more output growth uncertainty.

Again, following Edwards (2006), Campa and Goldberg (2002) as well as Gagnon and Ihrig (2004), we calculate the quarterly long-run real output growth rates and welfare costs of inflation uncertainty from equations [6] and [7] and of the form appearing in Table 2.

Table 2 Long-run output growth and welfare costs of inflation uncertainty under inflation targeting

Long-run growth rate	$\frac{\varphi_0}{(1-\varphi_1-\varphi_2)}$
Long-run growth rate under inflation targeting	$\frac{(\varphi_0+\varphi_3)}{(1-\varphi_1-\varphi_2)}$ =C
Long-run impact of inflation-targeting dummy	$\frac{\varphi_3}{(1-\varphi_1-\varphi_2)}$
Long-run effect of inflation uncertainty on growth	$\frac{\varphi_4}{(1-\varphi_1-\varphi_2)}$ =D

uncertainty according to Taylor (1979).

Percentage of welfare cost of inflation uncertainty on real growth	$\frac{D}{C}$

4 Data and descriptive statistics

This paper uses data from the first quarter of 1960 to the fourth quarter of 2009. The quarterly inflation rate and output growth rate were extracted from the database of the South African Reserve Bank. The descriptive statistics are shown in Table 2. The average real output growth rate over the period under study is 2,77 per cent and the mean inflation rate is 8,61 per cent. Real output growth rate variability of 8,58 per cent is higher than inflation rate variability of 4,95 per cent. The Jarque-Bera test for normality rejects the assumption of normality. The last part of Table 3 shows that there are ARCH effects in both the output growth and inflation series (calculated using the RATS 7.20).

Table 3 Descriptive statistics

	Output growth rate	**Inflation rate**
Mean	2.77	8.61
Median	3.35	8.57
Maximum	21.68	19.37
Minimum	-8.19	0.433
Std. Dev.	8.58	4.954
Skewness	-8.47	0.094
Kurtosis	103	1.857
Jarque-Bera(JB)	85647.2	11.17
Prob(JB)	0.000	0.004
Lags in ARCH LM test		
1	0.1(0.77)	181.2 (0.00)
5	14.3(0.01)	180.7 (0.00)
10	32.0(0.00)	176.5 (0.00)
15	41.5(0.00)	172.1 (0.00)

Nb. P-values are denoted in brackets (). LM refers to Lagrange multiplier.

4.1 Order of integration

We test whether both the gross domestic product (GDP) growth rate and the inflation rate series are stationary or integrated of order one. We consider three different tests: the Phillips-Perron (PP) test, the Kwiatkowski, Phillips, Schmidt and Shin (KPSS) test, and the Augmented Dickey Fuller (ADF) test with a lag length determined by AIC. The PP and ADF tests have non-stationarity as their null hypothesis, whereas the KPSS test uses the null of stationarity. The unit root test results are shown in Table 3.

Table 3 Unit root test statistics for GDP growth rates and inflation rate

Variable	Inflation rate	GDP growth rate
ADF	-1.77	-10.64***
Phillip-Perron	-2.02	-21.36***
KPSS	0.44	0.09

Note: ADF is the Augmented Dickey Fuller test statistic and KPSS is the Kwiatkowski, Phillips, Schimdt and Shin test statistic. A level and intercept including 14 lagged differenced terms are used for the ADF test. KPPS uses Newey-West automatic bandwidth using Bartlett kernel. The PP test uses Bartlett kernel and Newey-West bandwidth. The ADF lag length chosen by Schwarz Bayesian Criterion is 14.

* Signifcant at 10% ** Significant at 5% *** Significant at 1%

The results from the test statistics suggest that real output growth rate is stationary in all cases. The conclusion is less clear cut for the inflation rate with ADF and PP tests suggesting non-stationarity whereas KPSS suggests stationarity.

5 Empirical results

We used quarterly growth rate of real gross domestic product and consumer price inflation data for the sample period 1960q1 to 2009q4. Below we present the results of the mean and variance equations and the associated p-values. We also report the diagnostic tests.

5.1 Results for the impact of inflation uncertainty on inflation

The mean equation takes the form

$$\pi_t = 8.23 + 0.73\pi_{t-1} - 0.34\pi_{t-2} + 0.27\pi_{t-3} - 0.54\pi_{t-4} + 0.34\pi_{t-5} + 0.31\varepsilon_{t-1} + 0.65\varepsilon_{t-2} - 0.3\sigma_{\pi t}^{\ 2} \quad [8]$$

(p=) (0.07) (0.0) (0.0) (0.01) (0.0) (0.0) (0.0) (0.0) (0.048)

In the mean equation [8] we test the impact of inflation uncertainty on the inflation rate to determine whether the results indicate the dominance of the Cuikerman-Meltzer hypothesis or Holland's stabilisation hypothesis. We find a negative and significant contemporaneous effect of inflation uncertainty on inflation. We therefore reject the Cuikerman-Meltzer hypothesis. This negative sign of the in-mean-coefficient is consistent with the Holland's stabilisation hypothesis.

Since we estimate this mean equation together with the variance equation, we report the diagnostics under the variance equation. We apply the Wald test as part of the sensitivity test to make sure that the findings are robust to the lag-length choice, using three different lag lengths 1, 5 and 9. These results are shown in Table 4 and they support the Holland (1995) hypothesis of a stabilising central bank.

Table 4 Sensitivity analysis

Lags	Sum	F-value	P-value
1	(-)	3.92	0.049**
5	(-)	1.93	0.0917*
9	(-)	1.78	0.075*

Note: An (-) indicates that the sum of the lagged coefficients of the causing variable is negative. ** and * denote the significance 0.05 and 0.1 level respectively.

5.2 Results for the impact of inflation on inflation uncertainty

The inflation variance equation is of the form[5]:

$$\sigma^2{}_{\pi t} = 0.488 + 0.107\varepsilon^2{}_{t-1} + 0.513\sigma^2{}_{\pi t-1} + 0.009\pi_{t-1} + 0.134D_t\pi_{t-1} - 0.0818D_t \quad [9]$$

(p=) (0.0048) (0.0823) (0.0003) (0.5553) (0.0000) (0.0000)

Table 5 Diagnostic tests of the inflation mean and variance equations

LB		LB squared		Arch test	
lags	χ^2 p-value	lags	χ^2 p-value	lags	χ^2 value
9	0.105	3	0.148	1	0.372

5 The EGARCH model showed that there was no asymmetry suggesting that simple GARCH model was appropriate hence we chose to use it. The conditional variance from this GARCH equation will be used for further analysis in next sections.

14	0.078	6	0.141	10	0.152

NB. LB stands for Ljung-Box test values

The model satisfies the restrictions that $\beta_0 > 0$, $\beta_1 > 0$, $\beta_2 > 0$; $\beta_1 + \beta_2 < 1$ as shown initially in equation [3]. The model diagnostics shown in Table 5 reveal no remaining autocorrelation in both the mean and the variance equations, and no remaining neglected autoregressive conditional heteroscedastic effects.

We test two hypotheses in equation [9]. Firstly, we test for the effects of inflation on inflation uncertainty. These effects are separated into pre-inflation targeting and post-inflation targeting using the inflation targeting dummy in the variance equation [9]. We investigate evidence for the Friedman hypothesis which suggests that the effect of inflation on inflation uncertainty is positive. However, our specification investigates whether the effects varied between pre- and post-inflation-targeting period. This means that a positive inflation outcome will increase inflation uncertainty. Firstly, we find that the effect of inflation on inflation uncertainty is positive and significant in the post-inflation-targeting period only. This means that an elevated level of inflation will tend to increase the conditional inflation variance under inflation targeting. Secondly, the coefficient in the inflation-targeting dummy is significant and negative. This evidence implies that a significant reduction in the mean of conditional inflation variance in the post-inflation-targeting era relative to the inflation-targeting era. We conclude that the results of the post-inflation-targeting framework support Friedman's claim that a higher inflation rate leads to more uncertainty regarding the inflation rate. The next section focuses on the relationship between inflation uncertainty and output growth uncertainty and output growth.

5.3 The results for the effects of inflation uncertainty on output growth

The results are reported for the mean and conditional variance equations with the inflation uncertainty variable included in both mean equations as shown in Table 6. Furthermore, we assess the effect of inflation uncertainty on the conditional variance of output growth rate.

Table 6 Results from equations 4 and 5

Mean equation	Baseline EGARCH	Extended EGARCH
κ_0	3.08(0.00)***	3.44(0.00)***
κ_1	0.28(0.00)***	0.30(0.00)***
κ_2	0.180(0.01)**	0.13(0.01)***
κ_3	**-0.94(0.00)*** **	**-1.10(0.01)** **
Variance equation		
λ_0	-0.14(0.00)***	0.13(0.00)***
λ_1	-0.23(0.00)***	-0.02(0.00)***
λ_2	0.08(0.05)***	0.06(0.03)*
λ_3	0.99(0.00)***	1.00(0.00)***
λ_4	**-**	**-0.09(0.00)*** **
R^2	0.056	0.038
AIC	5.519	5.483
SC	5.653	5.635
Long run (LR) values		
Long-run output growth (%)	5.79	6.09
Long-run effect of inflation uncertainty	-1.77	-1.95
Welfare cost on output growth in the long run (%)	-30.5	-32.03
Diagnostics		
Q(12)	8.608(0.736)	9.299(0.677)
Q^2(12)	4.029(0.983)	4.874(0.962)
Arch LM(12)	0.346(0.979)	0.473(0.928)

NB LR refers to long run real output growth rate calculated using formulas in table 1. *** , ** and * denote the significance at 0.01; 0.05 and 0.1 levels. Q (k) and Q^2 (k) are Ljung-Box statistics of the levels and the squared residuals, respectively. Arch LM (12) is the test statistics of heteroscedasticty. All figures in parenthesis ( ) are p-values. The above estimations were chosen based on merits using economic significance and lowest AIC and SBC amongst competing models.

The models' diagnostics suggest that there are no remaining autocorrelation and neglected autoregressive conditional heteroscedasticty. Based on the mean equation, we find a highly significant negative effect of inflation uncertainty on output growth, which is consistent with Friedman's argument that increased inflation uncertainty has negative real effects. The finding that increased inflation uncertainty slows down economic growth, gives support to the central bank's goal to achieve price stability. In the variance equation we find evidence that is consistent with the Taylor-curve principle that more inflation uncertainty leads to lower real output growth uncertainty.

5.4 The results for the effect of inflation uncertainty on output growth under inflation targeting

We investigate the null hypothesis that a rise in inflation uncertainty does not affect output growth negatively under inflation targeting. In addition, we investigate the null hypothesis that the adoption of inflation-targeting framework has had a positive effect on real output growth. The results adjusted for the heteroscedasticty effects using the variants of the EGARCH (1,1) model, are reported in Table 7.

All model diagnostics in Table 7 show that these models were estimated satisfactorily with no remaining serial correlation and neglected heteroscedasticity. In all the mean equations the coefficients on the inflation-targeting dummy are positive, implying that the adoption of inflation targeting has significantly increased output growth. The negative coefficients on the interaction between inflation-targeting dummy and inflation uncertainty suggest that higher inflation uncertainty under inflation targeting reduces output growth significantly in the baseline and the extended model equations.

Furthermore, the study estimates the different variance equations using E-GARCH models. The negative coefficient on the inflation-targeting dummy implies that inflation targeting reduced the conditional volatility of output growth. The significant negative inflation uncertainty coefficient indicates that higher inflation uncertainty lowers output variability, indicating existence of the Taylor-curve principle. The coefficient of the interaction between inflation uncertainty and the inflation-targeting dummy is positive. The positive relation between inflation uncertainty and output growth uncertainty, specifically under inflation targeting, is consistent with the claim by Logue and Sweeney (1981) that lower inflation uncertainty leads to lower output growth uncertainty. This result also suggests that, with the implementation of inflation targeting, lower inflation uncertainty is consistent with lower output growth uncertainty. This implies that, with the implementation of inflation targeting, a central bank can achieve the objective of stabilising the volatility of both inflation and output growth.

Table 7 The results from equations 6 and 7a and 7b

	Baseline EGARCH	Extended EGARCH
Mean equation		
φ_0	1.80(0.00)***	1.24(0.00)***
φ_1	0.22(0.00)***	0.26(0.00)***
φ_2	0.15(0.02)**	0.22(0.00)***
φ_3	**2.24(0.00)*** **	**2.20(0.00)** **
φ_4	**-1.39(0.00)**	**-1.13(0.00)** **
Variance equation		
ϕ_0	0.02(0.00)***	0.16(0.00)***
ϕ_1	-0.04(0.00)***	-0.02(0.00)***
ϕ_2	0.09(0.00)***	-0.04(0.02)**
ϕ_3	1.00 (0.00)***	1.02(0.00)***
ϕ_4	**-**	**-0.32(0.00)*** **
ϕ_5	**-**	**-0.14(0.00)*** **
ϕ_6	**-**	**0.28(0.03)** **
R^2	0.08	0.07
AIC	5.45	5.40
SC	5.60	5.60
Long run real output growth rate values		
LR(%) under inflation targeting (IT)	6.73	6.57
LR(%) effect of inflation uncertainty under IT	-2.22	-2.15
LR(%) welfare cost from inflation uncertainty under IT	-33.05	-32.77
LR (%) impact of inflation targeting dummy	3.55	4.23
Diagnostics		
Q(12)	10.38(0.581)	10.7(0.555)
Q^2(12)	7.06(0.853)	6.04(0.914)
Arch LM(12)	0.57(0.862)	0.47(0.932)

NB. LR refers to long run real output growth rate calculated using formulas in table 1 *** , ** and * denote the significance at 0.01 ; 0.05 and 0.1 levels. Q (k) and Q^2 (k) are Ljung-Box statistics of the levels and the squared residuals, respectively. Arch LM (12) is the test statistics of heteroscedasticty. All figures in parenthesis () are p-values. The above estimations were chosen using economic significance and statistical criteria. The mean equation estimated with inflation uncertainty was statistically insignificant and the constant was insignificant and in some cases negative. Due to this, we dropped the inflation uncertainty from the estimation of the mean equation.

This study provides evidence for an indirect channel of welfare cost of inflation operating through inflation uncertainty, which makes us assess the economic welfare costs of inflation associated with higher inflation uncertainty. The results show that the long-run output growth rate (denoted by LR in Table 7) under the inflation-targeting framework ranges between 6,57 and 6,73 per cent under the baseline EGARCH and the extended EGARCH models respectively. In the long run, inflation uncertainty reduces output growth by 2,15 percentage points under the extended EGARCH model and by 2,22 percentage points under baseline EGARCH model. We can infer that inflation uncertainty reduces the real output growth rate as a fraction of long-run value by around 33 per cent in both the extended EGARCH model and the baseline EGARCH model under the inflation-targeting framework. This suggests that higher inflation uncertainty under the inflation-targeting framework has significant detrimental effects on output growth.

The high welfare cost of inflation can be due to higher inflation uncertainty, which makes it harder to determine the relative price levels, implying that it is difficult to allocate resources efficiently on the basis of relative prices. Alternatively, high welfare cost can be linked to the effects of inflation uncertainty on the firms' capital expenditure decisions as suggested by Huizinga (1993). Firms embark on investment projects when the real expected net present value is positive. Inflation uncertainty affects the discount rate used to calculate the net present value and the firms' cost of capital. Increased uncertainty about real future payoffs discourages capital expenditure.

The third channel of indirect welfare cost of inflation is in the context of the option pricing theory. This argues that in the allocation of capital, increased uncertainty leads to a delay in undertaking a project with a positive expected net present value. By contrast, the options of waiting are worth more when there is increased uncertainty.

6 Robustness analysis

6.1 Sensitivity analysis of Friedman hypothesis before and after inflation targeting

This section mainly tests the sensitivity of the findings to changes in the lag length used. We report the sign of the sum of indicated lags, the corresponding F-statistic and the associated p-values from using the mean equation in Table 7 according to the baseline and extended EGARCH models. The third column shows evidence that the negative significant effect at longer lags indicates the robustness of the findings of the Friedman hypothesis of negative real effects of inflation uncertainty. Moreover, in the last column we assess the sensitivity of the finding that inflation uncertainty has a negative effect on output growth under inflation targeting for different lag lengths presented. It is observed that the negative effect of inflation uncertainty on output growth is significant at the 1 per cent level for only lags 1 and 5. This evidence confirms that inflation uncertainty has a negative effect on real output for all lags.

Table 8 **Sensitivity analysis of Friedman hypothesis before and after inflation targeting (IT)**

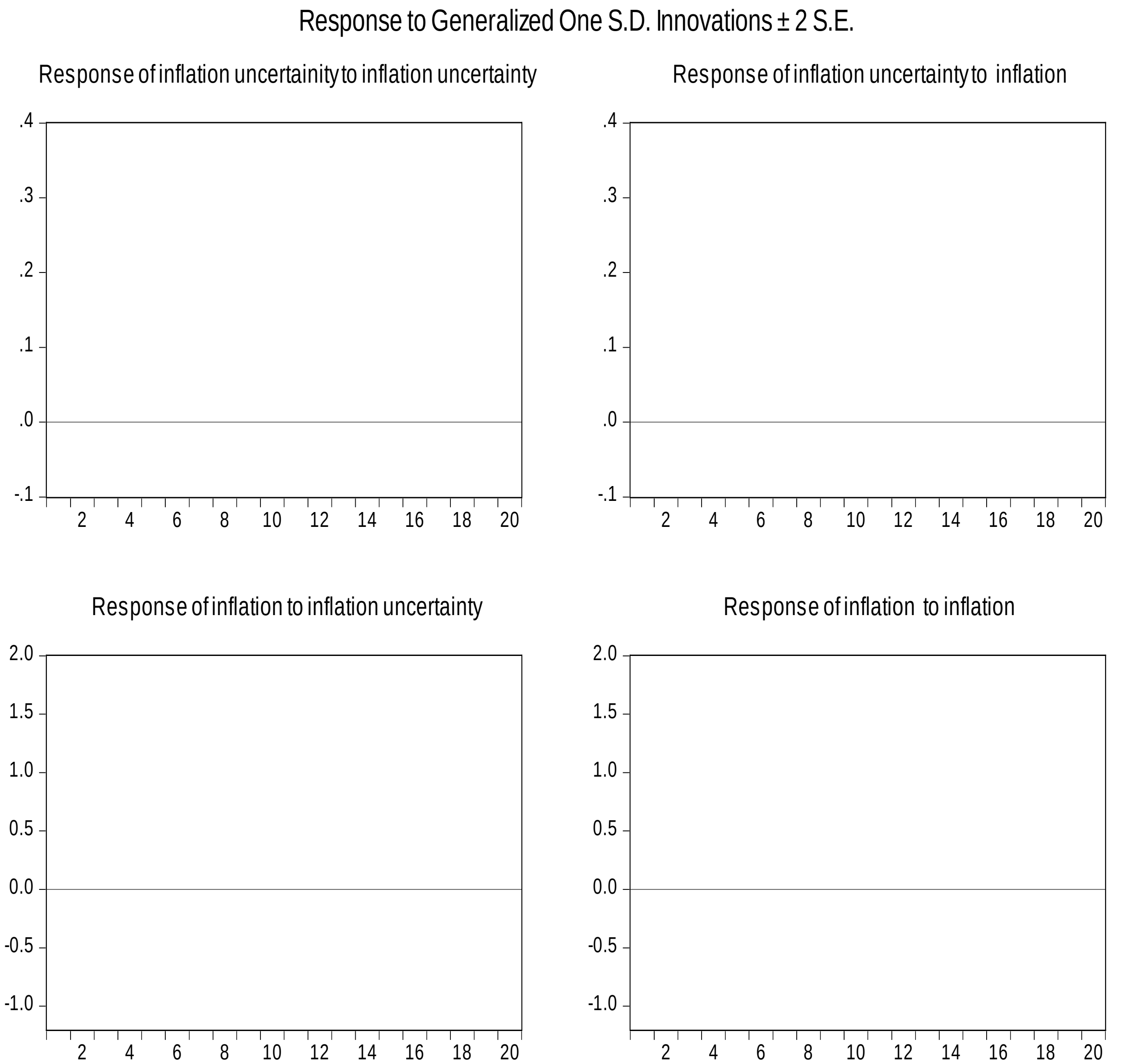
Model	Lags	$\sigma^2{}_{\pi} \rightarrow Y_{gt}$	$\sigma^2{}_{\pi} \rightarrow Y_{gt}$ *under IT*
EGARCH			
	1	7.00 (0.00***) N	9.33(0.000***) N
	5	2.02 (0.07*) N	4.21(0.000***)N
	10	1.89 (0.04**)N	0.167(0.999) N
Extended EGARCH			
	1	5.97 (0.00***)N	3.50(0.032**)N
	5	2.29 (0.04**)N	2.17(0.048**)N
	10	1.89 (0.04**) N	1.37(0.190) N

NB *** , ** and * denote the significance at 0.01 ; 0.05 and 0.1 levels, N represents the sum of all the coefficients of all lags used is negative sign. $\sigma^2{}_{\pi} \rightarrow Y_{gt}$ denotes the effect of inflation uncertainty on output growth in the third column. The last column examines the similar effect under the inflation-targeting framework.

6.2 Alternative VAR approach methodology

The main objective in this section is to test the robustness of the previous findings using a VAR with a generalised impulse response analysis. The results are presented in both Figures 1 and 2. Figure 1 shows the generalised impulse responses of various shocks. The generalised impulse responses suggest that the ordering of variables is less important and cannot influence the results (Pesaran and Shin, 1998). The VAR was estimated using the inflation and inflation uncertainty variables with four lags. We included the inflation-targeting dummy from the first quarter of 2000; a recession dummy from the first quarter of 1991 to the fourth quarter of 1992; a recession dummy between the first and third quarters of 2009; another dummy for the debt standstill between the second quarter of 1985 to the third quarter of 1989 and the Asian-crisis dummy in the third quarter of 1997 to the third quarter of 1998. Firstly, it is seen in the first row of Figure 1 that the inflation uncertainty increases in response to the positive inflation shock. This evidence is consistent with Friedman’s hypothesis of a positive inflation effect on inflation uncertainty. Secondly, it can be seen from the bottom row of Figure 1 that the inflation rate declines in response to a positive inflation uncertainty shocks. We conclude that this significant negative relationship between inflation uncertainty and inflation supports the central bank stabilisation hypothesis as suggested by Holland (1995).

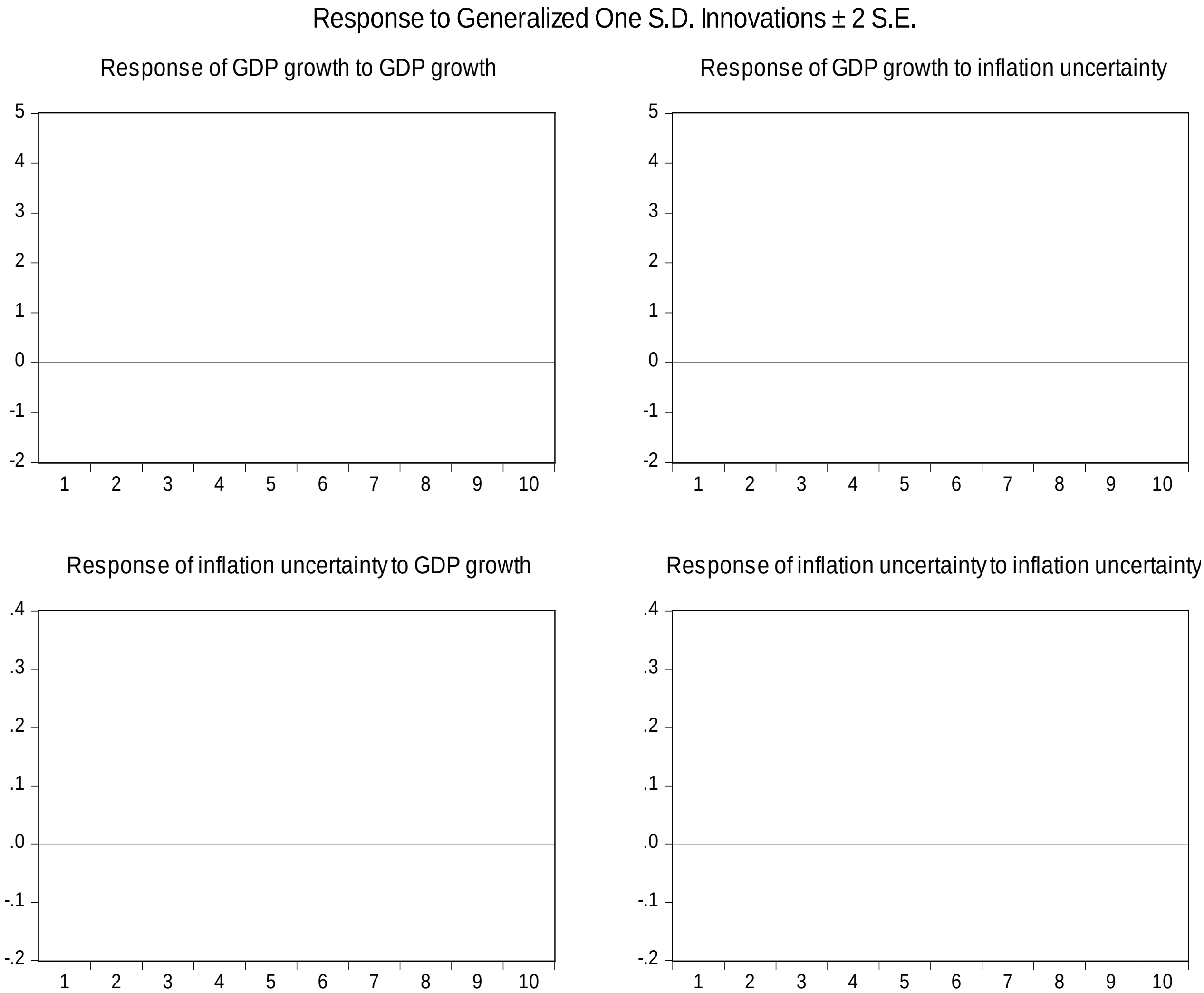
Figure 1 Generalised impulse responses



NB: The horizons are in quarters

Figure 2 shows the generalised impulse responses from a VAR estimated using GDP growth rate and inflation uncertainty using two lags including some dummies. These dummies are the inflation-targeting dummy from the first quarter of 2000, recession dummies in first quarter of 1991 to the fourth quarter of 1992, the debt standstill periods between second quarter of 1985 to third quarter of 1989 and Asian crisis dummy between the third quarter of 1997 to the third quarter of 1998. The main focus is on the relationship between inflation uncertainty and output growth. In the first row of Figure 2, the GDP growth declines in response to inflation uncertainty from the impact and becomes significant between the third and sixth quarters. This finding confirms that high inflation uncertainty has negative real effects on output, which is consistent with Friedman's hypothesis.

Figure 2 Generalised impulse responses: inflation uncertainty and output growth



7 Conclusions

This study finds evidence for the indirect channel of welfare cost in terms of output reduction from the inflation rate operating through inflation uncertainty. We tested the relationship between inflation and inflation uncertainty, as well as the real effects of inflation uncertainty on output growth and output growth uncertainty in South Africa. Firstly, evidence rejects the Cuikerman-Meltzer (1986) hypothesis in favour of the stabilisation hypothesis advanced by Holland (1995) in which monetary authorities prefer to reduce money supply to lower the inflation rate rather than embarking on an overly expansionary monetary policy in favour of output gains. This is confirmed by a significant negative effect of inflation uncertainty on inflation rate. Secondly, the results are consistent with Friedman's approach that a higher inflation rate leads to more uncertainty regarding the inflation rate.

Thirdly, we find that inflation uncertainty is detrimental to output growth. This is consistent with Friedman's arguments related to the negative real effects of inflation uncertainty on output growth. The negative coefficient on the interaction between the inflation-targeting dummy and inflation uncertainty suggests that higher inflation uncertainty under inflation targeting reduces real output growth significantly. In general, we find evidence of significant negative inflation uncertainty coefficient which suggests that higher inflation uncertainty lowers real output variability, which is consistent with the Taylor-curve principle. The significant positive coefficients on the inflation-targeting dummy in the mean equations suggest that the adoption of inflation targeting has significantly increased real output growth.

This study provides evidence for the indirect channel of welfare cost in terms of the output reduction from the inflation rate operating through inflation uncertainty. The specification of the mean equations enables the calculation of both the long-run quarterly output growth rates and the long-run impact of inflation uncertainty. The study finds that the long-run quarterly output growth rates are higher without accounting for the costs of inflation uncertainty and higher inflation uncertainty reduces quarterly real output growth rates. We infer that, in the long run, the welfare cost in terms of output reduction due to higher inflation uncertainty as a fraction of long-run real output growth rate is about 30 to 33 per cent. We are aware of the quantitatively high value of the welfare loss and the uncertainty of such magnitude, as well as a lack of such comparable quantifications in empirical studies. We conclude that there are welfare costs working through the indirect inflation uncertainty channel. In policy terms, this justifies commitment to a monetary policy framework that focuses on price stability, which may be an ideal approach to minimise the high welfare costs of inflation uncertainty.

The study found the Logue-Sweeney effect under inflation targeting because high inflation uncertainty under inflation targeting leads to higher output growth uncertainty. In policy terms, this suggests that policy framework that lowers inflation uncertainty should be able to lower output growth uncertainty. This implies that, with the implementation of inflation targeting, a central bank can achieve the objective of stabilising the volatilities of both inflation and output growth.

On the basis of our results, we conclude that price stability should be a priority for monetary authorities. The second conclusion is that the adoption of an inflation-targeting framework has significantly lowered the variability of both inflation and output growth rates.

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