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Inflation and output growth dynamics in South Africa: Evidence from the Markov switching vector auto-regression model

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Abstract. This paper introduces the possibility of switches in the long run impact of inflation to reinvestigate the output effect of inflation in South Africa in the context of signal extraction theroy. The Markov-switching vector autoregression model is introduced in assessing the asymmetric responses of output growth to shocks to inflation. The results of the empirical analysis show that, consistently with the monetary endogenous growth model, the output effect of inflation is significantly lower in size at higher inflation volatility.

Keywords: C23, E31, O40

JEL classification: Inflation, Economic Growth, Non-Linearity, MSVAR

1. Introduction

This paper assesses the dynamic responses of output growth to shocks to inflation across different regimes in South Africa. The paper contributes to the inflation-output nexus by showing that the extent of the response of output growth to shocks to inflation is regime dependent and contingent to the reaction of monetary policy to inflation shocks. This implies that shocks to inflations impact on economic growth through their effects on interest rates (monetary policy instrument), which effects are regime dependent.

It is often standard to model inflation-output trade-off as a linear relationship with time-invariant Phillips curve slope (See Ball et al., 1988; Dotsey et al., 1999). However, a number of studies have challenged the assumption that inflation-output nexus is well-described by a linear Phillips curve. These studies have suggested an asymmetric output-inflation trade-off. For example, Fillion and Léonard (1997) assess the shape of the Phillips curve in Canada over the period 1968Q4 to 1994Q4. The authors find an asymmetric relationship between the output gap and inflation and argue that this relationship varies due to the changing nature of inflation expectations. Amusa et al. (2013) test the long run super neutrality hypothesis in South Africa using Structural vector autoregressive approach with long run restrictions. The authors find that shocks to inflation have varying effects on output growth, in that they have nominal effect in the short term but exert no effect on the long-run level of output. Moreover, there are studies that have uncovered the link between volatility of inflation, inflation level and output. For example, Narayan and Narayan (2013) focus on the inflation-output nexus in three emerging economies including South Africa. Their empirical results, based on an augmented version of the generalized autoregressive conditional heteroskedasticity model, indicate that for a longer sample period (1960–2006), inflation volatility raises the level of inflation, while for a shorter sample period (1991-2006), inflation volatility reduces the level of inflation. Consistently in both sample horizons, the authors find that inflation volatility reduces output growth, albeit with higher magnitude in periods of higher inflation.

Ghosh and Phillips (1998), Harris at al. (2001) and Burdekin et al. (2004) support the relevance of the level effect in explaining the asymmetric effect between inflation and output growth. The authors show that the marginal growth effect of inflation is stronger at lower level of inflation rates than at higher ones. Lopez-Villevicencio and Mignon (2011) emphasize the existence of a threshold beyond which inflation exerts a negative impact on growth, and below which inflation might be growth enhancing, particularly in modernized economies. Naraidoo and Raputsoane

(2011) show how the asymmetric responses of monetary authorities to shocks to output gap affect the relationship between inflation and output. The authors show that the monetary authorities' responses to output fluctuations are asymmetric in South Africa. That is, they react more aggressively to negative deviation of output gap and such a reaction impact on inflation-output trade-off.

The literature describes five different approaches or models that may give rise to an asymmetric relationship between inflation and output (Dupasquier and Ricketts, 1998); the first model, known as *the capacity constraint* model, assumes that some firms find it difficult to adjust their capacity to produce in the short term. Thus, any increase in aggregate demand leads to greater inflation due to mismatch between supply and demand. This model is consistent with the finding of Phillips (1958) that the relationship between inflation and output is non-linear, in that, excess demand would increase inflation more than excess supply would reduce it. The second model, dubbed the *misperception or signal extraction model*, postulates that the relationship between inflation and output arises because firms are unable to distinguish between aggregate and relative price shocks, given that these shocks are not directly observable. Lucas (1973), the pioneer of this model, show that the relationship between inflation and output depends on the amount of noise in price signal. The author shows that if aggregate prices are extremely volatile, then output will respond less to aggregate demand shocks and inflation than when the aggregate price volatility is low. In emphasizing the role of volatility and policy responses, Brainard (1967) indicates that the extent of uncertainty or volatility influences the response to policy actions, thus alter the impact and effectiveness of a given policy. The third model, *the costly adjustment model*, assumes that the relationship between inflation and output varies with the level of inflation. This model is pioneered by Ball, Mankiw and Romer (1988) who show that under the assumption of menu costs, not all firms will change their prices in response to the demand shocks, thus, the authors postulate that as the level of inflation rises, aggregate demand shocks will have less effect on output and more effect on price level. The fourth model, *the downward nominal wage rigidity model*, postulates that workers are more reluctant to accept a decrease in their nominal wages than a decrease in their real wages due mainly to money illusion. As the rigidity applies only to downward wage adjustment, then when inflation rates are low excess supply might have less effect than excess demand, triggering asymmetry with respect to the output gap. A final model, known as *the monopolistically competitive model*, posits that producers might be inclined to lower price quickly during low inflation regimes. Nonetheless, they may be reluctant to raise price during high inflation regimes in order to crowd out potential new competitors. This producer behavior give rise to the asymmetric relationship between inflation and output.

Out of the five approaches that explain the asymmetric effect of inflation on output, this paper focuses on 'the misperception or signal extraction' model. Thus, the focus on the paper will be on assessing the extent to which the relationship between inflation and output growth varies with the magnitude of volatility of inflation in South Africa. In attempting to establish a link between inflation volatility, inflation level and output growth, as predicted by the signal extraction model, the paper identities two inflation volatility regimes, low and high inflation volatility regimes, and determines how the responses of output growth to shocks to inflation vary in accordance to the magnitude of inflation volatility. The paper contributes to the literature of inflation-output growth nexus by explaining the link between inflation volatility, monetary policy and inflation-output growth interconnection in the context of the Markov Switching Vector Autoregressive (MSVAR) model. The paper makes use of the Markov Switching Vector Autoregressive (MSVAR) model in which parameters change according to the phases of inflation volatility regimes. To the best of our knowledge, this paper is the first to assess the inflation-output nexus in the context of signal extraction model by using a MSVAR model. While there are very few studies that assess the asymmetric relationship between output growth and inflation in south Africa (Nell, 2006 and Burger and Manrikov, 2006; Naraidoo and Raputsoane, 2011)[1], there is no study that has ever incorporated regime switching model in the context of signal extraction and uncertainty while assessing the asymmetric relationship between output and inflation in South Africa. The rest of the paper is structured as follows. Section 2 presents the MSVAR methodology, section 3 present the data and discusses the empirical results and section 4 concludes the paper.

[1] The studies have focused on Phillips curve models in assessing the relationship between inflation and output in South Africa.

2. Markov Switching Vector Autoregressive Model

As described in Simo-Kengne et al. (2013), the MSVAR initially appeared in the form of switching regressions in Golfeld and Quandt (1973), and underwent a number of extensions and refinements. Hamilton (1989) and Krolzig (1998) made important contributions by combining switching models with vector autoregression to develop a MSVAR which is well equipped to characterise macroeconomic fluctuations in the presence of structural breaks or shifts, such as the changing volatility as in the context of this paper.

In this paper we make use of the MSVAR model where n endogenous variables Y_t are explained by intercepts α_i and autoregressive terms of order p and a residual $\lambda_i \mu_i$ that varies according to regimes. The advantage of imposing a regime-dependent residual resides in obtaining impulse response functions of shocks that are regime dependent. Thus, we use a MSVAR model with two regimes ($S_t = 1, 2$) specified as follows:

$$\alpha_1 + \beta_{11} Y_{t-1} + \ldots + \beta_{p1} Y_{t-p} + \lambda_1 \mu_t \qquad \text{if } S_t = 1 \qquad (1)$$

$$\alpha_2 + \beta_{12} Y_{t-1} + \ldots + \beta_{p2} Y_{t-p} + \lambda_2 \mu_t \qquad \text{if } S_t = 2 \qquad (2)$$

and $\mu_t \sim N(0; I_n)$

μ_t is a n-dimensional vector that is normally distributed with zero mean and the variance normalised to unity. As said earlier, the vector μ_t is pre-multiplied by a regime-dependent matrix λ_i to allow its variation according to different regimes. Thus, the variance-covariance matrix Σ_i of the residual $\lambda_i \mu_i$ will also vary accordingly as:

$$\Sigma_i = E(\lambda_i \mu_t \mu_t' \lambda_i') = \lambda_i E(\mu_t \mu_t') \lambda_i' = \lambda_i I_n \lambda_i' = \lambda_i \lambda'_i \qquad (3)$$

Given that the regimes S_t are assumed to follow a hidden m-state Markov-chain (2-state regime in our case), Ehrmann et al. (2003) show that the recursive nature of the likelihood function prevents standard estimation techniques from providing the maximised likelihood. One alternative suggested by Krolzig (1997) is the iterative maximum likelihood estimation technique known as *Expectation-Maximisation* (EM) algorithm which is designed for a general class of models where the observed time series depends on some hidden stochastic variables. This estimation technique consists of two steps, the *expectation* and *maximisation* steps. The *Expectation* step infers the hidden Markov chain conditioned on a given set of parameters and the

Maximisation step re-estimates the parameters based on the inferred unobserved Markov process. These steps are repeated until convergence.

As said earlier, one major attraction of the MSVAR is the possibility of regime-dependent Impulse Response Functions (IRFs), which helps determine the responses of variables to regime-dependent shocks. Equation (3) represents the mathematical definition of the regime-dependent IRFs for regime *i*. It traces the expected path of the endogenous variables at time *t+h* following a one standard deviation shock to the *n*-th initial disturbance at time *t*, conditional on regime *i* (Ehrmann et al., 2003).

$$\frac{\partial E_t Y_{t+h}}{\partial \mu_{n,t}} / S_t = \theta_{ni,h} \qquad (3)$$

Where $\theta_{ni,h}$ is the vector of the responses of the endogenous variables to a specific shock conditional on regime i.

It is important to note that EM algorithm only provides estimates of the variance-covariance matrix $\sum_{\mathrm{i}}$ and not the matrices λ_i. The latter is identified by imposing restrictions on the parameters estimates obtained from the reduced-form model. Thus, for the sake of this paper we apply Choleski factorisation and decomposition to identify λ_i.

3. Data, results and discussion of results

3.1. Data

The data sample is from 1969:01 until 2013:04 and covers the quarterly output growth, obtained as the first difference of the logarithm of gross domestic product, the three-month seasonally adjusted Treasury bill rate data and the inflation rate, obtained as the first difference of the logarithm of consumer price index (CPI) all items. The data are obtained from I-Net Bridge database. The data sample is chosen to include periods of different monetary policy regimes in South Africa, such as the "direct control regime" in 1970 and the 'inflation targeting framework" adopted in February 2000.

3.2 Results and Discussion

The stable MS-VAR is estimated based on two lags, as was consistently suggested by the popular lag-length tests: the Akaike information criterion and the Schwarz information criterion, applied to a constant parameter VAR. Table 1 reports the results of the stability test of the three-variable VAR (2) process used in this paper. The results show that the root and the modulus (the absolute value of the root) of the VAR process's characteristic equation are less than unity. This confirms the stability of the VAR process and thus, the reliability of the impulse response function results that are obtained from this process.

Table 1 VAR stability test

Root	Modulus
0.994851	0.994851
0.926497	0.926497
0.462387	0.462387
0.377401	0.377401
-0.325561	0.325561
-0.004645	0.004645

Note: given two lags in a three-variable VAR, a total of six roots is estimated.

Moreover to assess the possibility of regime changing in the relationship between inflation, interest rate and economic growth in South Africa, this paper performs the multiple breakpoints test suggested by Bai and Perron (1998, 2003). The results of this test suggest the possibility of five estimated break dates, namely, 1980Q3, 1987Q1, 1993Q3, 2000Q1 and 2007Q4. The 1980Q43 break date corresponds to the time when monetary policy has shifted from the direct control system to an increasingly market-related monetary policy system. The 1987Q1 corresponds with the adoption of the De Kock commission recommendations urging the South African Reserve Bank (SARB) to implement specific target in the growth of monetary aggreagate or the monetary targeting framework. The 2000Q1 corresponds with the adoption of inflation targeting monetary policy regime in South Africa, while the 2007Q4 break date is linked to the reaction of the SARB to the 2007 global financial crisis.

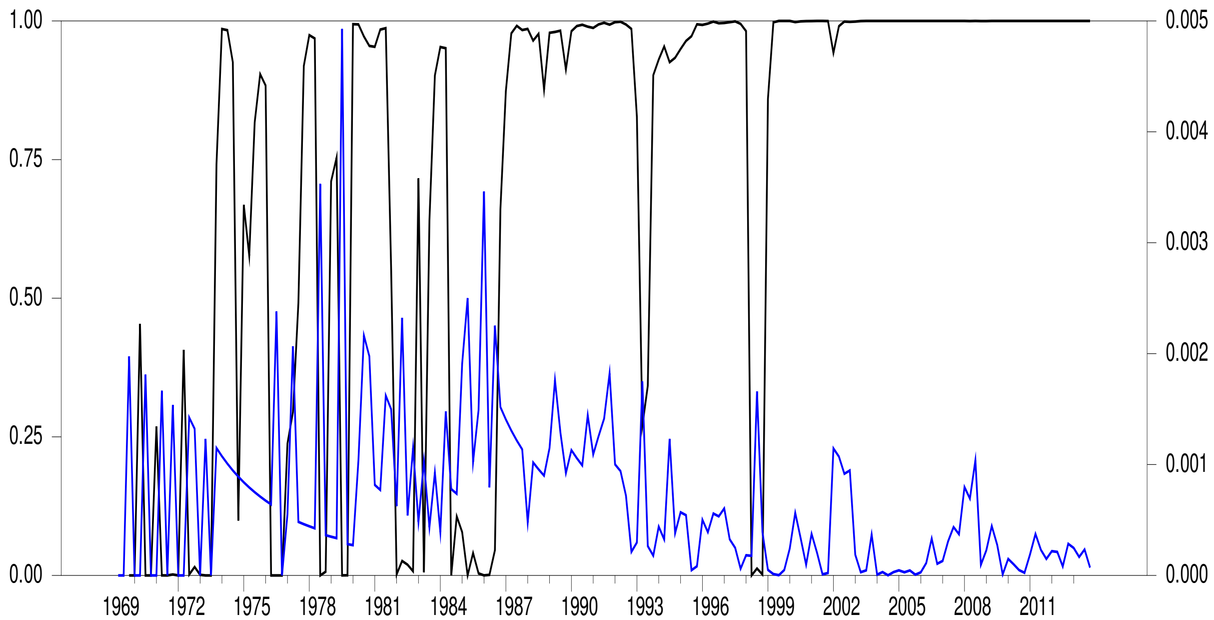
Table 2 provides the estimation of the probability of transition between the two possible regimes identified as low and high inflation volatility regimes . The results reported in Table 2 show that the regimes are persistent, with the probability of transition between regime 1, $P(1,1)$, being 0.97 and the probability of transition between regime 2, $P(2,2)$, standing at 0.93. The probability of transition between regime 1 to regime 2, $P(2,1)$ is 0.03. The results point to regime persistence in that the probability of remaining in the same regime is higher than the possibility of changing regimes.

Table 2. Probabilities of transition between regimes

Transition Probabities	Probability value
P(1,1)	0.97
P(2,1)	0.03
P(2,2)	0.94
P(1,2)	0.06

Given that these two regimes are hidden, this paper identifies the two regimes as the high and low inflation volatility regimes, as stated earlier. This is proven with the display in Figure 1 when overlaying the forecast of the smooth probability of regime 1 and the inflation volatility series in Figure 1. It is clear from the display in Figure 1 that regime 1 corresponds to low inflation volatility regime and consequently regime 2 should correspond to high inflation volatility regime in South Africa.

Figure 1: Smooth Probabilities of regime 1 and volatility of inflation in South Africa

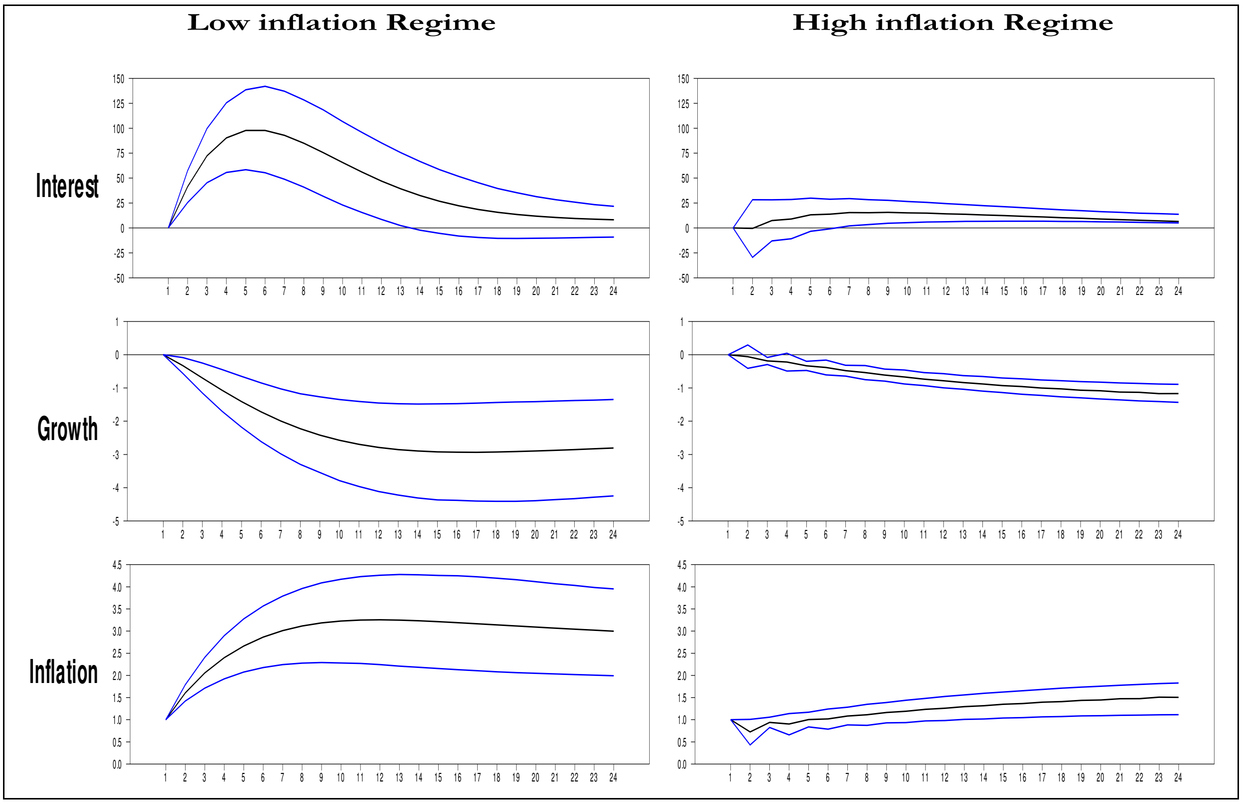


Note: on the left axis, the dark line is the smoth probability of low regime probability. On the right axis, the blue line displays the inflation variability or volatility.

It is clear from Figure 1 that South Africa experienced low inflation volatility periods in the late 1980s with the magnitude of the decrease in inflation volatility accelerating during the inflation targeting (IT) period. This finding is supported by a number of studies (see Bonga-Bonga and Lebese, 2016). However, high inflation volatility is the most prevailing regime over the pre-IT periods. Particularly, episodes from 1969 to 1987 appear to be the most unstable with the highest inflation volatility recorded in the second half of 1970s. This period coincides with the 1976 Soweto student uprising which had an adverse effect on expectations and economic performance. Following the increasing political pressure and the decrease in gold price, the resulting increase in interest rate translated into increasing inflation volatility observed between 1984 and 1986 in South Africa. The trend slowed down in 1990s with the advent of democracy, however, the contagion effect from the Asian crisis in 1996-1997 led to the depreciation of the rand with significant rise in interest rates (Simo-Kengne et al., 2013); and hence the resurgence of high inflation volatility towards the end of 1990s. On the other hand, with the introduction of IT policy in 2000, inflation volatility has been relatively low, except during the Latin America currency crisis in 2002 and the 2007-2008 global financial crisis, well identified in Figure 1.

The results of the impulse response functions obtained from the estimation of our MSVAR model are displayed in Figure 2. Figure 2 exhibits the IRFs with the 95% confidence interval for the responses of GDP growth (growth), interest rate (interest) and inflation resulting from a one-standard deviation shock to the inflation over a period of twenty four quarters. It is worth noting that the identification of MSVAR model is obtained from the Choleski decomposition where inflation is ordered the last to allow its exogenous effects on GDP growth and interest rates. The results displayed in Figure 2 show that shocks to inflation leads to a decrease in output growth in the two regimes. However, the magnitude of the decrease in output is higher in low inflation regime compared to high inflation regime. This outcome is in line with the signal extraction model that states that output reponds less to aggregate demand shocks when prices are extremely volatile (Lucas, 1973). As indicated in Figure 2, this outcome should be explained through the asymmetric reaction of the monetary authority to shocks to inflation. Monetary authority reacts to shocks to inflation by increasing the interest rate with higher magnitude during low inflation regimes. This aggressive reaction of the monetary authority results in a high decrease in output growth as displayed in Figure 2. However, during high inflation regime, the reaction of the monetary authority in increasing the interest rate, as a result to shocks to inflation, is quite moderate. Consequently, the decrease in output that ensues from such a benign monetary policy reaction is also moderate

Figure 2: Regime dependent IRFs to inflation shocks



Note: the blue line represents the 95% confidence interval

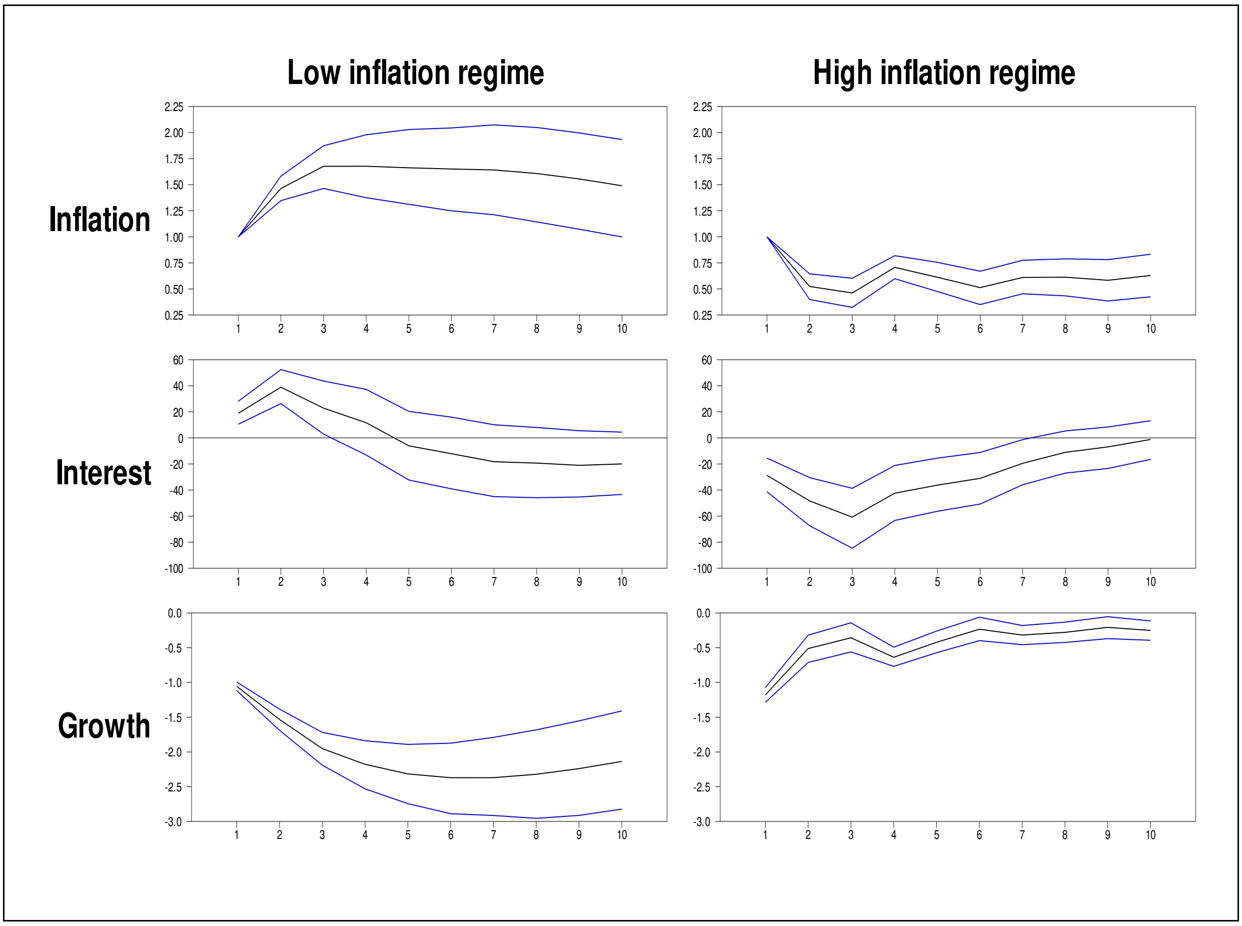
Contrary to past studies (Amusa et al., 2013; Burdekin et al., 2004), this paper shows that the reaction of output growth to shocks to inflation is asymmetric and concomitant to the reaction of monetary authority to inflation shocks. Regarding monetary policy reaction, the outcome displayed in Figure 2 is in line with Brainard's (1967) attenuation principle, supported by Wielard (2000) and Orphanides et al. (2000). The attenuation principle postulates that uncertainty dampens the monetary authorities' response to target variables of monetary policy relative to the situation when monetary policy decisions are made under certainty. Figure 2 supports the attenuation principle in South Africa by showing that monetary authorities in the country reacted to inflation shocks during high inflation regime (high uncertainty) with a moderate increase in interest rate. Thus, the moderate increase in interest rate during the high inflation regime led to the mild decrease in output growth.

Another possible reason for the moderate increase in interest rate during the high inflation regime could be attributed to the inability of the monetary authority to distinguish between the different noises to prices. As the economy is in high inflation regime, any additional shock to inflation may not affect the monetary policy reaction function. However, during low inflation regime, shocks to inflation affect discernibly the monetary policy reaction function.

3.3. Robustness test

To assess the robustness of the results, the order of the variables in the VAR specification are changed for the contemporaneous identification of shocks. The paper allows a contemporaneous erogeneity of output growth in the three-variable VAR. The results reported in Figure 3 are not different to the ones in Figure 2. During low inflation regimes, the magnitude of the decrease in output growth from positive shocks to inflation is higher than during the high inflation regime.

Figure 3 Regime dependent IRFs to inflation shocks with different ordering of variables



4. Conclusion

This paper investigates asymmetric effect of output growth to shocks to inflation in the light of the signal extraction model. Making use of the MSVAR model, the empirical results show that the extent of the response of output growth to shocks to inflation is regime dependent and contingent to the reaction of monetary policy to inflation shocks. This implies that shocks to inflations impact on economic growth through their effects on interest rates (monetary policy instrument), which effects are regime dependent. During high inflation regime, monetary policy reacts to inflation shocks by increasing moderately the level interest rate, consequently output growth decreases moderately compared to the low inflation regime. Contrary to past studies, this paper shows the importance of monetary policy and inflation volatility regimes in understanding the output-inflation nexus.

References

Amusa, K., Gupta, R., Karolia, S. and Simo-Kengne, B.D. (2013). The long-run impact of inflation in South Africa. *Journal of Policy Modeling*, 35: 798-812.

Bai J., Perron P. (1998), Estimating and Testing Linear Models With Multiple Structural Changes, Econometrica, 66, 47-78.

Bai J., Perron P. (2003), Computation and Analysis of Multiple Structural Change Models, Journal of Applied Econometrics, 18, 1-22.

Ball, Laurence, N. Gregory Mankiw, and David Romer. (1988) "The New Keynesian Economics and the Output–Inflation Trade-Off." *Brookings Papers on Economic Activity,* 1, 1–82.

Brainard (1967), "Uncertainty and the effectiveness of policy", American Economic Review Papers and Proceedings, Vol.57, pp. 411-425.

Burdekin, R., Denzau, A., Keil, M., Sitthiyot, T., Willett, T. (2004). When does inflation hurt economic growth? Different nonlinearities for different economies. *Journal of Macroeconomics,* 26: 519–532.

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

Dotsey, Michael, Robert G. King, and Alexander L. Wolman. (1999) "State-Dependent Pricing and the General Equilibrium Dynamics of Money and Output." *Quarterly Journal of Economics,* 114, 655–90.

Dupasquier, Chantal and Nicholas Ricketts (1998), "Nonlinearities in the Output-inflation relationship: Some empirical results for Canada", Bank of Canada working paper 98-14.

Ehrmann, M., Ellison, M. and Valla, N. (2003). Regime-dependent impulse response functions in a Markov-switching vector autoregression model. *Economics Letters*, 78:295-299.

Fillion, J.F. and Léonard, A. (1997), "La courbe de Phillips au Cananda: un examen de quelques hypotheses", Bank of Cananda working paper no. 97-3.

Ghosh, A., Phillips, S. (1998). Warning: inflation may be harmful to your growth. IMF Staff Papers 45, 672–710.

Golfeld, S.M. and Quandt, R.E. (1973). A Markov model for switching regressions. *Journal of Econometrics*, 1:3-16.

Hamilton, J. D. (1989). "A New Approach to the Economic Analysis of Nonstationary Time Series and the Business Cycle," *Econometrica*, 57, 357–384.

Harris, M., Gillman, M., Mátyás, L. (2001). The negative inflation-growth effect: theory and evidence. Melbourne Institute Working Paper Series, 12.

Krolzig, H.M. (1997). Markov switching vector autoregressions: modelling, statistical inference and application to business cycle analysis. Lecture Notes in Economics and Mathematical Systems. No. 454, Berlin: Springer-Verlag.

Krolzig, H.M. (1998). Econometric modelling of Markov-Switching vector autoregressions using MSVAR for OX, Department of Economics, University of Oxford.

Lopez-Villavicencio, A. and Mignon, V. (2011). On the impact of inflation on output growth: Does the level of inflation matters? *Journal of Macroeconomics*, 33: 455-464.

Lucas, R. (1973), " Some international evidence on output-inflation trade-offs", *American Economic Review, vol. 63, No. 3, pp.326-334.*

Naraidoo, Ruthira & Raputsoane, Leroi, 2011. "Optimal monetary policy reaction function in a model with target zones and asymmetric preferences for South Africa,"Economic Modelling, Elsevier, vol. 28(1-2), pages 251-258.

Narayan, S. and Narayan, P.K. (2013). The inflation-output nexus: Empirical evidence from India, South Africa and Brazil. *Research in International Business and Finance*, 28: 19-34.

Nell, k. (2006). Structural change and nonlinearity in a Phillips curve model for South Africa. Contemporary Economic Policy, 24(4): 600-617.

Orphanides, A., and David W. Wilcox (2002). The opportunistic approach to disinflation. *International Finance* 5: 47-71.

Phillips, A.W.(1958), " the relationship between Unemployment and the rate of change in money wages in the United Kingdom, 1861-1957", *Economica, Vol.25, pp.283-299.*

Simo-Kengne, B.D., Balcilar, M., Gupta, R., Aye, G.C. and Reid, M. (2013). Is the relationship between monetary policy and house prices asymmetric across bull and bear markets in South Africa? Evidence from a Markov-Switching Vector Autoregressive model. *Economic Modelling,* 32(1):161-171.

Wieland, Voler (2000). Monetary policy, parameter uncertainty, and optimal learning. *Journal of Monetary Economics* 46: 199-228.