DEAKIN UNIVERSITY AUSTRALIA

Faculty of Business and Law

School of Accounting, Economics and Finance

School Working Paper

Financial Econometrics Series

SWP 2011/06

The Inflation-Output Nexus: Empirical Evidence from India, Brazil, and South Africa

P.K. Narayan and S. Narayan

www.deakin.edu.au

The difference is **Deakin University.**

The Inflation-Output Nexus: Empirical Evidence from India, Brazil and South Africa

Paresh Kumar Narayan and Seema Narayan

CORRESPONDING AUTHOR

Professor Paresh Kumar Narayan
School of Accounting, Economics and Finance
Faculty of Business and Law
Deakin University,
221 Burwood Highway,
Burwood, Victoria 3125
Australia.
Telephone: +61 3 924 46180
Fax: +61 3 924 46034
Email: paresh.narayan@deakin.edu.au

The Inflation-Output Nexus: Empirical Evidence from India, Brazil and South Africa

ABSTRACT

In this paper we study the relationship between output and inflation for India, Brazil, and South Africa using the EGARCH model. For India and South Africa, we find evidence for: (1) the Cukierman and Meltzer hypothesis that inflation volatility raises inflation; (2) the Friedman hypothesis that inflation raises inflation volatility; and (3) the Black hypothesis that output volatility raises output growth, and that output volatility reduces inflation. For Brazil, we do not find any evidence of a systematic relationship between inflation and output growth.

Keywords: Output; Inflation; EGARCH Model; Volatility.

JEL Classification: C22; E31; E32.

1. Introduction

There is now a large body of both theoretical and empirical research on the relationship between inflation uncertainty and real economic activity. The consensus from this literature is that there is no clear-cut evidence on the relationship between inflation uncertainty and real economic activity. While one group of studies (Mullineaux, 1980; Hafer, 1986; Darrat and Lopez, 1989; Davis and Kanago, 1986; Al-Marhubi, 1998; Wilson and Culver, 1999; Grier and Perry, 2000; Hayford, 2000; Fountas *et al*., 2002; Grier *et al*., 2004, and Apergis, 2004) has discovered a negative relationship between output growth and inflation uncertainty, the other group of studies (Katsimbris, 1985; Thornton, 1988; Jansen, 1989; Levine and Renelt, 1992; Levin and Zervos, 1993; Bohara and Sauer, 1994; Clark, 1997) has not found a statistically significant relationship between inflation uncertainty and output growth.

Recently, some studies (see, for instance, Wilson, 2006; Grier and Perry, 2000; Grier *et al*. 2004) have attempted to model the relationship between inflation uncertainty and economic growth using generalised autoregressive conditional heteroskedasticity (GARCH) models or some augmented version of the GARCH model, such as the exponential GARCH (EGARCH) model. The goal of this paper is to add to this small group of studies that use the family of GARCH models to examine the relationship between inflation and economic growth. Our study is novel because, for the first time, we consider the relationship between inflation and economic growth for three large developing and emerging countries, namely India, Brazil, and South Africa. Of these countries, over the 2003-2005 period, India's economic growth has been around 8 per cent, the Brazilian economy has grown at around 2.6 per cent per annum, while South Africa's economic growth has been around 4.1 per cent per annum. Moreover, in 2005

India's GDP constituted around 6 per cent of world GDP, Brazil's GDP constituted around 2.6 per cent, and South Africa's GDP constituted around 1 per cent.

We organise the rest of the paper is organised as follows. In the next section, we discuss the theoretical motivation for the empirical analysis. In sum, theory permits us to test six hypotheses: (1) that higher inflation volatility increases mean inflation (Cukierman and Meltzer, 1986); (2) that higher output volatility increases mean inflation (Deveraux, 1989); (3) that higher mean inflation increases inflation volatility (Friedman, 1977); (4) that higher inflation volatility reduces economic growth rate (Friedman, 1977); (5) that higher output volatility increases economic growth rate (Black, 1987); and (6) that an increase in inflation volatility reduces inflation (Holland, 1996). In section 3, we discuss the estimable model. Our modelling framework is motivated by the work of Nelson (1991) and is based on the EGARCH model, augmented to allow a test for the six hypotheses highlighted above. In section 4, we discuss the results. Briefly foreshadowing our main results, for India and South Africa, we find evidence of: (1) the Cukierman and Meltzer hypothesis that inflation volatility raises inflation; (2) the Friedman hypothesis that inflation raises inflation volatility; and (3) the Black hypothesis that output volatility raises output growth, and that output volatility reduces inflation. For Brazil, we do not find any evidence of a systematic relationship between inflation and output growth. In the final section, we provide some concluding remarks.

2. Theoretical Motivation

Cukierman and Meltzer (1986) argue that the government may prefer a higher level of ambiguity simply because a greater degree of ambiguity provides the policy maker with greater control of the timing of monetary surprise. "When there is ambiguity about policy, he [the policy maker] can create large positive surprises when he cares most about stimulation and leaves the inevitable negative surprises for periods in which he is relatively more concerned about inflation" (Cukierman and Meltzer, 1986: 1122).

They further show that policy makers with relatively unstable objectives are more ambiguous and less credible. Imperfect credibility, which arises from policymaker's changing objectives and noisy control of monetary policy, gives policymaker's an advantage over the public. While the policymaker knows his objectives and the public does not, the public is always guessing, and thus is forming expectations of policymaker's behaviour. They argue that since the mean and variance of monetary growth rate is positively related to the level of noise in monetary control, it implies the existence of a positive cross-sectional relationship between mean and the variance of inflation. Their framework shows that an increase in inflation uncertainty (noise or surprise) leads to higher mean inflation. This is because, in their model, the rate of money growth is positively related to the marginal benefit of surprise creation by government. An opposing view, however, is provided by Holland (1995), who argues that increased inflation uncertainty lowers average inflation. He argues that higher inflation volatility is regarded costly by policymakers, inducing them to reduce inflation in future.

The theme of Friedman's (1977) Nobel lecture was the existence of a positive correlation between inflation and unemployment, and he argues that high inflation leads to more inflation volatility. He contends that inflation is not deliberate; rather, it is a function of policies, such as full employment and welfare-state policies. Friedman (1977: 466) puts it that "a burst of inflation produces strong pressure to counter it. Policy goes from one direction to another, encouraging wide variation in actual and anticipated rate of inflation. ... in such an environment no one has single valued anticipations. Everyone recognises that there is greater uncertainty about what actual inflation will turn out to be ...".

Friedman (1977) also establishes the link between greater inflation uncertainty and real activity. He explains that inflation uncertainty may: (1) raise the natural rate of unemployment; and (2) render market prices a less efficient system for coordinating economic activity. Thus, inflation volatility reduces economic efficiency.

Deveraux (1989) formalises the link between an increase in volatility of real variables and inflation in a "positive" theory of monetary policy framework. He shows that volatility of real variables lowers optimal amount of wage indexation. His main results are that there is a positive relationship between the mean rate of inflation and the magnitude of real disturbances in the economy and between mean inflation and output volatility. In formalising these outcomes, he argues that the lower the degree of wage indexation the greater is the incentive for surprise inflation. This leads to higher mean rate of inflation. Given that wage indexation is negatively related to the variance of real disturbances, mean inflation rate will be positively related to output volatility.

Finally, Black (1987) considers the nexus between output volatility and average growth rate. The main focus of his work is based on the relationship between risk and return. Using the concepts of risk and return, he argues that when an economy invests in risky specialised technology, the outcome is likely to be higher economic growth.

3. Modelling Framework

To examine the various hypotheses identified in section 2, we use the EGARCH model proposed by Nelson (1991). We assume a conditional t-distribution and specify an $\mathrm{ARMA}(p,q)-\mathrm{EGARCH}-\mathrm{M}(1,1)$ model. The model has the following mean, variance and covariance specifications:

$$\pi_t = \alpha_0 + \sum_{i=1}^{p} \delta_i \pi_{t-i} + \varepsilon_t + \sum_{j=1}^{q} \vartheta \varepsilon_{t-j} + \alpha_1 \sigma_{t,Y}^2 + \alpha_2 \sigma_{t,\pi}^2 + \alpha_3 Y_t \qquad (1)$$

$$\log\left(\sigma_{t,\pi}^2\right) = \alpha_4 + \alpha_5 \left(\left| \frac{\varepsilon_{t-1}}{\sigma_{t-1}} \right| - \sqrt{\frac{2}{\delta}} \right) + \alpha_6 \frac{\varepsilon_{t-1}}{\sigma_{t-1}} + \alpha_7 \log\left(\sigma_{t-1}^2\right) + \alpha_8 \pi_t + \alpha_9 \sigma_{t,Y}^2 + \alpha_{10} Y_t \qquad (2)$$

$$Y_t = \beta_0 + \sum_{i=1}^{p} \kappa_i Y_{t-i} + \mu_t + \sum_{j=1}^{q} \xi \varepsilon_{t-j} + \beta_1 \sigma_{t,Y}^2 + \beta_2 \sigma_{t,\pi}^2 + \beta_3 \pi_t \qquad (3)$$

$$\log\left(\sigma_{t,Y}^2\right) = \beta_4 + \beta_5 \left(\left| \frac{\varepsilon_{t-1}}{\sigma_{t-1}} \right| - \sqrt{\frac{2}{\delta}} \right) + \beta_6 \frac{\varepsilon_{t-1}}{\sigma_{t-1}} + \beta_7 \log\left(\sigma_{t-1}^2\right) + \beta_8 \pi_t + \beta_9 \sigma_{t,\pi}^2 + \beta_{10} Y_t \qquad (4)$$

$$COV_t = \rho_{\varepsilon\mu} \sigma_{\varepsilon_t} \sigma_{\mu_t} \qquad (5)$$

Equation (1) describes mean inflation as a function of p and q lags of the autoregressive and moving average components, respectively, inflation and output volatilities, and real output growth rate. Equation (2) describes the conditional variance of inflation. However, we augment this equation with the mean inflation rate, real output growth rate and output volatility variables. Equation (3) specifies real economic growth rate as a function of output volatility, inflation volatility, mean inflation rate, and the autoregressive moving average components. Equation (4) describes the conditional variance of the real output growth rate, augmented by the mean inflation rate, real output growth rate and inflation volatility. Finally, equation (5) is the constant conditional correlation model of the covariance between the residuals of equations (1) and (3).

The Deveraux hypothesis is related to α_1, the Cukierman and Meltzer hypothesis and the Holland hypothesis are related to α_2, the Friedman hypothesis is related to α_8 and β_2, while β_1 relates to a test of Black's hypothesis.

The models are estimated for India, Brazil and South Africa using quarterly data. The sample size is dictated by data availability. For India and South Africa data is for the period 1960 to 2006; and for Brazil, data is for the period 1991 to 2006. All data is obtained from the *International Financial Statistics* published by the International Monetary Fund. Output is proxied by industrial production for India and Brazil, while for South Africa gross domestic product is used.

To obtain robust inferences about the estimated models, we compute the robust standard errors as suggested by Bollerslev and Wooldridge (1992). We estimate the $\text{ARMA}(p,q)-\text{EGARCH}(1,1)$ using the maximum likelihood estimation technique, assuming that the errors follow a Student's t-distribution. The optimal lag lengths are selected using the Schwarz Bayesian Criterion.

4. Empirical Results

4.1. Preliminary analysis

The summary statistics for inflation and real economic growth rate for the three countries are presented in Table 1. Some general observations deserve particular discussion here. First, except for South Africa's inflation rate, the kurtosis is greater than 3 for inflation and output growth for India and Brazil, implying that the distribution is peaked (leptokurtic) relative to the normal. Because of excess kurtosis, it is not surprising that in most cases there is strong evidence of non-normality. Skewness is a measure of asymmetry of the distribution of the series around its mean. The skewness of an asymmetric distribution, such as a normal distribution, is zero. The skewness is positive (has a right tail) except for Brazil's output growth rate and India's inflation rate and output growth rate. The conditional volatilities in inflation and output growth for each of the three countries are plotted in Figure 1. We notice that the volatility in output is high and rapid than that for inflation.

We also report the test results on the integrational properties of inflation and output growth for the three countries in Table 1. To address the issue of the degree of integration, we use the ADF, the PP and the KPSS tests. We use two models for each of the tests, namely a model with a time trend and a model without a time trend. We find consistent evidence that inflation and output growth are stationary at the 5 per cent level of significance.

INSERT TABLE 1

INSERT FIGURE 1

4.2. EGARCH-M results for India

The results from the EGARCH-M model for mean inflation and inflation volatility for India are reported in column 2 of Table 2. Beginning with the mean inflation model, our results are as follows. First, inflation volatility has a positive and statistically significant effect on mean inflation. This finding is consistent with the Cukierman and Meltzer hypothesis. Second, our model includes the output volatility variable in the mean inflation model in order to capture the Black hypothesis. We discover a negative and statistically significant relationship between output volatility and mean inflation, consistent with Black's hypothesis that a risky technology leads to higher economic growth. Economic growth through technological shocks reduces inflation.

Moving to the inflation volatility results, we notice that the coefficient on α_6 is negative and statistically significant at the 10 per cent level, suggesting that positive shocks reduce inflation volatility more than positive shocks increase volatility. This means that shocks have asymmetric effects on India's inflation volatility. The coefficient on α_7, which measures shock persistence, is small (-0.02) and statistically significant at the 1 per cent level. The small coefficient implies that shocks to inflation die out fairly rapidly; thus, shocks to India's inflation volatility are transitory. In the inflation volatility equation, we had included the mean inflation variable in order to test the Friedman hypothesis that higher inflation generates more inflation volatility. The coefficient on mean inflation is positive and statistically significant at the 1 per cent level, supporting the Friedman hypothesis.

INSERT TABLE 2

We now turn to the results for India's output growth rate and output volatility models. The results are reported in column 2 of Table 3. We find that output volatility has a statistically significant positive effect on India's output growth rate. This finding is consistent with Black's hypothesis that investing in risky technology, which is a source of output volatility, stimulates economic growth. Results from the output volatility equation reveal that shocks to output volatility are symmetric and India's output volatility is not persistence: that is, shocks to output volatility have transitory effects.

INSERT TABLE 3

4.3. EGARCH-M results for South Africa

The results for mean inflation and inflation volatility for South Africa are reported in column 3 of Table 2. Beginning with the results for mean inflation, we find that inflation volatility has a positive and statistically significant effect on mean inflation, consistent with the Cukierman and Meltzer hypothesis. We notice that income volatility has a negative effect on mean inflation. This result is statistically significant at the 1 per cent level. Black (1987) argued that risky technology stimulates economic growth. It follows that risky technology is a source of positive output volatility, which negatively impacts inflation.

We had also included the economic growth variable in the mean inflation model. We discover that economic growth has a positive and statistically significant (at the 1 per cent level) effect on inflation.

We now turn to the inflation volatility model. We notice that the term α_6 is statistically insignificant, implying that shocks to inflation volatility are symmetric. The coefficient that measures volatility persistence, α_7, while statistically significant at the 1 per cent level has a relatively small coefficient of 0.11, implying that shocks to inflation volatility die out very rapidly; in other words, shocks to inflation volatility have transitory effects. In the inflation volatility equation, we had also included the mean inflation variable to test the Friedman hypothesis that higher inflation increases inflation volatility. The coefficient on the mean inflation variable is positive and statistically significant at the 1 per cent, implying that as mean inflation rises inflation volatility rises. We had also included the income volatility variable in the inflation volatility model. We find that income volatility positively impacts inflation volatility at the 1 per cent level of significance. This finding can be traced to Black's (1987) hypothesis. If risky technology stimulates economic growth and risky technology is a source of income volatility, then it is clear that a positive risky technology shock raises output and reduces inflation.

We now turn to the results from the output growth and output volatility models. The results are reported in column 3 of Table 3. The main results are as follows. First, the output volatility variable has a positive sign and is statistically significant at the 1 per cent level. This finding is consistent with Black's hypothesis that output volatility, which is a result of risky technology, stimulates economic growth. We notice, however, that inflation volatility variable has a statistically insignificant effect on South Africa's economic growth.

We now examine the results from the output volatility equation. First, we find that the coefficient on β_6, which measures volatility persistence, has a very small coefficient (0.23) and is statistically significant at the 1 per cent level. The low coefficient suggests that shocks to South Africa's output volatility die out fairly quickly; that is, shocks to output volatility have transitory effects. The coefficient on β_7, which measures whether or not shocks have asymmetric effects on output volatility is positive and statistically insignificant. The insignificance implies that shocks to South Africa's output volatility have symmetric effects.

4.4. EGARCH-M results for Brazil

The results for mean inflation and inflation volatility for Brazil are presented in column 4 of Table 2. The results for output growth and output volatility are reported in column 2 of Table 3. We do not find any evidence of the six hypotheses. In the mean inflation equation, inflation and output volatilities are statistically insignificant. Output growth is also statistically insignificant in the mean equation. In the variance equation, shocks have transitory and symmetric effects on inflation volatility. In the output growth equation, we do not find any evidence that inflation and output volatility have statistically significant effects on economic growth. Output volatility is not characterised by persistence, suggesting that shocks to Brazil's output volatility have transitory effects. There is also evidence that shocks to output volatility have symmetric effects.

One reason why we do not find any empirical support for the theoretical relationship between inflation and output growth may be due to the peculiar behaviour of inflation in Brazil. We plot the annual inflation rate for Brazil over the 1980-2005 period in Figure 2, and observe that inflation was substantially high. In 1980 inflation was 132.6 per cent. It increased to 1430.7 per cent in 1989, and to 2947.7 per cent in 1990. It declined to 2075 per cent in 1994, before sharply falling and settling at 6.9 per cent in 2005.

INSERT FIGURE 2

4.6. Comparative analysis of the results

In this section, we compare the results for India, South Africa, and Brazil. First, we compare the results for the different hypotheses that we identified and, second, we compare the results on the persistence of shocks and examine whether shocks to inflation volatility and output volatility have asymmetric effects.

The results for the hypotheses tests are summarised in Table 4. For India and South Africa, we find evidence for the Cukierman and Meltzer hypothesis that an increase in inflation volatility increases mean inflation. We do not find any evidence for the Deveraux hypothesis that an increase in output volatility increases mean inflation. For India and South Africa, we find evidence for the Friedman hypothesis that an increase in mean inflation increases inflation volatility; however, we do not find any evidence of the Friedman hypothesis that an increase in inflation volatility reduces output growth. We find evidence for the Black hypothesis that an increase in output volatility increases output growth, and we find evidence for the Black hypothesis that an increase in output volatility reduces mean inflation in the two countries.

INSERT TABLE 4

Next, we examine the nature of shocks to inflation volatility and output volatility. Beginning with the inflation volatility model, we find that while shocks to India's inflation volatility are asymmetric, for Brazil and South Africa shocks to inflation volatility have symmetric effects. In terms of volatility persistence, we find that for all the three countries, shocks to inflation volatility are not persistent, implying that shocks have a temporary effect on inflation volatility. We now turn to output volatility models for comparison. We find that while for South Africa shocks to output volatility have asymmetric effects, for India and Brazil shocks have symmetric effects on output volatility. In terms of volatility persistence, we find that for all three countries shocks to output volatility is not persistent; thus, shocks only have a transitory effect on output volatility.

4.6. Dynamic analysis of shocks

In this section, we attempt to examine the dynamic response of output growth, inflation, output volatility and inflation volatility to shocks to each of these variables. To achieve this objective, we use the Generalised Impulse Response Functions (GIRFs) proposed by Koop *et al*. (1996). There are two advantages of the GIRFs which motivate our work. First, they allow for composition dependence in multivariate models, in that the effect of a shock to output growth is not isolated from having a contemporaneous impact on inflation and vice versa (see, Lee and Pesaran, 1993 and Pesaran and Shin, 1998a). Second, they are invariant to the reordering of the variables in a multivariate model, and fully take into account the historical patterns of correlations observed amongst the different shocks (Pesaran and Shin, 1998b). Pesaran and Shin (1998b) show that the maximum likelihood estimator of the GIRFs is $\sqrt{T}-$ consistent and asymptotically normally distributed.

We present the results for the GIRFs for each of the three countries in Figures 3-5. The results are generated for the response of each of the variables (output growth, inflation, output volatility, and inflation volatility) to shocks in each of these four variables. Beginning with results for India, reported in Figure 3, we observe that output growth responds most to its own shocks and to shocks in output volatility, while the response of output growth to shocks in inflation and inflation volatility are mild. In terms of the response of inflation to shocks, we observe that inflation is most responsive to shocks to output growth, and behaves in an oscillatory manner, and shocks to inflation lead to a fairly sharp fall in inflation initially after which the impact tends to stabilise. The response of inflation to shocks to inflation volatility and output volatility are slightly different: while shocks to inflation volatility move inflation from positive to negative territory after 5 quarters, the impact of shocks to output volatility on inflation die out over time. The response of inflation volatility to shocks is as follows: shocks to output growth have a negative effect on inflation volatility, but after about 10-quarters inflation tends to converge towards zero; shocks to inflation increase inflation volatility; shocks to inflation volatility lead to a fall in inflation volatility overtime, and after 10-quarters, the response of inflation volatility is towards zero; and inflation volatility tends to move from negative to positive after 6-quarters in response to shocks to output volatility. Finally, India's output volatility tends to be very responsive to shocks to output growth and to a lesser extent to shocks to output volatility. The response of output volatility to shocks to inflation and inflation volatility are mild, however.

INSERT FIGURES 3-5

In Figure 4, we present the GIRFs for South Africa. Beginning with the response of output growth to shocks, we observe that South Africa's output growth falls in response to shocks to output growth over the first two quarters and in response to shocks to output volatility, while it rises initially in response to shocks to inflation and inflation volatility. All shocks, however, have a zero impact over the first 4-7 quarters. Inflation responds most to shocks to inflation, falling sharply over the first 3 quarters and then stabilising, but the response of inflation remains positive; inflation initially rises from negative to positive over the first 5 quarters due to shocks to output growth and stabilises thereafter; in response to shocks to inflation volatility, inflation falls over the first 5 quarters and stabilises thereafter; and in response to output volatility shocks, inflation rises over the first 5 quarters and stabilises thereafter. In response to output shocks, we notice that inflation volatility increases over the first 4 quarters after which the impact of shocks dies out; shocks to inflation raise inflation volatility; shocks to inflation volatility exert a stable but positive impact on inflation volatility; and shocks to output volatility reduce inflation volatility. Finally, output volatility in response to shocks to output rises over the first 2 quarters, falls to zero after 4 quarters, and the impact of shocks die out thereafter. There is zero response of output volatility to shocks to inflation volatility and output volatility after 6 quarters.

In Figure 5, we plot the GIRFs for Brazil. We begin with the results for the response of inflation, and observe that inflation responds most to shocks to inflation and inflation volatility. Inflation rises initially in response to a shock to inflation, but falls sharply into negative territory, and stabilises in this region after 5 quarters. In response to shocks to inflation volatility, inflation falls, while output volatility increases inflation after 6 quarters. Meanwhile, output growth responds to inflation and inflation volatility in an oscillatory manner, and mildly in response to shocks to inflation volatility and output volatility. We notice that inflation volatility in Brazil responds most to shocks to inflation and inflation volatility: after an initial rise, it falls sharply and after 4 quarters it responds negatively. There is a mild response of inflation volatility to shocks to output and output volatility, however. The impact of shocks to output volatility and output tend to die out after 4 quarters, while output volatility responds to inflation and inflation volatility in a cyclical manner.

5. Concluding remarks

In this paper we examined several hypotheses relating to the relationship between inflation and output for India, Brazil, and South Africa, using an augmented version of the EGARCH model. For India and South Africa, we found: (1) evidence of the Cukierman and Meltzer hypothesis that inflation volatility raises inflation; (2) evidence of the Friedman hypothesis that inflation raises inflation volatility; and (3) evidence of Black's hypothesis that output volatility raises output growth, and that output volatility reduces inflation in these two countries. However, for Brazil, we found no systematic relationship between inflation and output. In addition, we undertook a dynamic analysis of the response of output growth, inflation, inflation volatility and output volatility to shocks to each of these variables using the generalised impulse response functions. Broadly, we found results consistent with those from the EGARCH models for each of the three countries.

Our findings suggest that except for Brazil, for which we did not find any evidence in support of the proposed hypotheses, there were consistent evidence of similar relationships in the growth experience of India and South Africa. From a policy perspective, given our finding that inflation volatility will increase inflation, it is crucial for policy makers in India and South Africa to minimise inflation volatility. In doing so, what is important to identify is the factors that contribute to inflation volatility. A key determinant of inflation volatility is exchange rate volatility. This implies that monitoring the behaviour of exchange rates and their determinants will be imperative.

Our study, being the first comprehensive study in this literature, on three large emerging developing countries, thus offers the first insight on the complex nature of the relationship between output growth, inflation, output volatility and inflation volatility. Our work, hence, sets the foundation for future work on developing countries. One avenue of such work would be to analyse the inflation-output nexus for countries based on geographical locations.

REFERENCES

Al-Marhubi, F., (1998) Cross-country evidence on the link between inflation volatility and growth, Applied Economics, 30, 1317-13

Apergis, N., (2004) Inflation, output growth, volatility and causality: Evidence from panel data and the G7 countries, Economics Letters, 83, 185-191.

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

Berndt, E., Hall, B., Hall, R., and Hausman, J., (1974) Estimation and inference in nonlinear structural models, Annals of Economic and Social Measurement, 3, 653-665.

Bohara, A.K., and Sauer, C., (1994) The role of inflation uncertainty in Germany: Friedman's hypothesis revisited, Empirical Economics, 19, 611-627.

Bollerslev, T., (1986) Generalised autoregressive conditional heteroskedasticity, Journal of Econometrics, 31, 307-327.

Bollerslev, T., and Wooldridge, J.M., (1992) Quasi-maximum likelihood estimation and inference in dynamic models with time varying covariances, Econometric Reviews, 11, 143-72.

Clark, T.E., (1997) Cross-country evidence on long-run growth and inflation, Economic Inquiry, 35, 70-81.

Cukierman, A., (1992) Central Bank Strategy, Credibility and Independence, MIT Press, Cambridge, MA.

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

Darrat, A.F., and Lopez, F.A., (1989) Has inflation uncertainty hampered economic growth in Latin America? International Economic Journal, 3, 1-14.

Davis, G., and Kanago, B., (1996) On measuring the effect of inflation uncertainty on real GNP growth, Oxford Economic Papers, 48, 163-175.

Deveraux, M., (1989) A positive theory of inflation and inflation variance, Economic Inquiry, 27, 105-116.

Dickey, D.A. and W.A. Fuller (1979) Distribution of the Estimators for Autoregressive Time Series with a Unit Root, Journal of the American Statistical Association, 74, 427-431.

Dickey, D.A. and W.A. Fuller (1981) Likelihood ratio statistics for autoregressive time series with a unit root, Econometrica 49, 1057-72.

Elliott, G., T.J. Rothenberg and J.H. Stock (1996) 'Efficient test for an autoregressive unit root', Econometrica 64, 813-36.

Engle, R.F., (1982) Autoregressive conditional heteroskedasticity with estimates of the variance of the UK inflation, Econometrica, 50, 987-1008.

Fountas, S., Karanasos, M., and Kim, J., (2002) Inflation and output growth uncertainty and their relationship with inflation and output growth, Economics Letters, 75, 293-301.

Friedman, M., (1977) Nobel lecture: Inflation and unemployment, Journal of Political Economy, 85, 451-472.

Grier, R., and Grier, K.B., (2006) On the real effects of inflation and inflation uncertainty in Mexico, Journal of Development Economics, 80, 478-500.

Grier, K.B., and Perry, M.J., (2000) The effects of real and nominal uncertainty on inflation and output growth: Some GARCH-M evidence, Journal of Applied Econometrics, 15, 45-58.

Grier, K., Henry, O.T., Olekalns, N., and Shields, K., (2004) The asymmetric effects of uncertainty on inflation and output growth, Journal of Applied Econometrics, 19, 551-565.

Hafer, R.W., (1986) Inflation uncertainty and a test of the Friedman hypothesis, Journal of Macroeconomics, 8, 365-372.

Hayford, M.D., (2000) Inflation uncertainty, unemployment uncertainty and economic activity, Journal of Macroeconomics, 22, 315-329.

Holland, S.A., (1995) Inflation and uncertainty: Tests for temporal ordering, Journal of Money, Credit and Banking, 27, 827-837.

Jansen, D.W., (1989) Does inflation uncertainty affect economic growth, Federal Reserve Bank of St. Louis Economic Review, July/August, 43-54.

Katsimbris, G.M., (1985) The relationship between the inflation rate, its variability, and output growth variability: Disaggregated international evidence, Journal of Money Credit and Banking, 17, 179-188.

Koop, G., Peasarn, M.H., and Potter, S.M. (1996) Impulse response analysis in non-linear multivariate models, Journal of Econometrics, 74, 119-147.

Kwiatkoeski, D., Phillips, P.C., Schmidt, P.J., and Shin, Y., (1992) Testing the null hypothesis of stationarity against the alternative of a unit root: How sure are we that economic time series have a unit root, Journal of Econometrics, 54, 159-178.

Levin, R., and Renelt, D., (1992) A sensitivity analysis of cross-country growth regressions, American Economic Review, 82, 942-963.

Levin, R., and Zervos, S., (1993) What have we learned about policy and growth from cross-country analysis, American Economic Review Papers and Proceedings, 83, 426-430.

McLeod, A.I., and Li, W.K., (1983) Diagnostic checking ARMA time series models using squared residual autocorrelations, Journal of Time Series Analysis, 4, 269-273.

Mullineaux, D.J., (1980) Unemployment, industrial production, and inflation uncertainty in the United States, Review of Economics and Statistics, 62, 163-169.

Nelson, D., (1991) Conditional heteroskedasticity in asset return: A new approach, Econometrica, 59, 347-370.

Pesaran, H.M., and Shin, Y., (1998a) Cointegration and the speed of convergence to equilibrium, Journal of Econometrics, 71, 117-143.

Pesaran, H.M., and Shin, Y., (1998b) Generalised impulse response analysis in linear multivariate models, Economics Letters, 58, 17-29.

Phillips, P.C.B., and Perron, P., 1988, Testing for a unit root in time series regression, Biometrika, 75, pp. 335-359.

Thornton, J., (1988) Inflation and output growth: Some time series evidence, a note, American Economist, 32, 55-58.

Wilson, B.K., (2006) The links between inflation, inflation uncertainty and output growth: New time series evidence from Japan, Journal of Macroeconomics, 28, 609-620.

Table 1: Summary statistics

	India		South Africa		Brazil	
	Inflation	Output	Inflation	Output	Inflation	Output
Mean	0.0179	0.0145	0.0205	0.0107	0.1725	0.0076
Variance	0.0222	0.0592	0.0134	0.0193	0.2981	0.0277
Skewness	-0.0168	-0.7124	0.3518	1.1094	1.7073	-0.5092
Kurtosis	4.7187	3.7859	0.3518	9.4414	4.4908	3.8797
J-B	22.6553	20.2973	5.3474	355.8461	34.7045	4.5276
	(0.0000)	(0.0000)	(0.0689)	(0.0000)	(0.0000)	(0.1039)
ADF (no trend)	-4.0176	-3.9829	-2.8878	-13.1092	-2.2031	-6.5566
	(-2.8778)	(-2.8778)	(-2.8736)	(-2.8772)	(-2.9126)	(-3.4878)
ADF (trend)	-4.0238	-4.1211	-2.2193	-13.1971	-2.7644	-6.6178
	(-3.4356)	(-3.4356)	(-3.4349)	(-3.4346)	(-3.4892)	(-2.9117)
PP (no trend)	-9.0036	-25.0337	-5.5052	-13.1720	-1.3616	-6.7106
	(-2.8772)	(-2.8772)	(-2.8772)	(-2.8772)	(-2.9117)	(-2.9117)
PP (trend)	-8.9740	-25.4329	-5.6210	-13.2175	-2.4129	-6.6435
	(-3.4346)	(-3.4346)	(-3.4345)	(-3.4346)	(-3.4878)	(-3.4878)
KPSS (no trend)	0.0813	0.2156	0.4983	0.3091	0.5463	0.1022
	(0.1460)	(0.4630)	(0.4630)	(0.4630)	(0.7390)	(0.4630)
KPSS (trend)	0.0811	0.0920	0.4115	0.1475	0.1563	0.0967
	(0.4630)	(0.1460)	(0.1460)	(0.1460)	(0.2160)	(0.1460)

Table 2: Parameters of mean and variance equations for inflation model

	India	South Africa	Brazil
α_2	0.0089***	0.0111***	-0.0823
	(0.0006)	(0.0003)	(0.1039)
α_0	0.0609***	0.1663***	-0.4287
	(0.0088)	(0.0176)	(0.8059)
α_3	-0.0128	0.1248***	-0.6973
	(0.0143)	(0.0260)	(1.5595)
α_1	-0.1103***	-8.2654***	-27.2394
	(0.0367)	(2.2578)	(195.93)
δ	-0.3173***	0.0199*	0.9933***
	(0.0215)	(0.0103)	(0.1260)
ν	0.3355***	-0.1246***	-0.0518
	(0.0225)	(0.0091)	(0.0871)
α_4	-6.9755***	-13.9236***	-4.8222
	(1.1586)	(1.9662)	(5.9990)
α_5	-0.7075*	-0.0527	0.2176
	(0.4162)	(0.1019)	(0.6562)
α_6	-0.7002*	0.0097	-0.0405
	(0.4131)	(0.0352)	(0.1772)
α_7	-0.0161***	0.1137***	0.0785
	(0.0019)	(0.0019)	(0.1855)
α_8	112.1979***	88.9473***	-1.1045
	(7.5369)	(2.9875)	(1.0320)
α_{10}	1.4336	-11.2899***	-7.1757
	(0.8849)	(2.7559)	(14.01681)
α_9	4.8358	758.7150***	-270.7935
	(520.98)	(177.0455)	(2460)

Note: * (**) *** denote statistical significance at the 10 per cent, 5 per cent, and 1 per cent levels, respectively.

Table 3: Parameters of mean and variance equations for income model

	India	South Africa	Brazil
β_1	0.2243***	0.0117***	0.0256
	(0.0346)	(0.0005)	(0.0227)
β_0	1.3784***	0.1542***	0.2153
	(0.2992)	(0.0048)	(0.2753)
β_3	-0.7314	-0.0532	0.0402
	(1.1946)	(0.0798)	(0.0491)
β_2	-0.2863	0.3207	-0.0038
	(97.6875)	(18.7643)	(0.0093)
κ	-0.0056	-0.0019	-0.0085
	(0.0592)	(0.0038)	(0.2079)
ξ	-0.1893	-0.2258***	-0.0647
	(0.2928)	(0.0143)	(0.3419)
β_4	-5.8277***	-11.3059***	-7.7405
	(0.2582)	(0.2711)	(16.7258)
β_5	0.0060	-0.0375***	-0.4049
	(0.0412)	(0.0022)	(3.6630)
β_6	0.0443	0.0527***	-0.1110
	(0.0737)	(0.0003)	(2.4599)
β_7	0.0505	0.2265***	0.0866
	(0.0461)	(0.0136)	(0.5566)
β_8	0.7340	4.8452	-1.4094
	(5.6089)	(6.8607)	(1.1498)
β_9	-12.6587	-0.2179	0.1009
	(529.7167)	(1611.559)	(0.3863)
β_{10}	0.6217	85.6679***	34.8088
	(1.1643)	(3.8031)	(22.3484)

Note: * (**) *** denote statistical significance at the 10 per cent, 5 per cent, and 1 per cent levels, respectively.

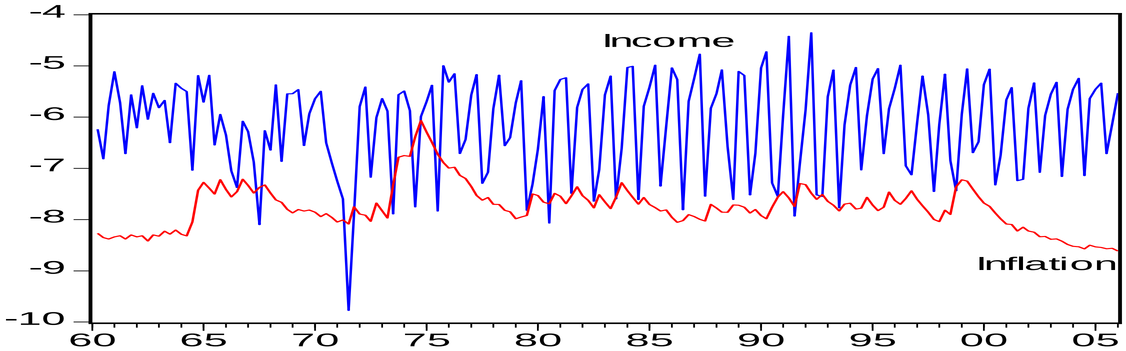
Table 4: Summary of the results on hypotheses tests

	India	Brazil	South Africa
Cukierman and Meltzer hypothesis: $\uparrow \pi v \Rightarrow \uparrow \pi$?	YES	NO	YES
Deveraux hypothesis: $\uparrow Yv \Rightarrow \uparrow \pi$?	NO	NO	NO
Friedman hypothesis: $\uparrow \pi \Rightarrow \uparrow \pi v$?	YES	NO	YES
Friedman hypothesis: $\uparrow \pi v \Rightarrow \downarrow Y$?	NO	NO	NO
Black hypothesis: $\uparrow Yv \Rightarrow \uparrow Y$?	YES	NO	YES
Black hypothesis: $\uparrow Yv \Rightarrow \downarrow \pi$?	YES	NO	YES
Holland hypothesis: $\uparrow \pi v \Rightarrow \downarrow \pi$?	NO	NO	NO

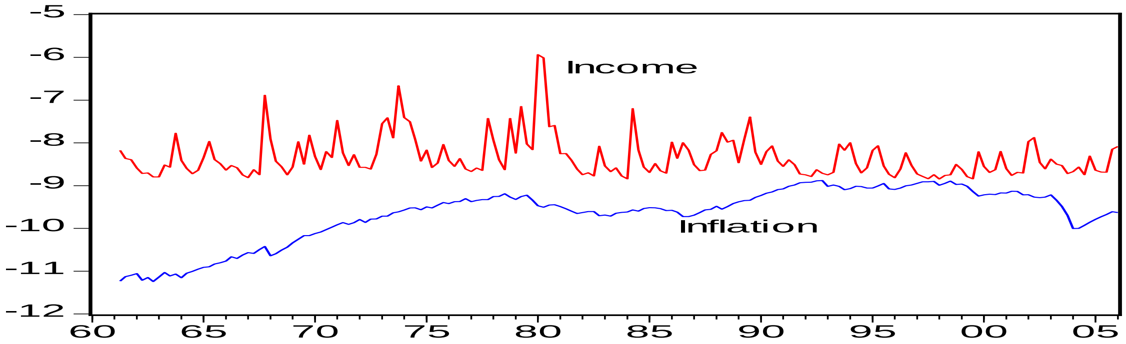
Note: πv and Yv stand for inflation volatility and output volatility, respectively, and π and Y are mean inflation and output growth, respectively.

Figure 1: Conditional volatilities of inflation and output

Panel A: India



Panel B: South Africa



Panel C: Brazil

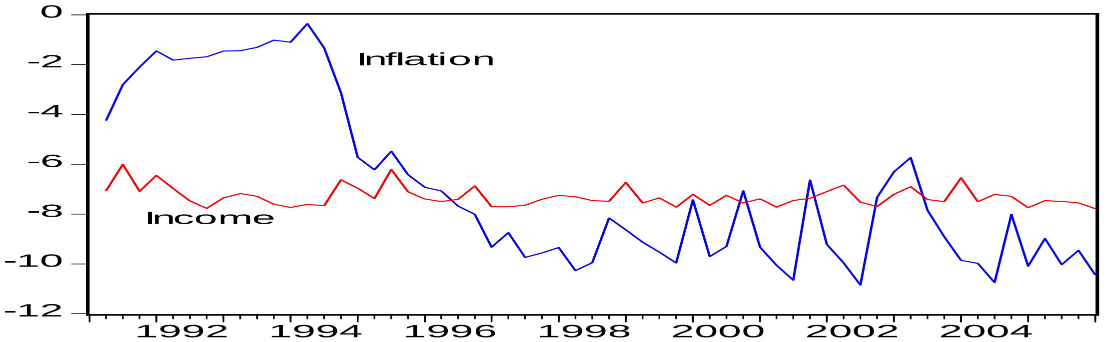
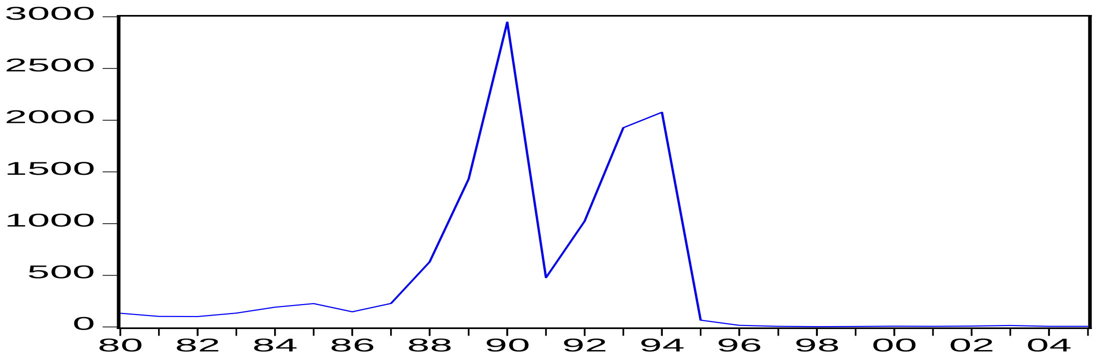


Figure 2: A plot of Brazil's inflation rate, 1980-2005



Source: International Monetary Fund, World Economic Outlook Database, September 2006.

Figure 3: Impulse response functions for India

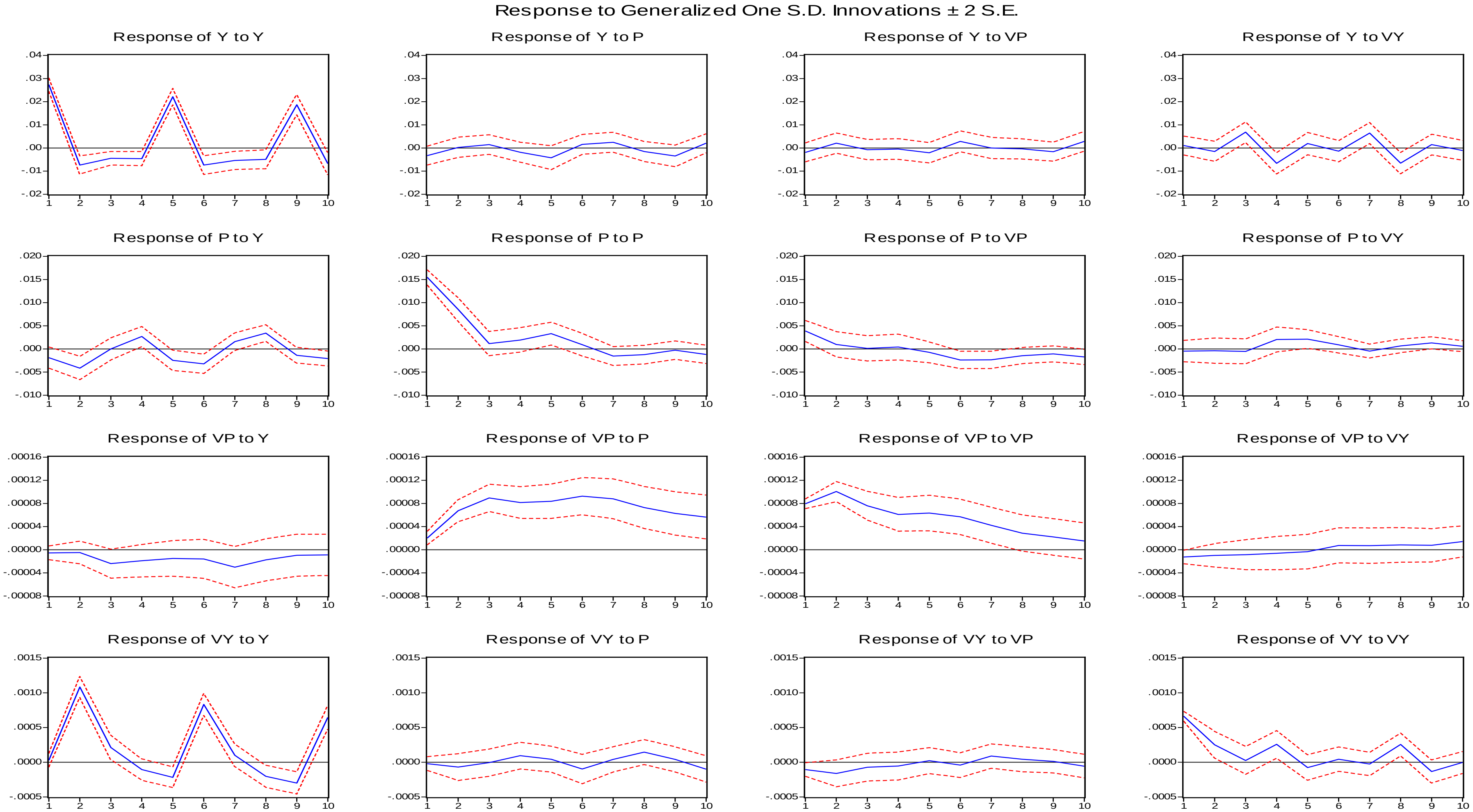


Figure 4: Impulse response functions for South Africa

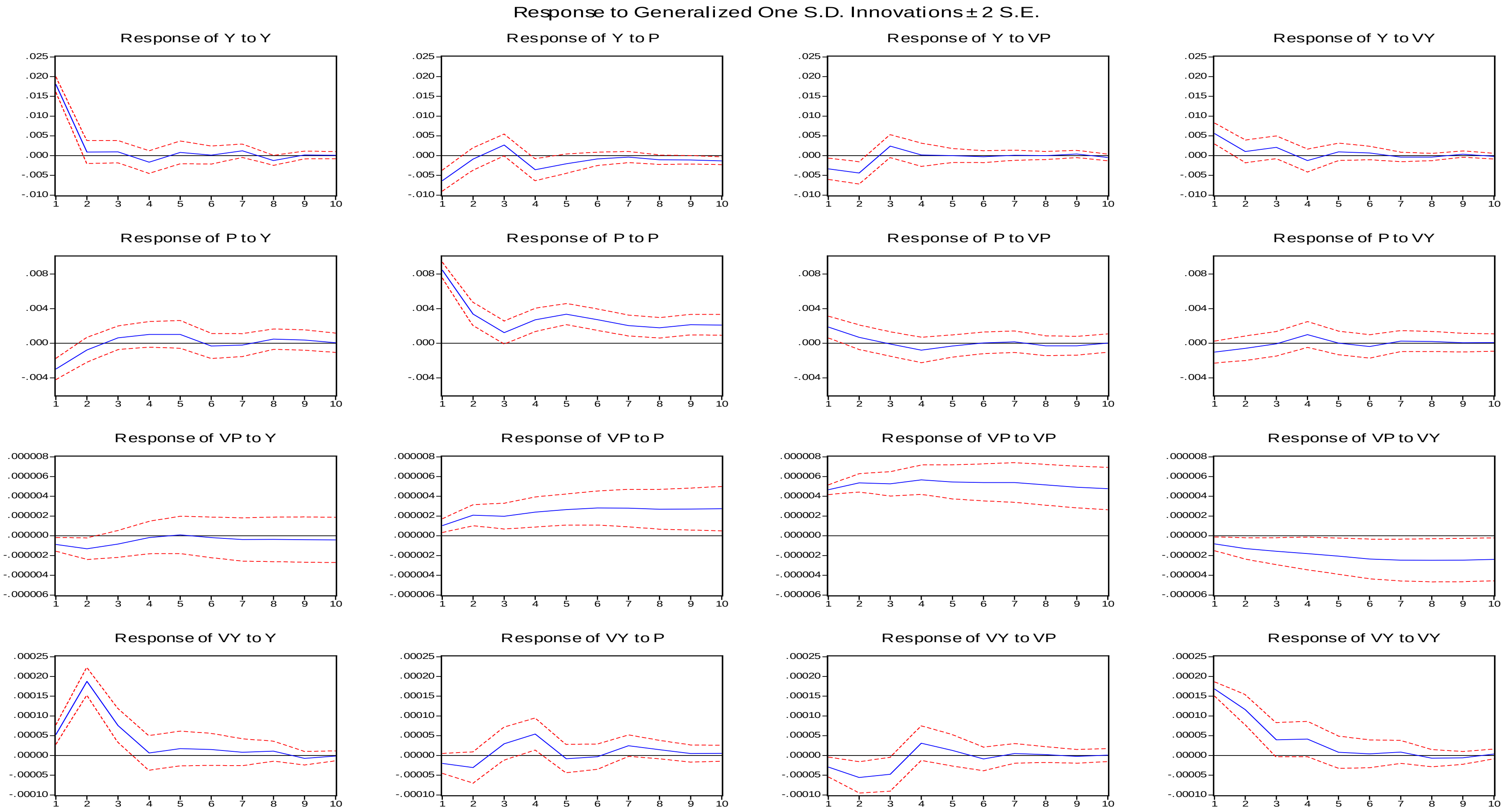


Figure 5: Impulse response functions for Brazil