Monetary Policy and Inflation-Output Variability in Developing Economies: Lessons from Sri Lanka

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Abstract

The purpose of this study is to examine the impact of monetary policy on inflation-output variability trade-off for developing economies, drawing on the experience of Sri Lanka. Using time series data over the period 1980-2017, we first examine how inflation-output variability trade-off has changed across different monetary policy episodes. Secondly, we investigate the persistence of the variability of inflation and output in the face of supply and demand shocks, before exploring the contribution of monetary policy to macroeconomic performance more generally. We find that the inflation-output variability trade-off shifted favourably over time, though no strong evidence of long-run variability association could be established. The study reveals that the economy witnessed the highest level of output growth during the periods in which the negative Taylor curve relationship is satisfied. Our findings further highlight that the impact of demand and supply shocks on the variability of inflation and output are not persistent. This confirms that the deviations from the Taylor curves caused by adverse shocks are transitory if the Central Bank operates efficiently. Meanwhile, the estimated aversion to inflation variability of the Central Bank increased significantly over time, suggesting that the monetary authority took the goal of inflation stability very seriously. Using the loss function of the Central Bank, we also find substantial improvements in welfare loss during the post-war period compared to other periods.

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1. Introduction

The popular and busy debate over the trade-off between inflation and output has been keenly discussed in both theoretical and empirical strands of the business cycle literature. In the context of developing economies however this area is less populated. In recent years, policymakers have argued that the trade-off between inflation and output can be well described in terms of their variability (Chatterjee, 2002; Walsh, 2009; Svensson, 2012; King, 2012; Taylor, 2013). Given this, the nature of the trade-off between the variability of inflation and output has provoked an extensive discussion in the recent empirical literature. This trade-off is widely described using the Taylor curve, which is considered as a second-order Phillips curve, that shows the long-term permanent trade-off between the variability of inflation and output (Ndou, Gumata, Ncube, & Olson, 2013). Meanwhile, Taylor (1993) argues that inflation stability comes at the cost of output variability. An attempt to maintain inflation at a stable level would result in larger fluctuations in output. Similarly, an attempt to minimize fluctuations in output would bring more inflation volatility. Therefore, policymakers do not face a trade-off between the levels of inflation and output but between the variability of inflation and output.

Over the past three decades, although the Sri Lankan economy has registered high levels of growth while recording low levels of inflation, it is also noted that both inflation and growth have been highly volatile with a notable and regular cyclical behavior. The variability of inflation has fallen noticeably while that of output has increased significantly. The Sri Lankan economy has experienced a transition from relatively low volatile regimes to more volatile regimes. In this context, understanding the impact of monetary policy on inflation-output variability trade-off would clearly link policy contribution made by the monetary authority in improving the macroeconomic performance of Sri Lanka. However, the existing empirical literature for Sri Lanka has almost exclusively focused on the impact of monetary policy on levels of inflation and output (Amarasekara, 2008; Perera & Jayawickrema, 2013; Vinayagathasan, 2014). To the best of our knowledge, only one study has focused on examining the possible trade-off between the variability of inflation and unemployment in Sri Lanka (Amarasekara and Bratsiotis, 2015). In this context, the main research question this study attempts to address is: has monetary policy really helped in reducing the inflation-output variability trade-off in Sri Lanka? Given the above research question, the main objective of this study is to examine the impact of monetary policy on the inflation-output variability trade-off in Sri Lanka. In light of the main objective, the present study has two specific objectives. First is to empirically examine the Taylor curve relationship under different monetary policy regimes. Second is to examine the contribution of monetary policy in macroeconomic performance. We consider a sub-sample analysis to identify how the trade-off between the variability of inflation and output evolved over time. We will further extend our analysis to examine how demand and supply shocks have affected the variability of inflation and output during the period under consideration.

This study departs from previous empirical literature in two key aspects. First, this study uses monthly time series datasets covering the period 1980-2017 and places special focus on the presence of structural breaks in the conduct of monetary policy. The entire sample period of this study will be divided into three sub-samples based on structural changes that have been taken place in the economy. We will examine the impact of monetary policy on observed macroeconomic performance across different monetary policy regimes. Secondly, we will estimate the preferences of the Central Bank with respect to the stabilization of inflation using the Structural Vector Autoregression (SVAR) model compared to previous studies which simply considered an average value (Ehelepola, 2015; Paranavithana, Tyers & Magnusson, 2017).

The rest of this paper is organized as follows. Section two presents the literature review. The first part of the literature focuses on theoretical literature while the second part focuses on the empirical literature. Section three outlines the data and methodology while section four offers quantitative insights on the impact of monetary policy on inflation-output variability trade-off in Sri Lanka. The final section summarizes the major findings of the study.

2. Literature Review

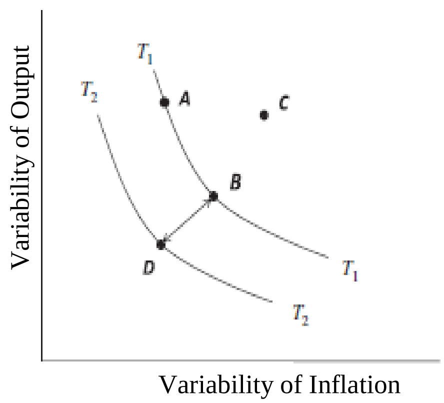
2.1 Theoretical Review

The theoretical literature on the trade-off between the variability of output and inflation has provided conflicting results. It is argued that greater inflation stability comes at the cost of greater output variability. Fuhrer (1997) argued that the existence of a long-run trade-off in variability does not imply a long-run trade-off in the levels of inflation and output. According to Fuhrer (1997), the output-inflation trade-off can be exploited only in the short run. Similarly, Hutchison and Walsh (1998) and Walsh (1998, 2009) argued that when an economy is continually hit by shocks, the existence of short-run trade-off between the level of inflation and output would result in long-run trade-off in their variability. Hence, in the long-term, any reduction in variability of inflation is possible only at the expense of increased variability of output. This indicates that the central banks must tolerate higher level of variability in real output to minimize the variability of inflation in the face of demand and supply shocks. In contrast, if a Central Bank wishes to make the variability in output small, it must allow the shocks that affect inflation to persist, thus increasing the variability in inflation. The argument of Fuhrer (1997) and Walsh (1998) with respect to the nature of the Taylor curve has been challenged by studies such as Dotsey and Sarte (2000). These researchers take the opposite route and argue that increased variability in inflation results in a larger output growth because of the precautionary savings motive.

The demand and supply shocks are considered as the primary sources of exogenous disturbances in the economy which requires a policy response (Ceccheti & Ehrmann, 2002). The demand shock moves output and inflation in the same direction while supply shock moves output and inflation in opposite directions. Hence, some economists believe only the supply shocks force the monetary authority to face a trade-off between the variability of output and inflation (Chatterjee, 2002; Cecchetti & Ehrmann, 2002). In the recent past, this trade-off has been widely investigated using the Taylor curve. The Taylor curve is an efficient policy frontier yielding the trade-off for optimal monetary policy (Friedman, 2006). As the Taylor curve is well-suited with current mainstream macroeconomic theory, Chatterjee (2002) and Taylor (2008) argued that the Taylor curve has replaced the so-called Phillips curve as a policymaker's menu of choice between the variability of inflation and output. They argue that central banks can reduce the variability of inflation (output) only if they agreed to take a higher level of variability in output (inflation).

Consider the Taylor curve shown in Figure 1. Each point in the curve shows the policy choices available to the policymakers (Taylor, 1999). Accordingly, the low level of variability in inflation can be derived for any given variability of output. An optimal monetary policy would result an economy operating at an efficient point such as A. Meanwhile, a movement of an economy towards the Taylor curve, such as a shift from point C to B, represents an improvement in monetary policy. However, the exact position in the Taylor curve depends on the nature of supply shocks and the policymaker's preferences with regard to the stabilization of inflation and output. When supply shocks are lower, then the efficiency frontier will be closer to the origin. If preferences of the policymakers with respect to stabilization of output increase, then the economy would move from point A towards point B. In such situations, a negative trade-off between the variabilities of output and inflation can be observed. Movements from point B towards point D owing to change in the efficiency of monetary policy would cause both variabilities to move in the same direction. This causes a positive correlation between them. The shift of the Taylor curve from T_1T_1 to T_2T_2 could result from a reduction in the variability of either demand shocks or supply shocks or combination of both. However, it is also possible for an economy to operate off the efficiency frontier such as point C because of suboptimal monetary policy (Friedman, 2006).

Figure 1. The Taylor Curve



Source: Adapted from Olson, E., and Enders, W. (2012)

2.2 Empirical Evidence

With the implementation of inflation targeting frameworks by many central banks, the preferences of the policymakers with respect to the stabilization of inflation and output has changed in recent times. Numerous studies have empirically estimated trade-off between the variability of output and inflation. These studies, in general, concluded that any attempt to stabilize inflation leads to higher output variability. Olson and Enders (2012) examined the efficiency of monetary policy in the United States during the period 1875-2000 using the Taylor curve. They used a simple near-VAR model to capture time-series properties of output and inflation without controlling for several sources of external shocks. They claimed that the distance between the origin and the Taylor curve was small during periods in which monetary policy was most satisfactory in terms of reducing the variabilities of output and inflation. Most notably, they showed that the opportunity cost of reducing variability of inflation in terms of output variability was very low after the 1950s. Using a similar VAR approach, Cecchetti and Ehrmann (2002) explored how the policy preferences of central banks has changed during the 1980s and 1990s while estimating inflation-output variability trade-off in a cross-section of 23 countries including 9 countries that explicitly adopted inflation targeting monetary frameworks. The study finds that aversion to inflation variability has increased in all 23 countries during the 1990s compared 1980s. Further, the study finds that the inflation targeting countries have attached higher weight to stabilizing inflation compared to non-inflation targeting countries. However, the study showed that reduced inflation variability among inflation targeting countries has resulted in increased output variability. In contrast, Levin, Natalucci, and Piger (2004) find that inflation targeting countries do not seem to exhibit higher levels of variability in output in comparison to non-inflation targeting countries. Most of the findings drawn by Cecchetti and Ehrmann (2002) were consistent with the later study by Cecchetti, Alfonso, and Stefan (2006) who found the improved efficiency of monetary policy at cross-country level was largely supported by structural changes in the economy and the reduction in the variability of supply shocks.

Ndou et al. (2013), who investigated how demand and supply shocks have affected the trade-off between the variability of inflation and output over time in case of South Africa, showed that the Taylor curve has shifted inwards during the inflation targeting regimes compared to other regimes. Their results confirmed that the performance of South African economy was improved during the period when the Taylor curve relationship holds. Lee (2002) investigated similar study for the United States covering the period 1960-1999. Considering the structural changes that took place during the period 1979-1982 in the conduct of monetary policy, the author carried out two sub-sample analyses while employing a bivariate generalized autoregressive conditional heteroskedasticity (GARCH) model. The results of the study showed the existence of a long-term trade-off between the variability of output and inflation. The study further showed that the magnitude with respect to the impact of monetary policy on the variability of output and inflation varies across periods. Using similar methodology, Stephanos and Vangelis (2015) investigated the effectiveness of monetary policy of the Federal Reserve under different levels of transparency over the period 1982-2011. Through incorporating conditional variances of inflation and output along with transparency in a VAR approach, they found a positive shock in the Federal Reserve's transparency significantly reduced the variability of both inflation and output.

Using the bivariate GARCH method, Onyukwu, Nwosu, and Ito (2011) investigated how monetary policy under different regimes has affected the nature of trade-off between the variability of output and inflation in Nigeria. Their results showed that the magnitude of monetary policy's impact on output and inflation varies across different policy regimes, however, there is no evidence to establish a strong trade-off between the variability of inflation and output. The study showed that monetary policy had a robust impact on output growth compared to price stability during the period of direct control, however, it also provided substantial evidence to show that monetary policy had a much larger impact on inflation during the period when a market-based regime was in place. Meanwhile, using the GARCH model, Conrad and Karanasos (2015) showed that output variability adversely affected the variability of inflation in the US. In particular, the study presented strong evidence supporting the theory proposed by Logue and Sweeney (1981) that argued inflation uncertainty has a positive impact on the variability of output.

Fuhrer (1997) studied the nature of trade-off between the variability of inflation and output in the United States over the period 1966-1993. The study finds that the variability trade-off becomes quite severe when the standard deviation of inflation or output was reduced to below 2 percent. In particular, the study argued that when an economy constantly affected by economic shocks, the short-run trade-off between the level of inflation and output confronted by policymakers would results in a substantial trade-off between the variability of inflation and output in the long-run. Interestingly, the literature found that the performance of monetary policy during the 1990s was close to the Taylor curve frontier and policymakers more vigorously responded to output gap, regardless of their policy preferences over inflation and output stabilization.

Fackler and McMillin (2011) estimated inflation-output variability trade-off under inflation forecast targeting using monthly data for two sample periods 1962-1983 and 1980-2000. Their estimation was based on the moving average representation of a vector autoregressive (VAR) model. They showed that the trade-off between the variability of inflation and output for the United States changed favorably over time. Their results argued that less policy interventions are required to achieve the targeted level of inflation announced by the Fed during the second sample period compared to first sample period. The study showed that the variability of inflation was largely associated with lower levels of variability in output and interest rate in the first period compared to second period. Their results suggest that the trade-off between the variability of inflation and output and between inflation and interest rate shifted favourably over the periods.

Amarasekara and Bratsiotis (2015) compared the efficiency of monetary policy in inflation targeting and non-inflation targeting countries. Using an inflation-unemployment variability frontier within micro-founded models over the period 1980-2007, the authors found a possible trade-off between the variability of inflation and unemployment for 14 countries. Their results suggest that lower inflation variability was coupled with higher unemployment variability during the post-1993 period in all the countries, except for Ireland and Pakistan. Amarasekara and Bratsiotis argued that countries that implemented inflation targeting registered low level of variability in both inflation and unemployment. However, in the case of non-inflation targeting countries, the study confirmed that the reduced inflation variability was attained at the cost of increased unemployment variability. Hence, the literature argues that adopting an explicit inflation targeting framework provides clarity and transparency to the inflation stabilization objective of the Central Bank and thereby helps to improve the trade-off between the variability of inflation and output. These arguments were previously addressed by Fraga, Goldfajn, and Minella (2004), but they compared the performance of monetary policy caused by inflation targeting in emerging and advanced economies. Their results showed that the emerging market economies registered a greater level of trade-off between the variability of inflation and output compared to advanced economies. A similar study was conducted by Arestis, Caporale, and Cipollini (2002), however employing stochastic volatility models, to examine whether implementation of inflation targeting frameworks by the central banks improved the trade-off between the variability of output and inflation during the 1980s and 1990s. Their results suggest that the implementation of inflation targeting frameworks has significantly improved monetary policy trade-offs. The literature highlighted that the improved performance was largely supported by a relatively high degree of monetary policy transparency and the presence of flexible institutional frameworks.

3. Data and Methodology

As this study mainly focuses on inflation-output variability trade-off, we will first derive the Taylor curve equation. Section 3.2.1 focuses in-depth on the theoretical derivation of the standard Taylor curve equation while Section 3.2.2 discusses the approach that will be followed to investigate the persistence of variability of inflation and output in response to demand and supply shocks. Thereafter, we will estimate the relevant parameters of the Taylor curve equation using the Structural Vector Autoregressive (SVAR) model. A detailed description of the SVAR model is given in Section 3.2.3. Using the estimated parameters of the Taylor curve equation, we will examine the contribution of monetary policy in macroeconomic performance.

3.1 Data

With the economic and financial sector reforms undertaken in 1977, the Central Bank of Sri Lanka (CBSL) moved from direct policy instruments to market-based policy instruments in conducting monetary policy. In line with the development in the financial system, the CBSL formally adopted a monetary targeting policy framework in 1980. Meanwhile, since January 2001 the CBSL allowed the exchange rate to be determined freely through market forces. This has reduced the role of exchange rate as a stabilization tool but increased the role of reserve money as a nominal anchor of monetary policy. Considering these structural changes, the present study uses time series monthly data for the period January 1980 to December 2017. This study begins in 1980 to coincide with the adoption of the monetary targeting monetary policy framework in Sri Lanka. Thus, our first sub-sample runs from January 1980 to December 2000. Meanwhile, the civil war that started in 1983 ended in May 2009. Therefore, our second and third sub-sample runs from January 2001 to May 2009 and from June 2009 to December 2017 respectively. The data on the exchange rate, interest rate, and fiscal variables are mainly drawn from various annual reports of the Central Bank of Sri Lanka (CBSL). Data for other variables have been extracted from three different sources. Growth rates of real Gross Domestic Production (GDP) and inflation rate are mainly based on various publications of the Department of Census and Statistics (DCS) of Sri Lanka. The monthly real GDP series are not available for Sri Lanka.

The DCS published real GDP data annual basis until 1996 and thereafter publishes both annual and quarterly basis. Hence, we use the interpolation technique proposed by the Fox (2000) to convert the annual series (and the quarterly series from 1996) to the monthly series using a cubic spline procedure. Due to unavailability of time series monthly data for policy rates of the CBSL, we considered the 3-months Treasury Bill rate as the short-term interest rate. Meanwhile, the output gap is calculated as the percentage deviation of the real GDP from its trend value obtained by the Hodrick–Prescott (HP) filter. The detailed description of the data series and their sources are given in Appendix.

3.2 The Methodology

3.2.1 The Derivation of Taylor Curve

As this study mainly focuses on the inflation-output variability trade-off, this section focuses on the theoretical derivation of Taylor curve equation. The theoretical Taylor curve can be derived using the minimization of quadratic loss function of the Central Bank subject to the dynamics of output and inflation [2].

$$L = E[\lambda(\pi - \pi^*)^2 + (1 - \lambda)(y - y^*)^2] \ , \quad 0 < \lambda < 1 \qquad (1)$$

Equation 1 is the standard quadratic loss function of the Central ank widely used in empirical studies to examine the monetary policy. Where E denotes the expectation, π is the inflation and y is the output. π^* and y^* are the desired levels of inflation and output. The parameter λ is the policymaker's preferences given to squared deviation of inflation from its target level. This is also known as policymaker's aversion to inflation variability (Cecchetti and Ehrmann, 2002). As per Equation 1, deviation in actual output from the potential output or current inflation from targeted inflation generates a loss for the Central Bank.

Meanwhile, the dynamics of output and inflation are assumed as a function of interest rate and given in Equations 2 and 3.

$$y_t = \varphi(r_t - d_t) + s_t, \quad \varphi < 0 \qquad (2)$$

$$\pi_t = -(r_t - d_t) + \omega s_t \qquad (3)$$

[2] The quadratic loss function includes only output and inflation. As policy decision on exchange rate is an intermediate target, we have not included exchange rate in the loss function.

where d_t and s_t denote demand and supply shocks while r_t denotes interest rate. φ measures the ratio between the responses of output and inflation to a monetary policy shock. This is generally referred as the inverse slope of the aggregate supply (AS) curve. Similarly, the parameter ω measures the slope of the aggregate demand (AD) curve. According to Equations 2 and 3, demand and supply shocks are considered as primary sources of exogenous disturbances in the economy and therefore policy responses are extremely crucial. Demand shock moves output and inflation in the same direction while supply shock moves them in opposite directions and creates a policy dilemma (Cecchetti and Ehrmann, 2002). Supply shocks will force the monetary authorities to face a trade-off between the variability of output and inflation in the long-run. This trade-off can be used to construct an efficiency frontier known as the "Taylor Curve" that traces minimum points of variability of inflation and output.

Combining Equations 2 and 3, we can derive the optimal policy of the Central Bank as given in Equation 4. Accordingly, the interest rate set by the policymakers is a linear function of demand and supply shocks. In the presence of both shocks, the policymakers need to behave optimally to minimize any welfare loss.

$$r_t = \; ad_t + bs_t \qquad (4)$$

After substituting Equation 3.4 into Equations 2 and 3, we can obtain the variances of output (σ_y^2) and inflation (σ_π^2) as given in Equations 5 and 6.

$$\sigma_y^2 = (a-1)^2\varphi^2 + (1+\varphi b)^2\sigma_s^2 \quad (5)$$
$$\sigma_\pi^2 = (1-\varphi)^2 + (\omega + b)^2\sigma_s^2 \qquad (6)$$

Similarly, after substituting Equations 5 and 6 into Equation 1 and minimizing the loss function with respect to a and b, we will derive the following solution.

$$a = 1 \qquad (7)$$
$$b = \frac{a(\varphi-\omega)-\varphi}{a(1-\varphi^2)} + \varphi^2 \quad (8)$$

The solution 7 indicates policymakers completely offset demand shocks one for one on both output and inflation. However, according to Solution 8, the reaction of monetary policy to supply shocks is complicated because they generate a trade-off. It further shows the degree of monetary reaction depends on structure of the economy as measured by ω, φ and policymakers' aversion to inflation variability (λ). Substituting Solutions 7 and 8 into Equations 5 and 6, we can derive the ratio between the variability of inflation and output. This ratio shows the unit cost of output variability in terms of inflation variability, which is generally described as the Taylor curve.

$$\frac{\sigma_y^2}{\sigma_\pi^2} = \left[\frac{\lambda}{\varphi(1-\lambda)}\right]^2 \qquad (9)$$

According to Equation 9, the trade-off between the variability of output and inflation depends on the value of λ and φ. Allowing λ to vary between zero and one, we can derive output-inflation variability frontier. The shape of this frontier depends on 1/φ but unaffected by ω. The implication is that if the value of φ is higher, then any reduction in inflation variability results in larger increases in output variability. Similarly, when policymakers are concerned only with output variability (λ= 0), the ratio between variability of output and inflation will be equal to zero. In contrast, if policymakers place their entire attention only on minimizing variability of inflation, then the ratio between variability of output and inflation will be equal to infinity. In order to derive the Taylor curve relationship given in Equation 9, we need to first estimate the parameter of λ. In the case of Sri Lanka, many empirical studies used plausible values for λ. However, in this study, we will estimate λ for both full sample and sub-sample periods using a SVAR approach. Additionally, we need to estimate φ and ratio between the variability of output and inflation. For this purpose, our baseline assumption is that policymakers are interested in minimizing the variability of inflation and output.

This study follows the methodology used by Cecchetti and Ehrmann (2002) to estimate the variability of output and inflation. Accordingly, we define the variability of output as squared deviations of actual output from the potential output (y*). The potential output will be estimated using the Hodrick-Prescott (HP) filter approach. Similarly, the variability of inflation is defined as the squared deviations of actual inflation from the targeted level of inflation (π*). We will consider the average inflation rate registered for each regime as targeted inflation. As Sri Lanka registered monthly inflation rate of more than 20 percent during the 1980s and 1990s, assuming the targeted level of inflation as 5 percent can be viewed as an unrealistic policy goal during these periods. Thus, throughout the analysis, we will consider average inflation in each regime as a targeted inflation. The procedures that will be applied to estimate the required coefficients of the Taylor curve Equation 9 are described in Section 3.2.3.

3.2.2 Estimating the Persistence of Variability of Output and Inflation to Demand and Supply Shocks

This section describes the approach that will be used to explore the persistence of the variability of output and inflation in response to demand and supply shocks. In order to identify the trend of demand and supply shocks, we have to first estimate the aggregate demand and Phillips curve equations. For this purpose, we follow the aggregate demand and supply model developed by Ndou et al. (2013). Equation 10 represents the aggregate demand equation, where the output gap is a function of its own lags, lags of the inflation rate, lags of the nominal interest rate, lags of the exchange rate and lags of the deviation of oil prices from the potential level. The potential level of the oil prices is estimated using the HP filter approach.

$$y_t = c_{1,0} + \sum_{i=1}^{n} \delta_{1,t}\, y_{t-1} + \sum_{i=1}^{n} \beta_{1,t}\, \pi_{t-1} + \sum_{i=1}^{n} \kappa_{1,t}\, i_{t-1} + \sum_{i=1}^{n} \phi_{1,t}\, exr_{t-1} + \textstyle\sum_{i=1}^{n} \psi_{1,t}\, oil_{t-1} + \varepsilon_{1,t} \qquad (10)$$

$$\pi_t = c_{2,0} + \sum_{i=1}^{n} \delta_{2,t}\, y_{t-1} + \sum_{i=1}^{n} \beta_{2,t}\, \pi_{t-1} + \sum_{i=1}^{n} \phi_{1,t}\, exr_{t-1} + \textstyle\sum_{i=1}^{n} \psi_{1,t}\, oil_{t-1} + \varepsilon_{2,t} \qquad (11)$$

Meanwhile, Equation 11 denotes the Phillips curve equation where the inflation is a function of its own lags, lags of the output gap, lags of the exchange rate and lags of the oil prices gap. In both equations, the exchange rate is included to capture the impact of openness on aggregate demand and supply. $\varepsilon_{1,t}$ and $\varepsilon_{2,t}$ are the demand and supply shocks. We will first estimate a VAR model in the form of above two equations for both full sample and sub-sample analysis. Thereafter, we will use the impulse response functions (IRFs) to investigate the persistence of the variability of output and inflation to demand and supply shocks.

3.2.3 Estimating the Impact of Monetary Policy on Output and Inflation

To estimate the value for φ given in Equation 9, we need to examine the impact of monetary policy on output and inflation. For this purpose, we use the SVAR model developed by Kim and Roubini (2000) to identify monetary policy shocks from a combination of long-run and short-run restrictions. A detailed description of the SVAR model is presented below.

Assume the economy is described by a structural form equation as follows,

$$G(L)x_t = e_t \qquad (12)$$

where $G(L)$ is a matrix polynomial in the lag operator of L, x_t is an (n×1) vector of variable, and e_t is an (n×1) vector of structural disturbances serially uncorrelated with constant variance, var(e_t) = Λ. And Λ is a diagonal matrix and diagonal elements represent variances of structural disturbances assumed to be uncorrelated. For simplicity, we have omitted the constant terms in the model. The reduced form equation of VAR can be estimated as given in Equation 13.

$$x_t = B(L)x_t + u_t \qquad (13)$$

where $B(L)$ is a k×k matrix polynomial (without the constant term) in lag operator L. The lag operator of B(L) can be written as $B(L) = I_k - B_1L - B_2L^2 - \cdots B_pL^p$. The variance of u_t implies that E $(u_t u_t^i) = \Sigma$.

There are several ways of recovering the parameters in the structural form equations from the reduced form equations. Econometric methods including the method proposed by Sims (1980) provide restrictions only on contemporaneous structural parameters. However, the generalized SVAR suggested by Blanchard and Watson (1986), and Sims (1986) allows nonrecursive structures while providing restrictions only on contemporaneous structural parameters. Let G_0 be the coefficient matrix (non-singular) on L^0 in G(L), that is, the contemporaneous coefficient matrix in the structural form. And let G^0(L) be the coefficient matrix in G(L) without contemporaneous coefficient G_0 (see Equation 14). Then, the parameters in the structural form equation and those in the reduced form equation can be related by Equation 15.

$$G(L) = G_0 + G^0(L) \qquad (14)$$

$$\mathrm{B(L)} = -G_0^{-1}\mathrm{G}^0(\mathrm{L}) \qquad (15)$$

The structural disturbances and the reduced form residuals are related by $\mathrm{e_t = G_0U_t}$. Accordingly, the relationship between reduced form and structural model can be expressed as follows:

$$\Sigma = G_0^{-1}\Lambda G_0^{-1} \qquad (16)$$

As per Equation 16, there is n×(n+1) number of free parameters that must be estimated. Since Σ contains n×(n+1)/2 parameters, we need at least n×(n+1)/2 restrictions. By normalizing diagonal elements of G_0 to 1's, we need at least n×(n+1)/2 restrictions on G_0 to achieve identification. In the structural VAR approach, G_0 can be any structure if it has enough restrictions. We use a similar set of six variables as used by Cecchetti and Ehrmann (2002) to estimate a SVAR model. The six variables are represented in vector X_t:

$$X_t = i_t, y_t, \pi_t, E_t, O_t, FF_t \qquad (17)$$

where i_t is the short-term policy interest rate, y_t is output, π_t is the price level expressed by the Consumer Price Index (CPI), E_t is the exchange rate and O_t is the global price of oil. FF_t is the Federal funds rate. Of the six variables, the global price of oil and the Federal funds rate represent the foreign variables, while the real GDP, CPI, short-term interest rate and exchange rate represent the domestic variables. However, due to unavailability of short-term policy interest rate data for long time series, we use 3-months Treasury Bill rates. Studies such as Kim and Roubini (2000) and Brischetto and Voss (1999) have established that these six variables are adequate to analyze the monetary policy framework of a small open economy. The SVAR model that will be estimated to analyze the impact of monetary policy on inflation and output is given as follows:

$$\begin{bmatrix} i_t \\ y_t \\ \pi_t \\ E_t \\ O_t \\ FF_t \end{bmatrix} = \begin{bmatrix} \delta_1 \\ \delta_2 \\ \delta_3 \\ \delta_4 \\ \delta_5 \\ \delta_6 \end{bmatrix} + \begin{bmatrix} \varphi_{11} & \varphi_{12} & \varphi_{13} & \varphi_{14} & \varphi_{15} & \varphi_{16} \\ \varphi_{21} & \varphi_{22} & \varphi_{23} & \varphi_{24} & \varphi_{25} & \varphi_{26} \\ \varphi_{31} & \varphi_{32} & \varphi_{33} & \varphi_{34} & \varphi_{35} & \varphi_{36} \\ \varphi_{41} & \varphi_{42} & \varphi_{43} & \varphi_{44} & \varphi_{45} & \varphi_{46} \\ \varphi_{51} & \varphi_{52} & \varphi_{53} & \varphi_{54} & \varphi_{55} & \varphi_{56} \\ \varphi_{61} & \varphi_{62} & \varphi_{63} & \varphi_{64} & \varphi_{65} & \varphi_{66} \end{bmatrix} \begin{bmatrix} i_{t-i} \\ y_{t-i} \\ \pi_{t-i} \\ E_{t-i} \\ O_{t-i} \\ FF_{t-i} \end{bmatrix} + \begin{bmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \\ \varepsilon_{3t} \\ \varepsilon_{4t} \\ \varepsilon_{5t} \\ \varepsilon_{6t} \end{bmatrix}$$

The short-run restrictions specified for the monetary policy analysis are given as follows:

$$G_0 \times X_t = \begin{bmatrix} \varepsilon_i \\ \varepsilon_y \\ \varepsilon_\pi \\ \varepsilon_E \\ \varepsilon_O \\ \varepsilon_{FF} \end{bmatrix} = \begin{bmatrix} 1 & \varphi_{12} & \varphi_{13} & \varphi_{14} & 0 & 0 \\ \varphi_{21} & 1 & \varphi_{23} & \varphi_{24} & \varphi_{25} & 0 \\ 0 & \varphi_{32} & 1 & 0 & \varphi_{35} & 0 \\ \varphi_{41} & \varphi_{42} & \varphi_{43} & 1 & \varphi_{45} & \varphi_{47} \\ 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} e_i \\ e_y \\ e_\pi \\ e_E \\ e_O \\ e_{FF} \end{bmatrix}$$

The interest rate equation is interpreted as the policy reaction function of the Central Bank in which output, inflation and exchange rate are included. The output is expressed in the second equation where we assumed output is a function of four variables, namely, oil price, inflation, interest rate and exchange rate. Since price expectation in Sri Lanka depends on factors such as oil price to a considerable extent, we have included variable on oil prices in our forward-looking monetary policy model. The third equation includes the adverse impact of global oil prices on domestic inflation. The exchange rate is considered as an information market variable that reacts quickly to all relevant economic disturbances. Thus, the structural equation for exchange rate shows it has been contemporaneously affected by all the variables included in the model. Equations five and six represent global price of oil and Federal funds rate respectively and both are independent of all other variables. The Federal funds rate is used as a proxy for global financial conditions.

3.2.4 Estimating the Contribution of Monetary Policy in Macroeconomic Performance

As second specific objective of this study is to examine the contribution of monetary policy on observed changes in macroeconomic performance, in this section, we will describe the procedures that will be followed to measure the macroeconomic performance. For this purpose, we will adopt the methodology used by the Taylor (2013) and Cecchetti and Ehrmann (2002). Accordingly, we will measure the macroeconomic performance using the welfare loss function of the Central Bank that shows how well the Central Bank stabilizes both inflation and output subject to various shocks. Moreover, we will assume that the Central Bank chooses an optimal monetary policy. The optimal monetary policy is defined as a policy that minimizes the variability of the Central Bank's ultimate objectives from their target (Fuhrer, 1997). This implies that the Central Bank focuses on levels of inflation and output relative to potential and therefore adjusts its policy rates to minimize the variability of output and inflation.

$$P_i = \lambda Var(\pi_i) + (1-\lambda) Var(y_i) \quad 0 \leq \lambda \geq 1 \quad (18) \qquad (i=1,2,3,\ldots\ldots \text{periods})$$

$$\Delta P_{it} = P_{it-1} - P_{it} \quad (19)$$

The macroeconomic performance that will be estimated in this study is given by the variability of output and inflation weighted by λ value (Equation 18). Since we seek to compare welfare loss across different policy regimes, we will not consider a discount factor in the loss function. Meanwhile, the changes in the macroeconomic performance will be measured as given in Equation 19. $\Delta P_{it} > 0$ shows an improvement in macroeconomic performance. However, to allow for an appropriate comparison across periods, we need to assume λ to be constant over the periods. Allowing different values for λ may lead to the wrong conclusion. For instance, ΔP can show a slowdown in macroeconomic performance even when variability of both output and inflation remain at the lowest level.

3.2.5 Analytical Framework

Given that our sample involves the period around the introduction of the flexible exchange rate in January 2001 and the end of civil war in 2009, we place special focus on the presence of the structural break in the conduct of monetary policy in Sri Lanka. The selection of the start of the period as 1980 corresponds with the introduction of a monetary targeting framework in Sri Lanka. The entire sample period of the study will be divided into three sub-samples. As the country adopted a flexible exchange rate since January 2001, we consider the first sample period from January 1980 to December 2000. The civil war that started in 1983 ended in May 2009, therefore, the second and third study period runs from January 2001 to May 2009 and June 2009 to December 2017 respectively. The analysis will be conducted for both full sample and sub-sample periods.

As many time series variables, in general, contain the unit root, in the first step towards empirically estimating the Taylor curve and the Taylor rule, we will examine the stationary properties of all the series considered in this study. This will be tested using the Augmented Dickey-Fuller (ADF), Phillips-Perron (PP) and Kwiatkowski-Phillips-Schmidt-Shin (KPSS) tests. In order to select the order of augmentation in ADF regression, we will use the Akaike Information Criteria (AIC) with default lag order. Further, we will use the default settings of Bartlett Kernel and Newey-West Bandwidth for KPSS tests. The unit root test will be carried out at both levels and first differences of each series. Further, the test will be conducted with intercept, and with intercept and trend. The form of ADF regression to be adopted in this study can be expressed as follows.

$$\Delta y_t = \phi y_{t-1} + \delta + \sum_{i=1}^{k} \Delta y_{t-1} + \varepsilon_t \qquad (20)$$

$$i = 1, 2, 3 \ldots\ldots\ldots k$$

where, y_t is the individual time series, $\Delta y_{t,}$ is the first difference of the series y_t. ($\Delta y_t = y_t - y_{t-1}$). k is the lag order, t is the linear time trend. ε_t is serially uncorrelated random term and 'δ' is a constant. The above ADF test suggests that a time series is said to be non-stationary if the

ADF test revealed that the null hypothesis of $\phi = 0$ could not be rejected. Meanwhile, the Phillips-Perron (1988) tests is a modification of ADF's procedures. The ADF tests assume that residuals are statistically independent with constant variance. However, the PP tests assume that error term need not to be serially uncorrelated. Meanwhile, the KPSS test takes $y_t \sim I(0)$ as the null and $y_t \sim I(1)$ as the alternative hypothesis. The KPSS statistic is estimated using the Equation 21. Where squaring ensures a positive test statistic and scaling by T^{-2} is required for $\sum_{t=1}^{T} S_t^2$ to have a valid asymptotic distribution. $\widehat{\sigma^2}$ is the variance estimator.

$$K = T^{-2} \frac{\sum_{t=1}^{T} S_t^2}{\widehat{\sigma^2}} \qquad (21)$$

After the order of integration is established, in the second step we will estimate the unrestricted VAR to identify the optimal lag length to be used in this study. The optimal lag length will be selected by examining the lag structure in the unrestricted VAR. Generally, VAR lag order selection is based on the following criteria: Sequential modified LR test statistic (LR), Final Prediction Error (FPE), Akaike information criterion (AIC), Schwarz Information Criterion (SIC), and Hannan-Quinn Information Criterion (HQIC). In the above options, the model that best fits the data is the one that minimizes the Information Criterion Function (ICF). As the SIC is widely known as a parsimonious model and selects smallest possible lag length, we will use it to select optimal lag length in this study (Babu and Rao, 2004).

4. Empirical Results and Discussion

In this Section, we will first examine the stationary properties of the variables and then will study the Taylor curve relationship in Sri Lanka. Next, we will study how the variability of output and inflation moved in response to both demand and supply shocks while exploring the contribution of monetary policy to observed changes in macroeconomic performance across different monetary policy regimes.

4.1 Testing for Unit Roots

As this study mainly uses time series monthly data, examining the order of integration of the variables is essential. The graphical representation of variables considered in this study illustrated series such as Consumer Price Index (CPI) and exchange rate (EXR) have a clear trend, but other variables do not show any trend over the study period (see Figure A1 in Appendix A). Therefore, we include both ‘trend’ and ‘intercept’ components in examining unit root tests. The stationary properties of all the series are examined using the ADF, PP and KPSS tests. The results of unit root tests for the full sample period are presented in Table 1. It confirms that four variables are non-stationary since the null hypothesis of the ADF, PP and KPSS tests cannot be rejected at 5 percent level of significance. However, it is found that the remaining variables are integrated with order one in first differences. The results drawn from the ADF, PP and KPSS tests are consistent for all variables. As this study places much attention on the presence of structural break in the conduct of monetary policy, the stationary properties of all variables need to be investigated for sub-sample periods as well. The results of unit root tests for sub-sample periods are presented in the Appendix Table B1 to B3. As the SVAR model does not account for time series properties of the data, we will include all variables in their level form though they display mixed order of integration to estimate SVAR model (MacDonald, Mullineux, and Sensarma, 2011).

Table 1: Unit Root Tests – Levels and First Differences (Full Sample)

Variable	ADF Test				PP Test				KPSS Test				Order of Integration
	Levels		First Differences		Levels		First Differences		Levels		First Differences		
	Intercept	Trend and Intercept	Intercept	Trend and Intercept	Intercept	Trend and Intercept	Intercept	Trend and Intercept	Intercept	Trend and Intercept	Intercept	Trend and Intercept	
CPI	4.9022	-0.6368	-11.0026*	-16.8477*	4.2141	-0.6790	-17.5240*	-17.6984*	2.4005	0.6366	1.5799	0.0913*	I (1)
FOODPI	-1.6401	-2.7581	-9.0853*	-9.0751*	-1.3372	-2.4072	-12.6145*	-12.6012*	1.7343	0.2967	0.0693*	0.0569*	I (1)
RGDP	-4.6868*	-4.7417*	-9.8796*	-9.8748*	-4.3089*	-4.3365*	-13.9667*	-13.9462*	0.1279*	0.0987*	0.0677*	0.0462*	I (0)
TBILL	-2.9338**	-3.7319**	-13.6918*	-13.6981*	-3.0159**	-3.7901*	-23.2074*	-23.2056*	0.9325	0.1844**	0.0605*	0.0234*	I (0)
EXR	0.6854	-2.7292	-8.9320*	-9.0061	1.0176	-2.2981	-14.8817*	-14.9416*	2.6167	0.3589	0.2190*	0.0409*	I (1)
OIL	-2.0482	-2.9758	-14.1337*	-14.1212*	-1.3093	-2.4049	-13.6507*	-13.6361*	1.5246	0.3484	0.0785*	0.0619*	I (1)
FB	-2.7957***	-3.4580**	-7.3576*	-7.3784*	-3.6453*	-4.0928*	-17.2131*	-17.2032*	1.5299	0.1675***	0.1027*	0.0376*	I (0)
FED	-2.7802***	-6.6428*	-14.5323*	-14.4668*	-2.1425	-3.2827***	-12.9329*	-13.0172*	2.1809	0.1731*	0.0939*	0.0307*	I (0)

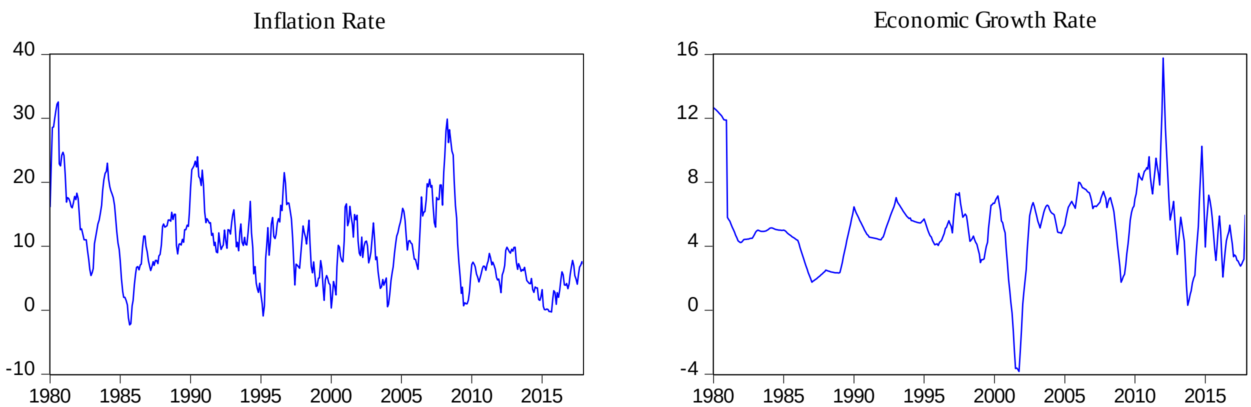
Notes: *indicates significance at 1%, ** indicates significance at 5%, *** indicates significance at 10%.

Source: Author's Calculation

4.2 The Examination of the Taylor Curve Relationship for Sri Lanka

Before starting to examine the Taylor curve relationship, which shows the trade-off between the variability of output and inflation, we first looked at the movements of the inflation and economic growth in both their level and first differences forms. As per Figure 1, both series do not exhibit any trend over the periods. The Sri Lankan economy registered more than 30 percent of inflation rate during the early 1980s. However, this trend declined till 1985 and thereafter escalated during the early part of the 1990s. These trend shows that Sri Lanka experienced very high levels of inflation during the 1980s and 1990s, suggesting that inflation variability must have had a much lower weight in the policymaker’s loss function. However, after late 2009, the inflation rate was at single-digit levels. Meanwhile, the economy witnessed an average growth rate of five percent during the study period. Especially, high levels of economic growth can be observed following the end of the civil war in 2009. However, the fluctuations in inflation rate are higher than for economic growth rate.

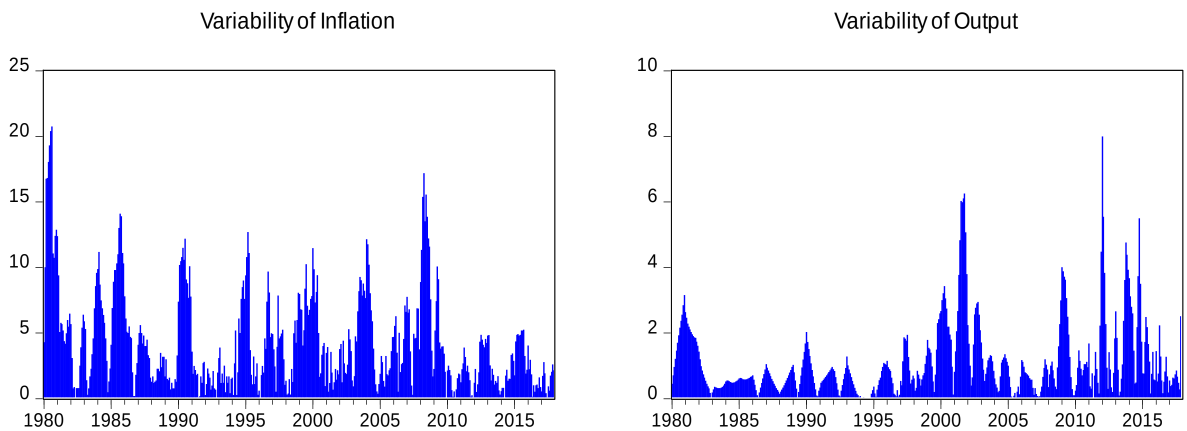
Figure 1: Movements of the Inflation and Output Growth in Levels



Source: Author’s Calculation

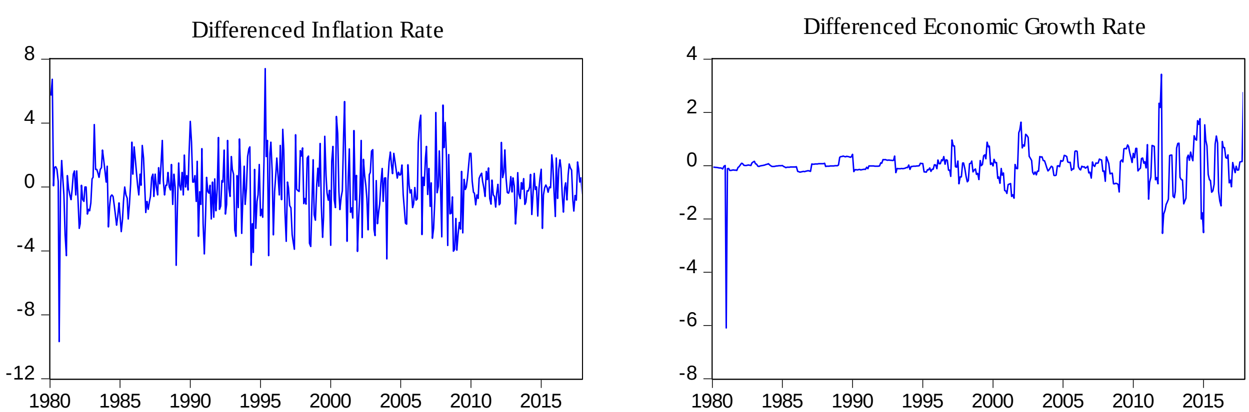
As this section focuses on examining the trade-off between the variability of inflation and output, next we will study how the variability of inflation and output growth changed during the period 1980-2017. From Figure 2, several conclusions can be drawn. First, over this period the variability of inflation has decreased while the variability of output has increased, implying an unambiguous improvement in macroeconomic performance. Inflation variability fell during the early 1990s and 2000s. After 2012, the country witnessed inflation variability of less than five percent. This indicates that the Central Bank has predominantly placed a higher level of importance on implicit inflation targeting. However, we can also see that monetary policy was less effective in reducing output variability during the periods 1997-2005 and then from 2010-2015. This further shows that low inflation variability was attained at the expense of increased output variability.

Figure 2: Movements of the Variability of Inflation and Output Growth



Source: Author's Calculation

Figure 3: Movements of the Inflation and Output Growth in First Differences



Source: Author's Calculation

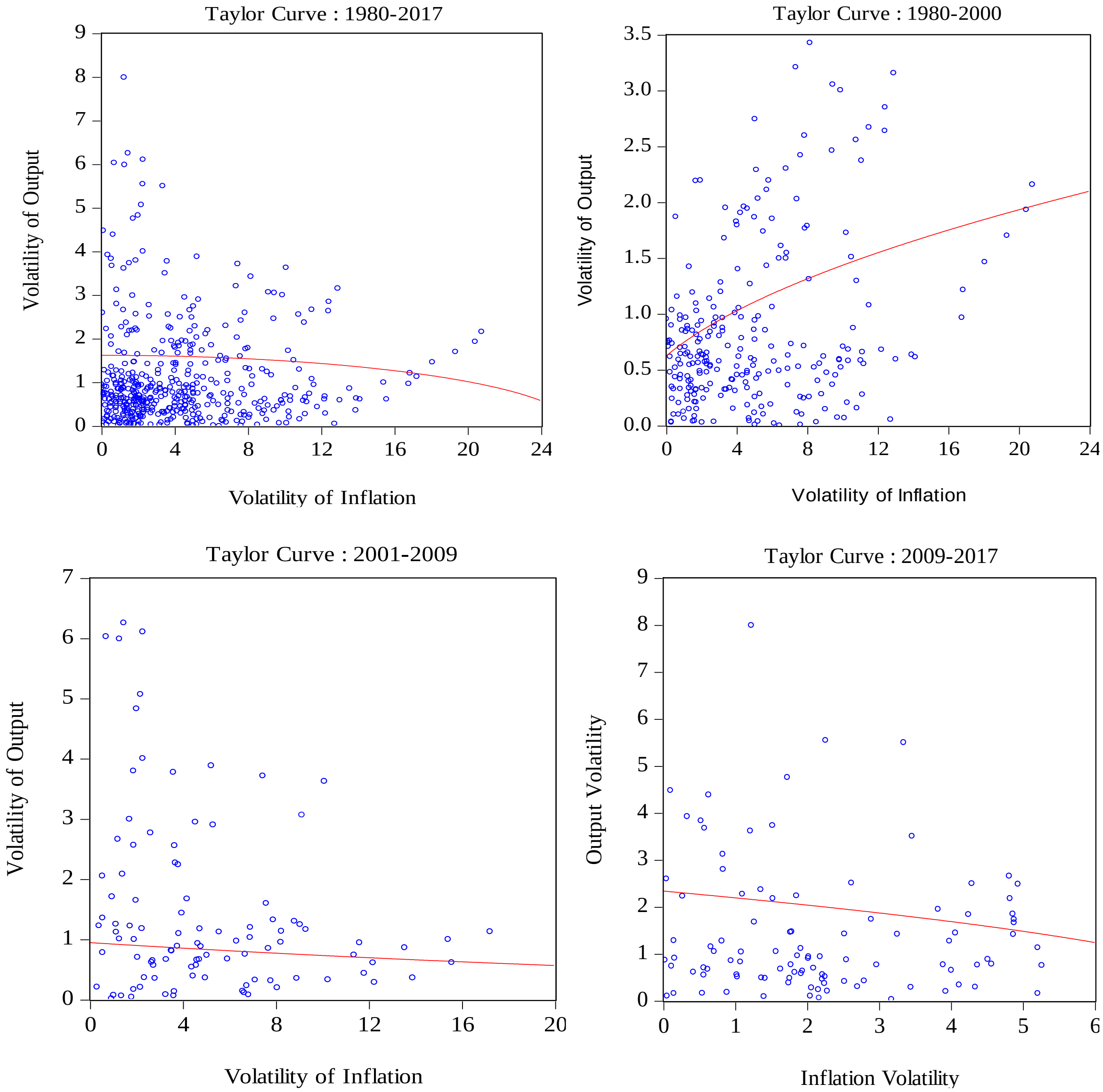
However, for comparison purposes, we examined movements of inflation and output growth at their first differences. According to Figure 3, the volatility of inflation is much higher compared to that of output growth. Although the high level of volatility in inflation could be observed prior to 2010, the trend of volatility diminished afterward. This implies that the Sri Lankan economy experienced a transition from relatively higher volatile inflation regimes at the beginning of the study period to more stable regimes thereafter. The reduced volatilities in inflation could be largely supported by the low level of external and domestic supply shocks, a more stable economic structure and the implementation of better monetary policy (Jegajeewan, 2016). However, the examination of these factors is beyond the scope of this study. It is also noted that the volatility of output growth was almost stable till the end of 1995. However, this volatility increased gradually after 1996. Notably, much more volatility could be seen after 2010. Thus, the conclusion drawn from these figures is in line with that of Figures 2.

As a preliminary step to identify the Taylor curve relationship, we first analysed the relationship between the variability of inflation and output for both the full sample and sub-samples using the scatter diagram. The Figure 4 comprises four panels: the first panel is for the full sample period 1980-2017; the second panel is the period 1980-2000, immediately after the introduction of monetary targeting framework; the third panel is the period 2001-2009, just after the introduction of a flexible exchange rate; the final panel is the period 2009-2017, immediately after the end of the civil war. In the presence of shocks to output and inflation, the policymakers should maintain the variability of inflation and output at the lowest levels to maximise the loss function of the Central Bank shown by Equation 1.

As shown in Figure 4, the patterns of the Taylor curve relationships have changed across different monetary policy regimes. The negative trade-off can be established in all the periods, except 1980-2000. However, these diagrams do not provide clear evidence to understand the nature of the relationship. Therefore, we calculated the constant correlation between the variability of inflation and output, and the results are presented in Table 2. What stands out in Table 2 is that the lowest growth rate was witnessed when variability of both inflation and output registered at the higher level. This is particularly notable during the period 2001-2009 where the economy registered its lowest average growth rate while recording the highest level of variability in both inflation and output growth relative to other periods[3]. This suggests that it is imperative to maintain the low level of fluctuations in inflation to attain the higher level of output growth. It is also evident that the economy witnessed the highest level of output growth during the periods in which the negative Taylor curve relationship is satisfied.

[3] The terms variability, volatility and variance are used interchangeably in this study.

Figure 4: The Pattern of the Taylor Curves in Sri Lanka



Source: Author's Calculation

It is also observed in Table 2 that monetary policy was optimal during the study period, except 1980-2000.[4] The positive correlation established during the period 1980-2000 suggest that the monetary authority in Sri Lanka has placed more weight on stabilizing both inflation and output. Although constant correlation coefficients provide valuable evidence with respect to the nature of

[4] According to Taylor (1999), monetary policy is optimal when the trade-off between the variability of output and inflation is negative. But, according to Friedman (2006), if the trade-off between the variability of inflation and output is positive, then monetary policy is characterized as suboptimal.

the relationship, estimating correlation coefficients as a time-varying process would provide more insights on how the Taylor curve relationship has evolved over time. For this purpose, we estimated rolling window correlations for years 1 to 4 for both full sample and sub-samples. However, in this section, we focus only on smoothed correlations using a rolling window of 2 years. This approach assumes that the CBSL implemented its monetary policy in a forward-looking manner where the real effects of changes in the interest rates on the economy will be taken place after 2 years. The correlations for the remaining years are given in Appendix C.

Table 2: The Trade-off between the Variability of Inflation and Output

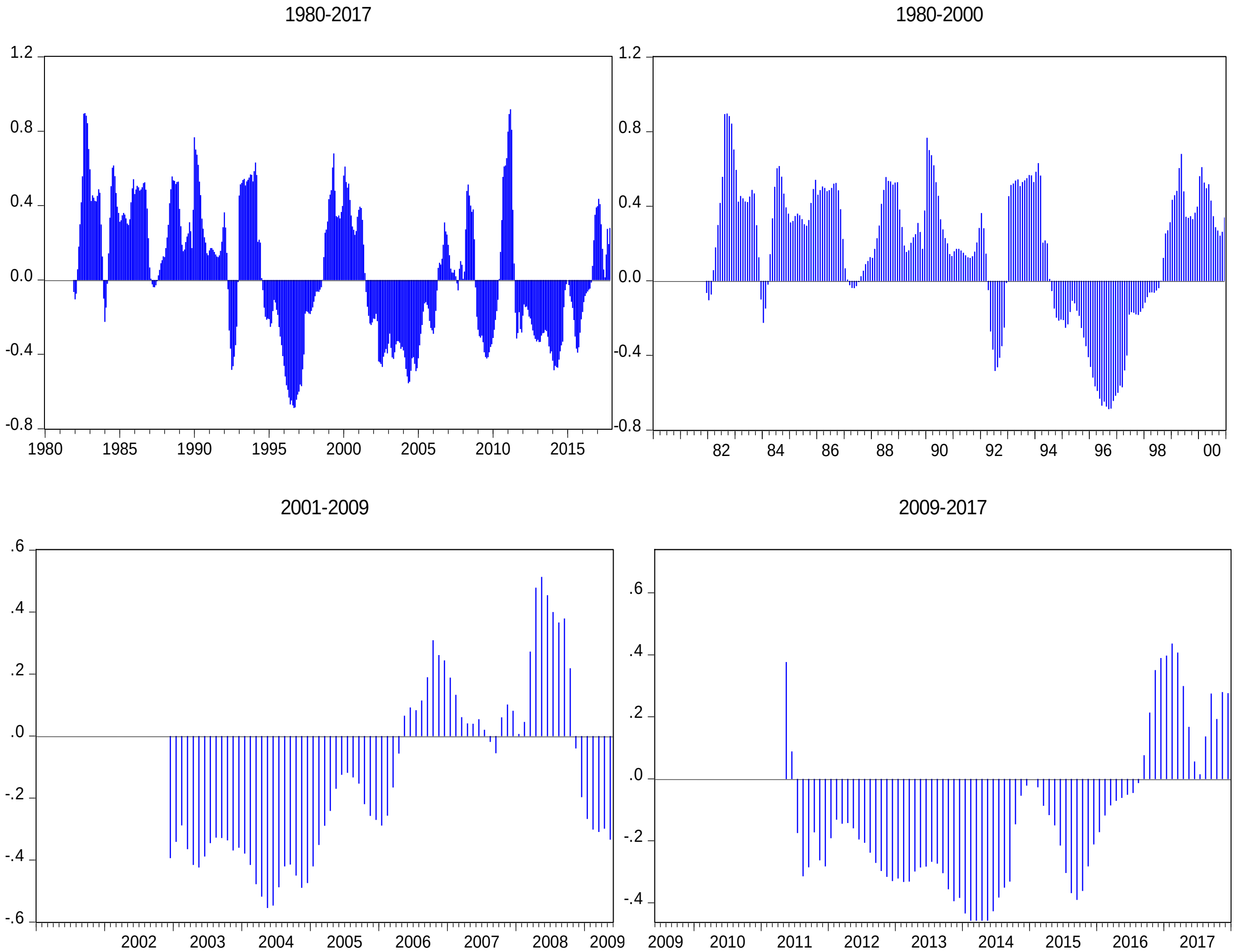
Periods	**Average**		**Correlation**	**Average**		**Monetary Policy Stance**
	Inflation Variability	Output Variability		Inflation Rate	Economic Growth Rate	
1980-2017	4.3282	1.1085	-0.0384	10.4605	5.2020	Optimal
1980-2000	4.9142	0.8408	0.2908	11.8086	5.0697	Suboptimal
2001-2009[5]	**5.0341**	**1.4474**	**-0.1991**	**12.5638**	**4.9079**	Optimal
2009-2017	**2.1949**	1.4411	-0.1068	4.9846	**5.8001**	Optimal

Source: Author's Calculation

It is apparent from the time-varying correlations analysis shown in Figure 4.5 that monetary policy during the study period was operating at both optimal and suboptimal levels. The correlation was positive during the period 1980-1994 except for 1992, indicating monetary policy was suboptimal. However, the existence of a negative correlation between the variability of inflation and output showed that monetary policy was optimal during the period 2001-2005. Although this relationship supports the presence of a negative trade-off between both variabilities, this relationship has changed in the later part of the study period. Most notably, the study found a positive correlation during the period 2006-2008, and the latter part of 2010. This positive relationship again observed from the third quarter of 2016, authenticating that monetary policy was suboptimal during these periods.

[5] Up to May 2009

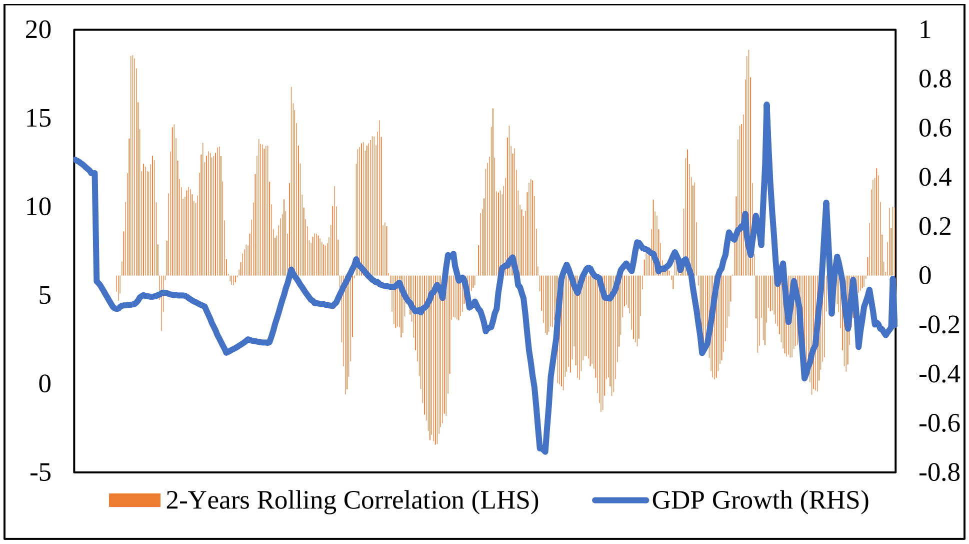
Figure 5: Time-Varying Rolling Correlation between Variability of Output and Inflation



Source: Author's Calculation

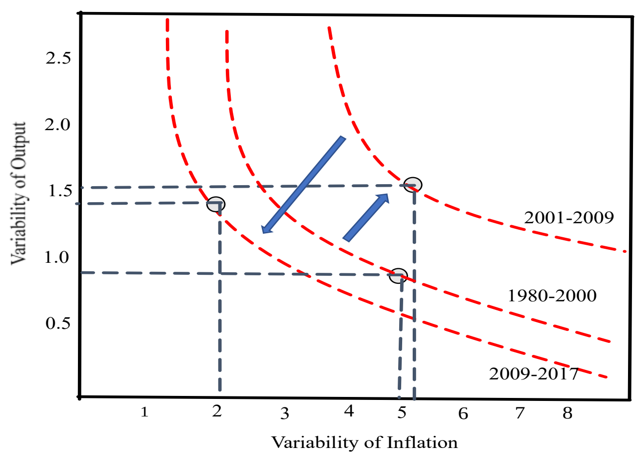
Although time-varying correlation analysis provided valuable insights about the nature of the relationship between the variability of output and inflation and the stance of monetary policy, it would be interesting to know how the patterns of the Taylor curves changed during the business cycles. For this purpose, we plotted the 2-years rolling correlation against to GDP growth rate (see Figure 6). We find that in most of the periods the positive trade-off between the variability of inflation and output is followed by a slowdown in output growth. This suggests that the suboptimal monetary policy could adversely affect the economic growth in Sri Lanka. We further investigate this relationship while deriving the Taylor curves using the average variability of inflation and output witnessed in respective policy regimes (see Figure 7).

Figure 6: Rolling Correlation of Volatilities and GDP Growth (1987-2017)



Source: Author's Calculation

Figure 7: Shifts in Taylor Curves in Sri Lanka



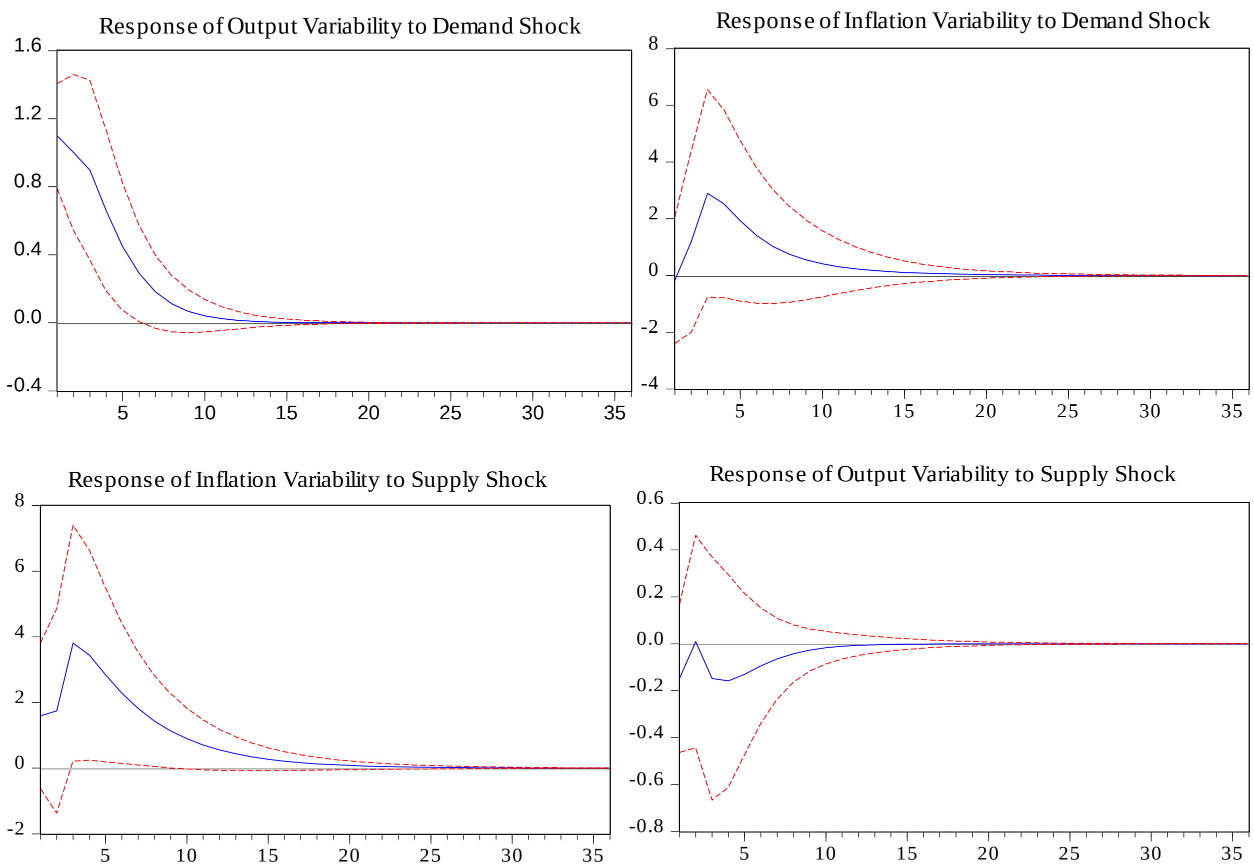
Source: Author's Calculation

As can be seen in Figure 7, the Taylor curve for the period 2001-2009 moved outward compared to that observed for the period 1980-2000. The increased fiscal and the balance of payments deficits, the sharp increase in energy prices and increased defense expenditure, notably during the period 2006-2009, could be the main causes that induced an outward shift in the Taylor curve. However, the study found that the distance between the origin and the Taylor curve was small in the post-war period, indicating monetary policy was most satisfactory in reducing the variabilities of output and inflation. In other words, the opportunity cost of reducing the variability of inflation in terms of output variability was low during the post-war period.

4.3 The Persistence of Variability of Output and Inflation to Demand and Supply Shocks

We extend our analysis to study how demand and supply shocks have affected the variability of output and inflation during the period under consideration. After estimating aggregate demand and Philips curve equations,[6] we estimated the IRFs to check how the variability of output and inflation reacted in response to demand and supply shocks. We used the generalized IRFs to deal with orderings of the variables.

Figure 8: Responses of the Variability of Output and Inflation to Demand and Supply Shocks



Source: Author's Calculation

The estimated IRFs are presented in Figure 8. The IRFs clearly show that both demand and supply shocks do not a have highly persistent impact on the variability of inflation and output, but they do have transitory effects. In case of output variability, both demand and supply shocks died out after 15 months. However, for inflation variability, the persistent was moderate where the demand and supply shock died out after 20 months and 24 months respectively. We conducted a similar

[6] Estimated equations are presented in Appendix D.

analysis for the sub-sample as well. The results are presented in Appendix D. Surprisingly, the sub-sample analysis showed that inflation was highly persistent in response to both demand and supply shocks. This is particularly evident during the periods 1980-2000 and 2001-2009. However, the former results contradicted the results carried out for the period 2009-2017. Most notably, during the period 2009-2017, both variabilities were not significantly affected by demand and supply shocks and therefore had substantially lower levels of persistence. This highlights that the Central Bank effectively reacted to minimize the adverse impact caused by these shocks on inflation and output during the post-war period. As the response of variability of inflation and output are not persistent, it can be concluded that deviations from the Taylor curve should be transitory if the Central Bank conducts its monetary policy efficiently.

4.4 The Contribution of Monetary Policy to Macroeconomic Performance in Sri Lanka

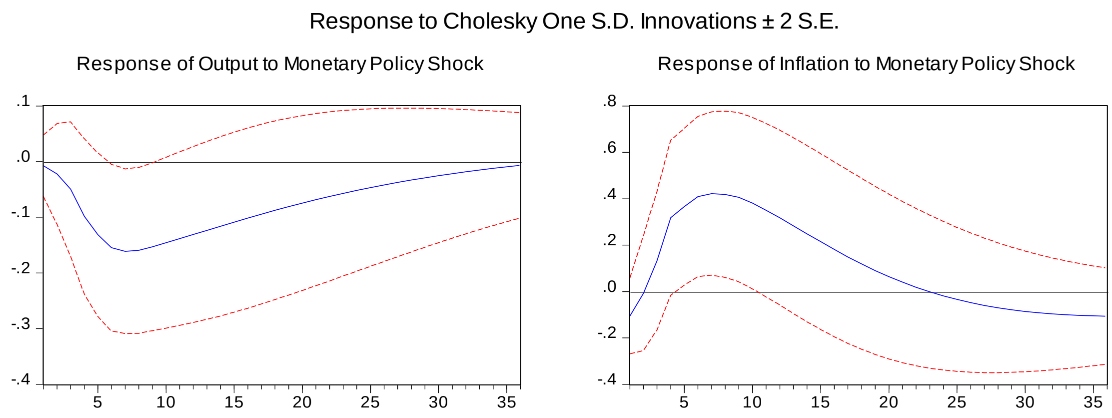
In this section, we will examine the contribution of monetary policy to observed changes in macroeconomic performance under different monetary policy regimes. The macroeconomic performance will be measured using the loss function of the Central Bank. We will assume that the Central Bank chooses an interest rate path to minimize its loss function. We will first estimate the welfare loss for both full sample and sub-sample and thereafter will compare across different policy regimes. However, to estimate welfare loss, we first need to investigate how the policy preferences of the Central Bank with respect to the stabilization of inflation have changed over time. For this purpose, we need to compute the inverse slope of the Aggregate Supply (AS) curve ($1/\varphi$).[7] With the purpose of estimating $1/\varphi$, we need to identify the impact of monetary policy on output and inflation. For this purpose, we will employ the SVAR approach. Having established a valid baseline SVAR model, the IRFs will be used to analyse the impact of monetary policy shock on output and inflation. Using the estimated value of $1/\varphi$ along with the ratio between the variability of output and inflation, we will estimate the preference parameter (λ) of the Central Bank. Afterward, we will use the estimated preference parameter to study the contribution of monetary policy to observed changes in macroeconomic performance in terms of welfare loss during the period 1980-2017. We will calculate the welfare loss for sub-sample as well. This will help to understand whether monetary policy in Sri Lanka became more efficient over the periods in terms of reducing welfare loss.

[7] The Taylor curve Equation 9 provides rationale for estimating the inverse slope of the AS curve.

4.4.1 The Estimation of Inverse Slope of the Aggregate Supply Curve

The IRFs shown in Figure 9 depicts the responses of output and inflation to monetary policy shock for the full sample period. The patterns of IRFs vary quite dramatically. Accordingly, an unexpected rise in short-term interest rates causes a statistically significant decline in output growth. It generated a U-shaped response of the output that bottoms-out after 7-10 months. The immediate reduction in output in response to contraction of monetary policy is compatible with previous findings of authors such as Disyatat and Vongsinsirikul (2003), Arin and Jolly (2005), and Perera and Wickramanayake (2013).

Figure 9: Responses of Output and Inflation to Monetary Policy Shock (1980-2017)

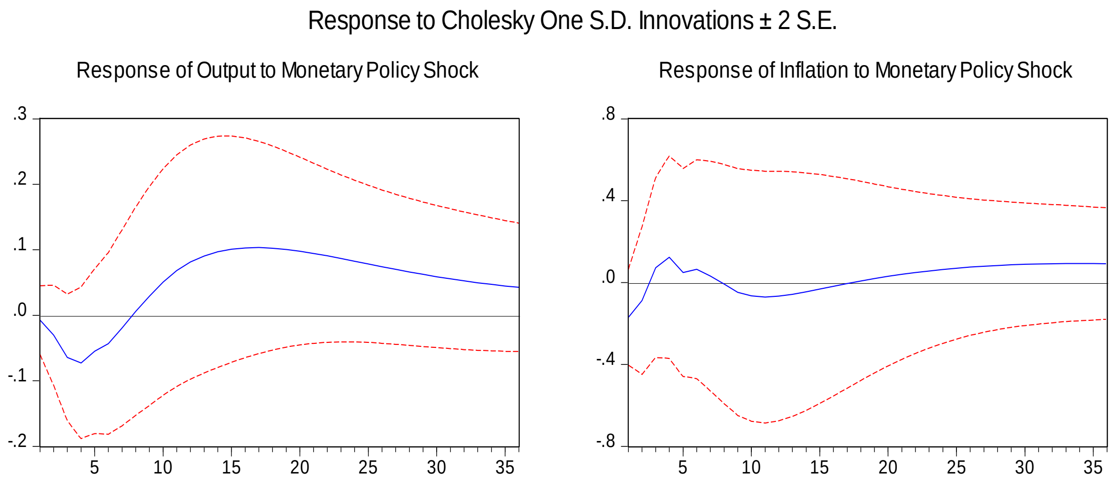


Source: Author’s Calculation

The response of inflation to a positive interest rate innovation is positive until the end of an 8 months period but thereafter gradually falls. This finding challenges the theoretical literature that is referred to as a ‘price puzzle’. However, the results are consistent with previous empirical literature (Leeper, Sims, and Zha (1996), Morsink & Bayoumi (2001), Arin & Jolly (2005) and Perera & Wickramanayake (2013)). Although there is modest evidence that monetary policy shock has produced a much larger response in inflation compared to output, the results are far from conclusive.

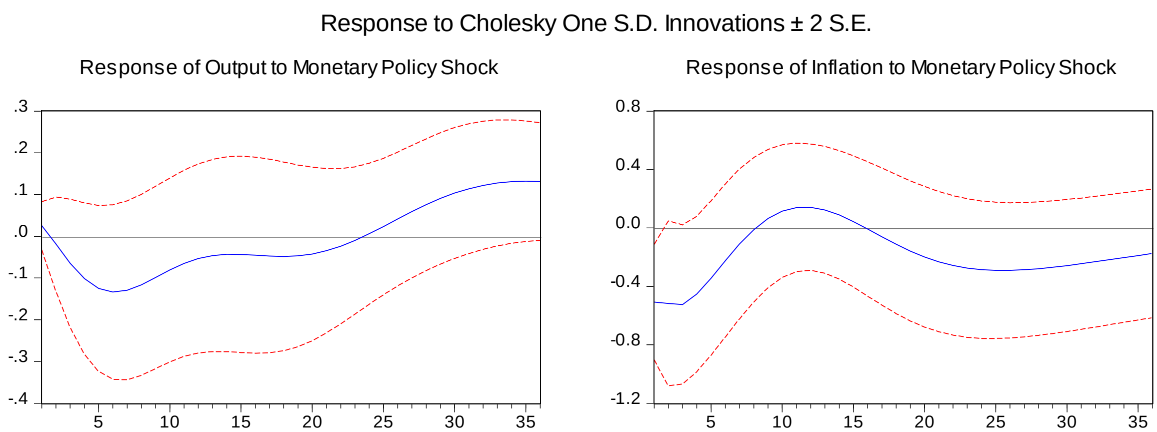
We also studied the impact of monetary policy on output and inflation for sub-sample periods. Although we found that positive innovation in monetary policy adversely affected output level in the short-term, the empirical price puzzles can be seen in sub-sample as well. As shown in Figures 10 to 12, a positive monetary policy shock increased inflation at least in the short-run but it feels after a 7 to 8 months period in all the regimes. Using the estimated IRFs, we calculated the maximum impact of monetary policy shock on inflation and output for both full sample and sub-sample. The results are presented in Table 4.3. It also reports the estimated inverse slope of the AS curve (φ). We will use the φ to calculate the policymaker's preferences. The interesting aspect here is that the magnitude of the estimated φ appears to be different across different policy regimes.

Figure 10: Responses of Output and Inflation to Monetary Policy Shock (1980-2000)



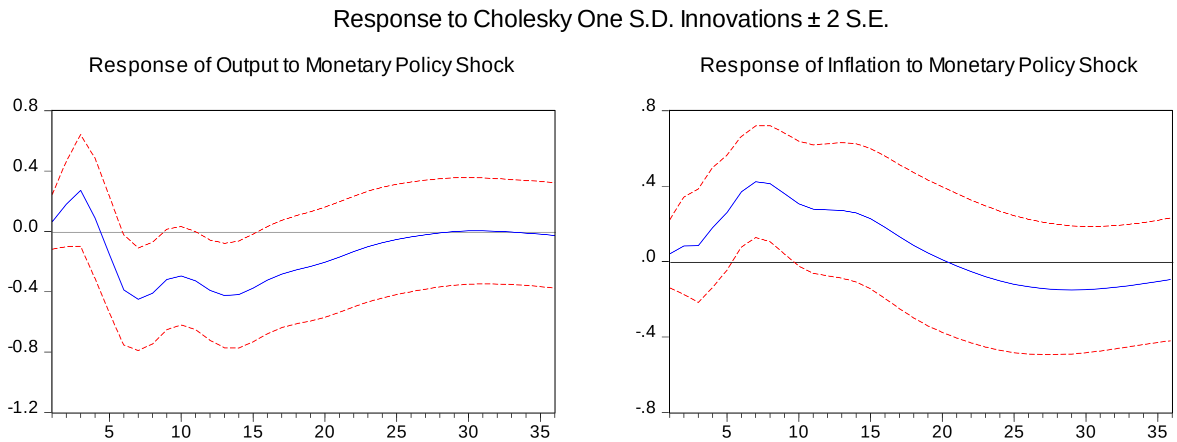
Source: Author’s Calculation

Figure 11: Responses of Output and Inflation to Monetary Policy Shock (2001-2009)



Source: Author’s Calculation

Figure 12: Responses of Output and Inflation to Monetary Policy Shock (2009-2017)



Source: Author's Calculation

Table 3: The Impact of Monetary Policy Shock on Output and Inflation

Period	Maximum Impact		Inverse Slope of Aggregate Supply Curve (φ)[8]
	On Output	On Inflation	
Full Sample	-0.0106	-0.4486	0.2893
1980-2000	-0.0322	-0.0049	0.2012
2001-2009	-0.1889	-0.2284	0.2830
2009-2017	-0.2138	-0.3576	0.2937

Source: Author's Calculation

4.4.2 The Estimation of Policymakers' Aversion to Inflation Variability

Using the ratio between the variability of output and inflation along with the estimated value for φ shown in Section 4.4.1, we estimated the policymakers' aversion to inflation variability (λ). Our baseline assumption to measure inflation and output variability is that policymakers are interested in minimizing the variability of inflation around its target level and output around its potential level. However, as the country registered a monthly inflation rate on average of more than 20 percent during the 1980s and 1990s, a 5 percent rate of inflation as a target could be perceived as an unrealistic policy goal during these periods. Therefore, we assumed that the targeted level of inflation is equivalent to the average level of inflation recorded in each policy regime that we

[8] Three years average of the impact of monetary policy innovation on output divided by three years average of the impact of monetary policy on inflation.

considered. However, for comparison purposes, we estimated policymakers' aversion to inflation variability in both cases[9] and the results are presented in Table 4.

Table 4: Shifts in the Aversion to Inflation Variability

	Aversion to Inflation Variability (λ)	
Period	y^* = trend, π^* = average π	y^* = trend, π^* = 5%
Full Sample	0.6504	0.7017
1980-2000	0.5272	0.6543
2001-2009	0.6773	0.6085
2009-2017	0.7278	0.6675

Source: Author's Calculation

The estimated value of λ for the full sample suggest that the monetary authority in Sri Lanka has taken the goal of inflation stabilization very seriously during the period 1980-2017. Notably, when desired inflation was assumed to be 5 percent, it is evident that the country registered an increased level of aversion to inflation variability (0.7017).[10] The estimated value of λ for the full sample period provides interesting insights in to the stabilization objective of the CBSL. Most notably, the estimated value shows that inflation stabilization remains the major concern of the monetary authority in Sri Lanka. However, with the gradual improvement in the conduct of monetary policy and possible structural changes that have taken place in the economy, investigating how inflation stabilization objectives of the CBSL changed under different policy regimes is vital.

The estimated λ values under different policy regimes are quite prominent. It is evident that the estimated λ increased substantially at varying degrees over the periods. The exceptions are during the period 1980-2000, where the estimated level of λ was relatively small (0.5272) compared to other periods. This suggests that the CBSL has placed more weight on stabilizing both inflation and output during the period 1980-2000. This is consistent with our previous finding shown in Section 4.2. However, it is found that policymakers' preferences with respect to inflation

[9] The desired level of inflation (π^*) in the first case equivalent to average inflation while in the second case it is equivalent to the fixed level of 5 percent.
[10] Throughout the period we assumed that the estimated φ is unchanged.

stabilization were 0.7278 during the period 2009-2017. This shows that the policymakers attached a higher level of weight to stabilizing inflation in the recent past compared to other regimes. This, on the other hand, confirms that the CBSL significantly reduced relative weight with respect to stabilization of output during the latter part of the study period.

4.4.3 The Estimation of Welfare Loss in Sri Lanka

We believe that a reduction in both average inflation and its variability for a given variability of output should be identified with an improved welfare loss. Using the value estimated for λ in Section 4.4.2, we compute the welfare loss measured by the Central Bank loss function to study the changes in macroeconomic performance over time[11]. However, the selection of various λ for each regime is not appropriate to compare the welfare loss across different policy regimes and therefore we must identify a value for λ. For this purpose, we considered the value estimated for the full sample period (0.6505).

As depicted in Table 5, Sri Lanka exhibited a slight increase in welfare loss during the period 2001-2009 (3.7816) compared to 1980-2000 (3.4904). This could be partly contributed by increased inflation variability caused by adverse supply shocks. However, it could be noted that welfare loss improved significantly during the post-war period (2009-2017). Most notably, this confirms that monetary policy during this period was optimal compared to other periods because it has minimized the loss function of the CBSL. The time-varying welfare loss shown in Figure 13 provides further evidence of how the welfare loss has changed over time. The graph 'A' shows the time-varying welfare loss for constant λ (λ=0.6505) while 'B' shows for different λ estimated in Section 4.4.2. It is interesting to note that welfare loss from fourth quarter of 2016 to the end of 2017 fell significantly though the time-varying correlation analysis in Section 4.2 showed that monetary policy was suboptimal in this period. The reduced welfare loss could be due to lag effects of optimal monetary policy implemented before 2016. However, further research is required to address the research question on how suboptimal monetary policy could result in lower welfare loss.

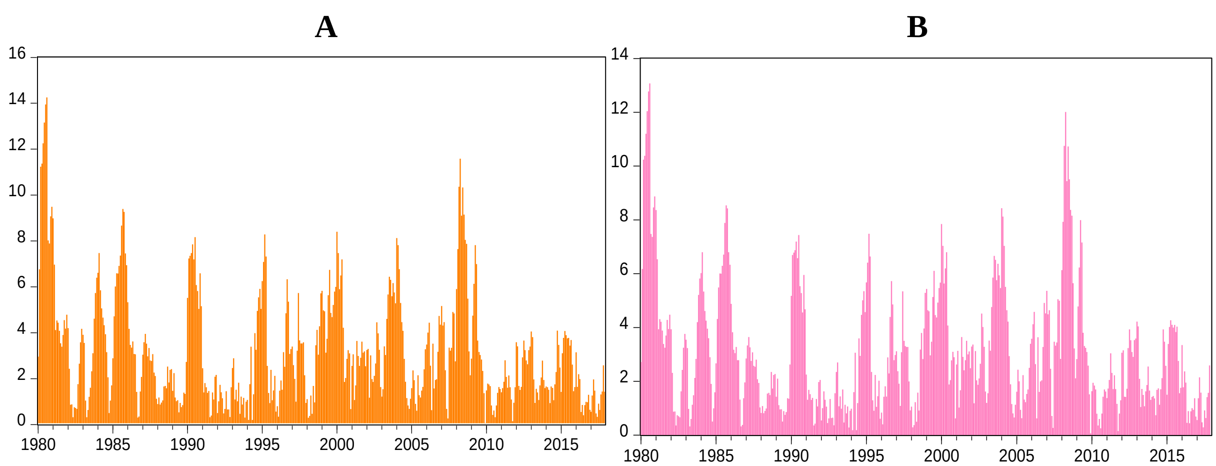
[11] The loss function shows how well the Central Bank has stabilized both inflation and output subject to various shocks.

Table 5: The Estimated Welfare Loss and Performance Change

Period	Estimated λ	Estimated Welfare Loss (For different λ)	Estimated Welfare Loss (For constant λ)
1980-2000	0.5872	3.2325	3.4904
2001-2009	0.6773	3.8783	3.7816
2009-2017	0.7278	1.9898	1.9315
1980-2017	0.6505	3.2028	3.2028
Performance Gain (Loss) in %	1980-2000 to 2001-2009	(19.974)	(8.342)
	1980-2000 to 2009-2017	38.446	44.664
	2001-2009 to 2009-2017	48.694	48.924

Source: Author's Calculation

Figure 13: Estimated Time-Varying Welfare Loss



Source: Author's Calculation

The results further demonstrate that around 45 percent of performance gain is equivalent to a drop of around 58 percent points in the average annual inflation rate between 1980-2000 and 2009-2017. Further, around a 49 percent performance gain is equivalent to a drop of around 60 percent points in the average annual inflation rate between 2001-2009 and 2009-2017. Overall, we can conclude that a larger increase in performance gain indicates substantial improvements in welfare loss. Although improved welfare performance could be partly contributed by the improved monetary policy, however, further research should be undertaken to investigate other factors that could have contributed to these improvements.

5. Conclusion

This study examined the impact of monetary policy on inflation-output variability trade-off in Sri Lanka. We first investigated the trade-off between the variability of inflation and output under different monetary policy regimes in Sri Lanka and then investigated how policy preferences of the CBSL with respect to inflation stabilization have changed over time. Finally, we examined the contribution of monetary policy to observed changes in macroeconomic performance measured by the standard loss function of the Central Bank. We found that Sri Lanka experienced a transition from relatively higher volatile inflation regimes to more stable regimes, however, the variability of output increased over the periods. This confirmed that the reduced inflation variability, which was largely supported by the increased level of importance placed by the CBSL on implicit inflation targeting, was attained at the expense of increased output variability. Meanwhile, we also found that the patterns of the estimated Taylor curves varied under different monetary policy regimes though no strong evidence of long-run variability association could be established. It was evident that the country witnessed the highest level of economic growth during the periods in which it satisfied the negative Taylor curve relationship. Based on the rolling window correlations, the study has found the conduct of monetary policy was optimal during the study period, except for 1980-2000.

The impulse response function shows that the response of variability of output and inflation to demand and supply shocks are not persistent. Thus, we concluded that deviations from the Taylor curves caused by adverse shocks are transitory if the Central Bank operates efficiently. The study further exhibited that the responses of output and inflation to monetary policy shock vary quite dramatically. Interestingly, an unexpected rise in short-term interest rates causes a significant decline in output. The study also revealed that the reaction of inflation to a positive interest rate innovation was positive. Although this was contradicted by theoretical literature, the results are consistent with previous findings drawn in many empirical studies. Overall, monetary policy shock produced a much larger response in inflation compared to output.

The estimated policymakers' aversion to inflation variability reveals that the CBSL took the goal of inflation stability very seriously in the recent past confirming that policymakers attached a greater level of weight with respect to the stabilization of inflation. This on the other hand showed that the CBSL significantly reduced relative weight on stabilization of output over the periods. The study found substantial improvements in welfare loss during the post-war period and confirmed that monetary policy during post-war period was optimal compared to other periods.

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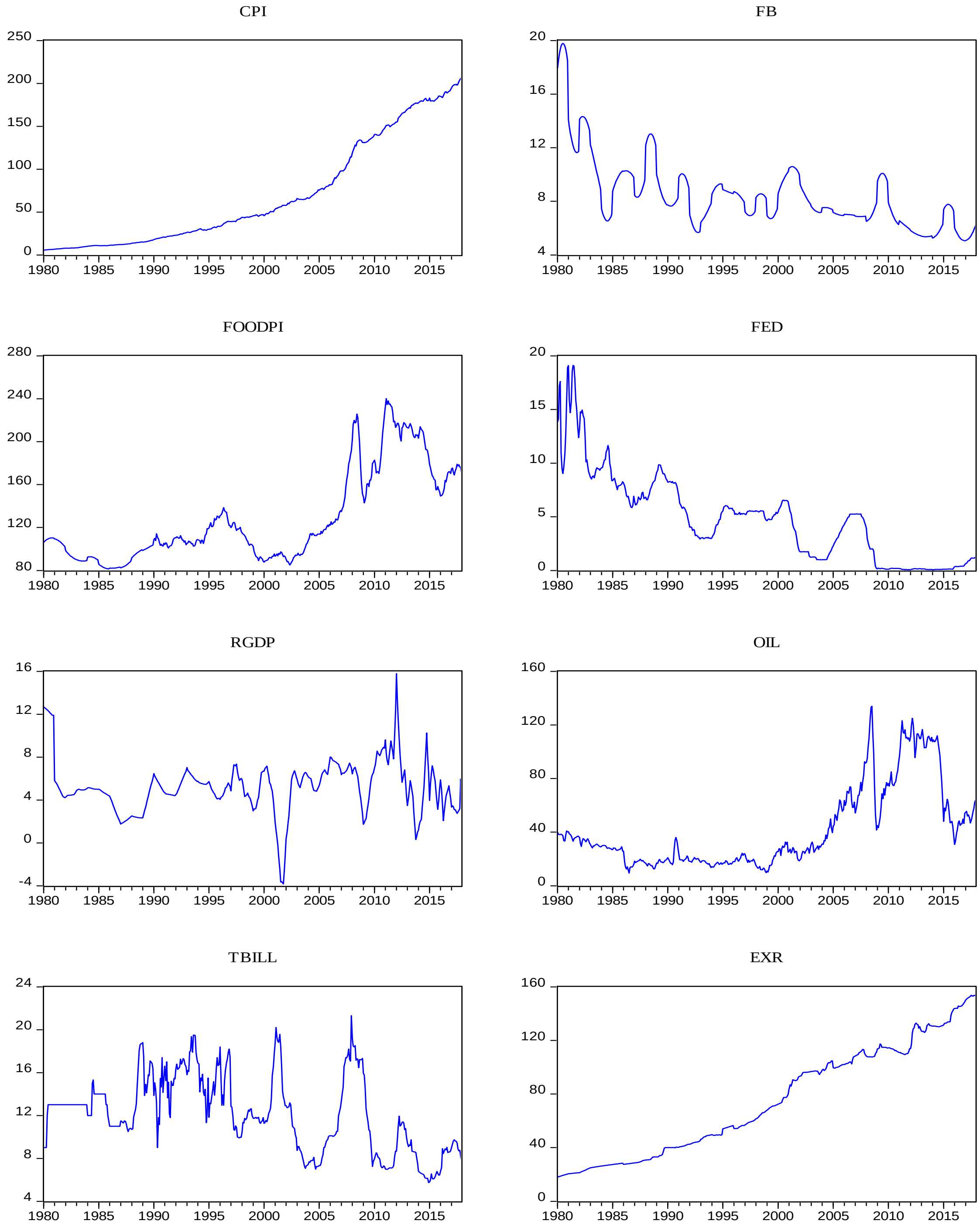
Appendices

Appendix A: Information on Data

Figure A1: Behaviour of the Variables



Note: The detailed descriptions of the variables are given in Table A1

Table A1: Definition of the Variables and Data Sources

Variable	Definition of Variables	Data Source
CPI	Consumer Price Index	DCS
RGDP	Real GDP	DCS
TBILL	Shor-term Interest Rate (Tbill-3 months)	CBSL
EXR	Exchange Rate (USA/LKR)	CBSL
FED	Federal Funds Rate	Federal Reserve Bank of St. Louis
OIL	Brent Oil Price	Bloomberg
FOODPI	Global Food Price Index	FAO
GDPGAP	Output Gap	Estimated
INFGAP	Inflation Gap	Estimated
FB	Fiscal Balance (surplus/deficit) (% of GDP)	CBSL
CPIRATE	Inflation Rate	DCS

Note: CBSL-Central Bank of Sri Lanka, DCS-Department of Census and Statistics of Sri Lanka, FAO-Food and Agricultural Organization

Table A2: Descriptive Statistics of the Variables (Full Sample)

	CPI	CPIRATE	FOODPI	RGDP	TBILL	FED	EXR	OIL	FB
Mean	69.603	10.460	127.643	5.202	12.142	4.810	74.677	42.143	8.457
Median	44.976	9.862	109.864	5.055	12.000	4.885	67.700	29.575	7.729
Maximum	206.595	32.557	240.093	15.780	21.300	19.100	153.670	133.87	19.784
Minimum	5.402	-2.300	81.438	-3.836	5.740	0.070	18.000	9.450	5.065
Std. Dev.	62.303	6.472	42.677	2.466	3.508	4.106	40.693	30.765	2.716
Skewnes	0.806	0.716	1.056	0.217	0.199	0.985	0.234	1.255	1.846
Kurtosis	2.184	3.444	2.854	5.999	2.221	4.081	1.689	3.433	7.557
JB-Stat	62.019	42.813	85.182	174.572	14.543	96.016	36.790	123.31	653.632
Obs	456	456	456	456	456	456	456	456	456

Source: Author's Calculation

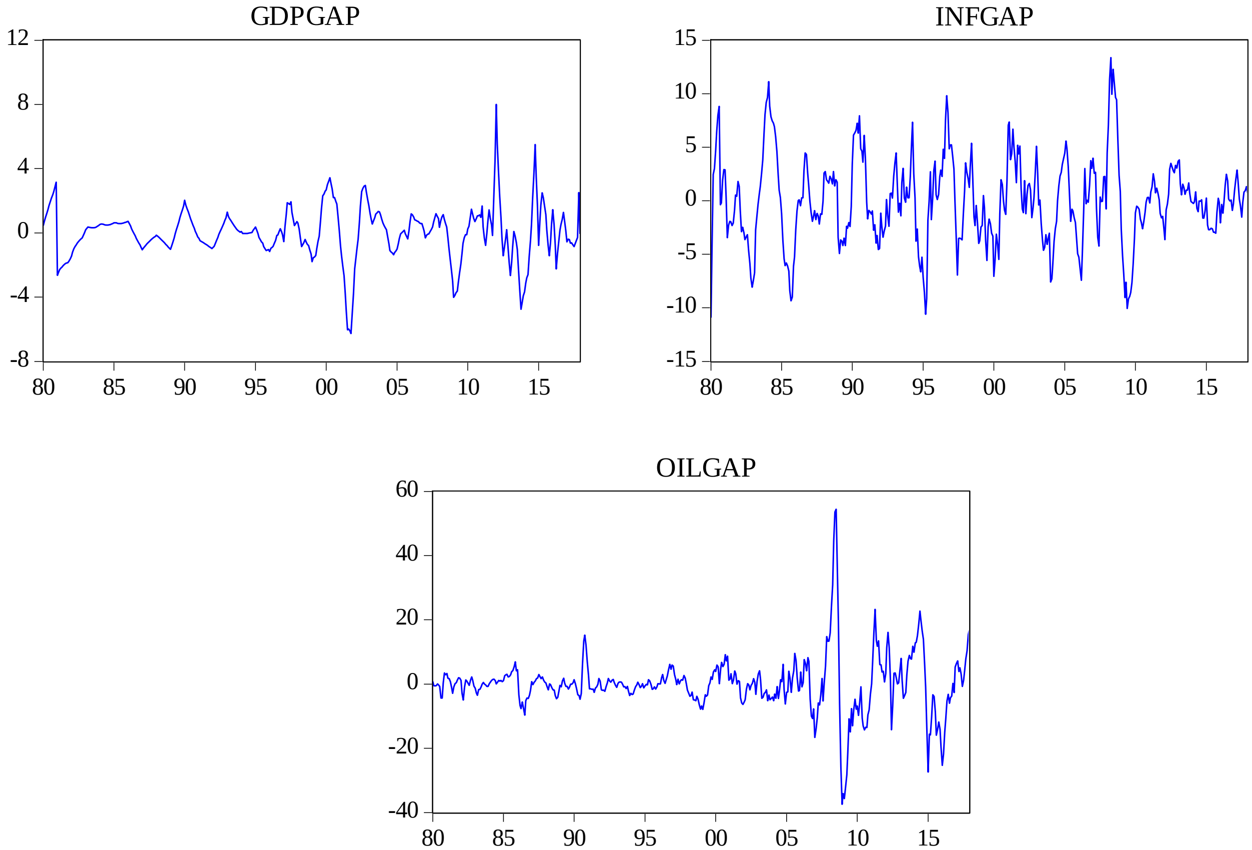
Note: The detailed description of the variables is given in Table A1

Table A6: Simple Correlation Matrix (Full Sample)

	CPI	FB	FOODPI	FED	GDP	OIL	TBILL	EXR
CPI	1							
FB	-0.57805	1						
FOODPI	0.86286	-0.48424	1					
FED	-0.76377	0.69971	-0.60480	1				
GDP	0.08900	0.06373	0.27969	0.02958	1			
OIL	0.77259	-0.38053	0.90007	-0.48211	0.32379	1		
TBILL	-0.53489	0.23588	-0.36248	0.38918	-0.21277	-0.38667	1	
EXR	0.95180	-0.62381	0.74765	-0.82599	0.04295	0.67927	-0.49862	1

Source: Author's Calculation

Figure A3: Behaviour of the Variables Inflation Gap, Output Gap and Oil Price Gap (1980-2017)



Note: The potential output, inflation and oil prices were calculated using the HP filter
Source: Author's Calculation

Table A7: Descriptive Statistics of Output Gap, Inflation Gap and Oil Price Gap (1980-2017)

	GDPGAP	INFGAP	OILGAP
Mean	-6.5812	1.9612	-2.5013
Median	0.0710	-0.0575	0.0439
Maximum	7.9945	13.3582	54.4181
Minimum	-6.2586	-10.9213	-37.4203
Std. Dev.	1.5898	4.0123	8.8753
Skewnes	-0.2730	0.1962	0.8291
Kurtosis	6.6070	3.5017	12.4993
JB-Stat	252.8712	7.7105	1766.754
Obs	456	456	456

Source: Author's Calculation

Appendix B: Testing for Stationary Properties of Variables

Table B1: Unit Root Tests: Levels and First Difference (1980-2000)

Variable	ADF Test				PP Test				KPSS Test				Order of Integration
	Levels		First Differences		Levels		First Differences		Levels		First Differences		
	Intercept	Trend and Intercept	Intercept	Trend and Intercept	Intercept	Trend and Intercept	Intercept	Trend and Intercept	Intercept	Trend and Intercept	Intercept	Trend and Intercept	
CPI	2.2489	1.0289	-1.5407	-3.292***	3.3845	-0.6379	-12.5876*	-13.3694*	1.9657	0.4984	1.0917	0.0340*	I (1)
FOODPI	-1.2082	-1.3029	-12.5801*	-12.5534*	-1.3163	-1.3846	-1.9390*	-12.9180*	0.6317*	0.1935*	0.1748*	0.1736*	I (1)
RGDP	-3.9487*	-3.8900*	-5.9975*	-6.0201*	-3.7449*	-3.6252**	-13.3687*	-13.3813*	0.2225*	0.2234	0.1965*	0.1115*	I (0)
TBILL	-3.8250*	-3.8457*	-18.6845*	-18.6469*	-3.9196*	-3.9517*	-18.5571*	-18.5255*	0.3181*	0.2336	0.0345*	0.0335*	I (0)
EXR	2.7057	0.0920	-11.4190*	-11.8867*	3.2393	0.4604	-11.4190*	-11.7671*	1.9882	0.4290	0.7907	0.0764*	I (1)
OIL	-2.9549**	-3.212***	-11.3821*	-11.3786*	-2.697***	-2.5708	-10.5905*	-10.5310*	1.0958	0.3386	0.1563*	0.0247*	I (1)
FB	-2.3065	-1.8553	-7.1495*	-7.2507*	-3.0402	-2.8629	-12.5920*	-12.6563*	1.0357	0.2095	0.1603*	0.0296*	I (1)
FED	-2.7403***	-2.5500	-10.5457*	-10.5466*	-2.0970	-2.4118	-10.0518*	-10.3731*	1.3480	0.2829	0.1196*	0.0349*	I (1)

Notes: *indicates significance at 1%, ** indicates significance at 5%, *** indicates significance at 10%.

Source: Author's Calculation

Table B2: Unit Root Tests: Levels and First Differences (2001-2009)

Variable	ADF Test				PP Test				KPSS Test				Order of Integration
	Levels		First Differences		Levels		First Differences		Levels		First Differences		
	Intercept	Trend and Intercept	Intercept	Trend and Intercept	Intercept	Trend and Intercept	Intercept	Trend and Intercept	Intercept	Trend and Intercept	Intercept	Trend and Intercept	
CPI	1.4983	-1.1309	-4.6733*	-7.9287*	1.1958	-1.3413	-8.0280*	-8.3281	1.1285	0.2827	0.3618**	0.0824*	I (1)
FOODPI	-1.3005	-3.228***	-3.9396*	-3.9076*	-1.1895	-2.2939	-3.8700*	-3.8354*	0.9464	0.1221**	0.0664*	0.0660*	I (1)
RGDP	-2.9321**	-2.9389	-3.5344*	-3.6143*	-1.7768	-1.4478	-3.5050*	-3.5850**	0.4665	0.2059*	0.1439*	0.0508*	I (0)
TBILL	-1.5752	-2.0138	-9.0165*	-9.2137*	-1.7117	-2.0280	-9.2599*	-9.3237*	0.3537**	0.2651	0.3234*	0.1948*	I (1)
EXR	-0.7206	-2.8422	-8.6179*	-8.5681*	-1.3150	-3.3480**	-8.6240*	-8.5742*	1.1920	0.0519*	0.0931*	0.0847	I (1)
OIL	-2.0070	-3.423***	-5.6491*	-5.6157*	-1.7579	-2.5366	-5.6492*	-5.6157*	0.9359	0.0698*	0.0629*	0.0551*	I (1)
FB	-1.8818	1.5473	-6.8845*	-8.0738*	-1.6735	0.9663	-7.1623*	-8.1398*	0.5529	0.2439	0.6143*	0.1024*	I (1)
FED	-1.4390	-1.4194	-4.3073*	-4.2739*	-1.6691	-1.7089	-4.3073*	-4.2739*	0.1871*	0.1544	0.2739	0.2719	I (1)

Notes: *indicates significance at 1%, ** indicates significance at 5%, *** indicates significance at 10%.

Source: Author's Calculation

Table B3: Unit Root Tests: Levels and First Differences (2009-2017)

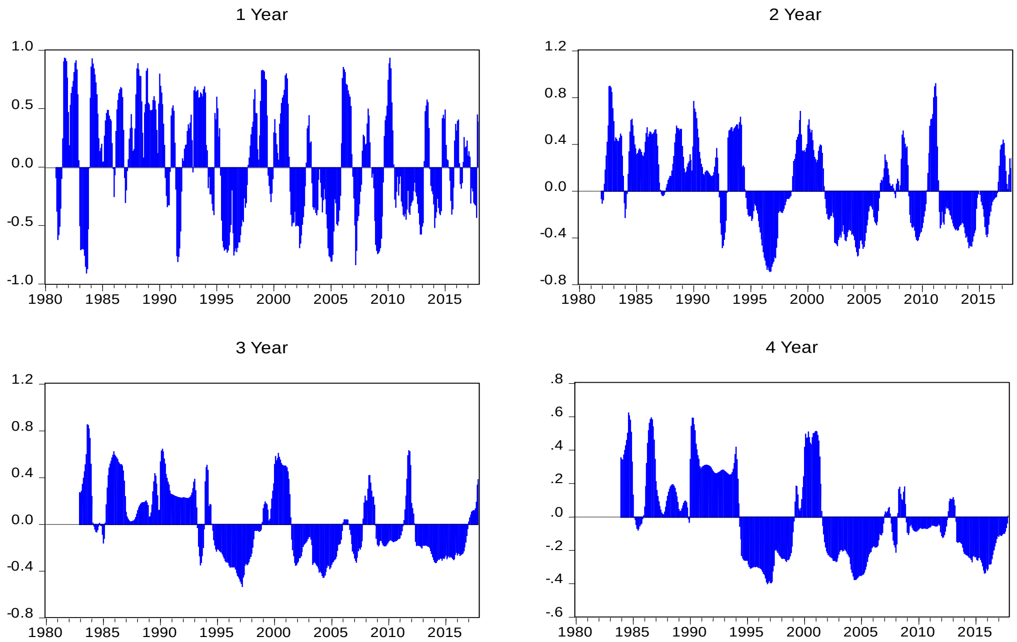
Variable	ADF Test				PP Test				KPSS Test				Order of Integration
	Levels		First Differences		Levels		First Differences		Levels		First Differences		
	Intercept	Trend and Intercept	Intercept	Trend and Intercept	Intercept	Trend and Intercept	Intercept	Trend and Intercept	Intercept	Trend and Intercept	Intercept	Trend and Intercept	
CPI	-0.4207	-1.6266	-8.2877*	-8.2440*	-0.4356	-1.6266	-8.2086*	-8.1627*	1.2243	0.2070	0.1122*	0.1062*	I (1)
FOODPI	-1.5855	-2.6925	-6.3139*	-6.5314*	-1.5611	-2.3131	-6.4278*	-6.6512*	0.4786	0.1940	0.2629*	0.1115*	I (1)
RGDP	-1.5335	-2.5802	-7.9181*	-7.9399*	-2.1724	-2.9804	-6.0340*	-6.0613*	0.5424	0.0824*	0.1241*	0.0918*	I (1)
TBILL	-2.2496	-2.2048	-7.6121*	-7.5804*	-2.6265	-2.5354	-7.6216*	-7.5938*	0.1288*	0.0975	0.1306*	0.0848*	I (1)
EXR	-0.2572	-3.5938*	-6.1858*	-6.1976*	-0.1342	-2.5859	-6.3885*	-6.4024*	1.1413	0.0863*	0.1044*	0.0522*	I (1)
OIL	-1.3445	-2.2678	-7.3474*	-7.3858*	-0.9354	-1.9321	-7.2419*	-7.2250*	0.6136	0.2369	0.2321*	0.1345*	I (1)
FB	-3.5236*	-3.0122	-7.0951*	-7.4942*	-3.0822**	-2.4659	-7.6131*	-7.8311*	0.4055*	0.1676*	0.3018*	0.0966*	I (0)
FED	3.1527	1.7357	-5.6415*	-6.7013*	4.3060	1.9768	-5.6287*	-6.7013*	0.6514*	0.2539	0.7716	0.1934*	I (1)

Notes: *indicates significance at 1%, ** indicates significance at 5%, *** indicates significance at 10%.

Source: Author's Calculation

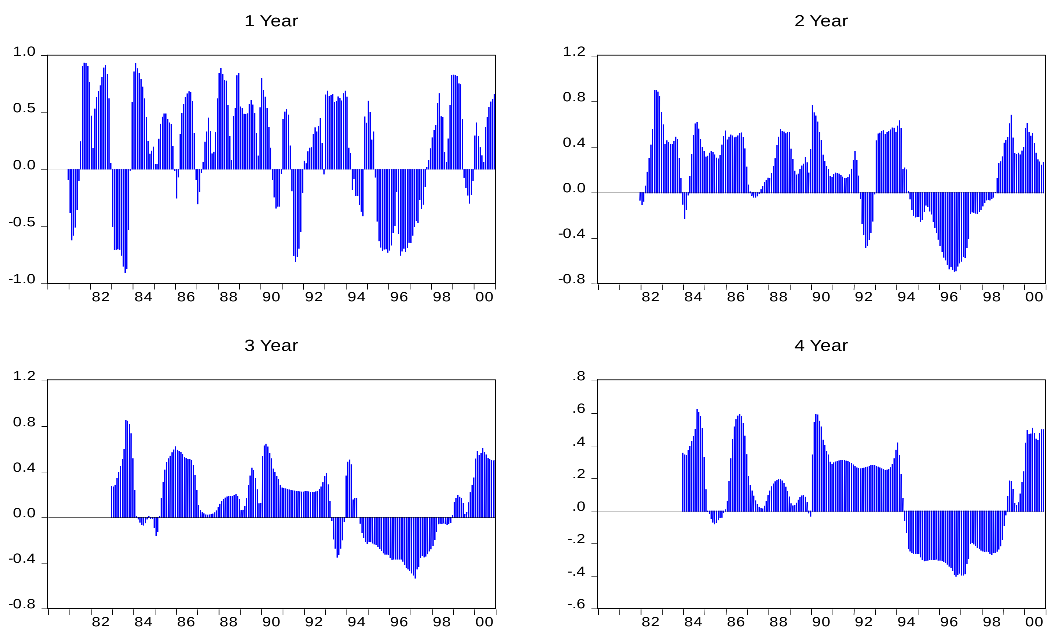
Appendix C: Relationship between the Variability of Inflation and Output

Figure C1: Rolling Window Correlation (1980-2017)



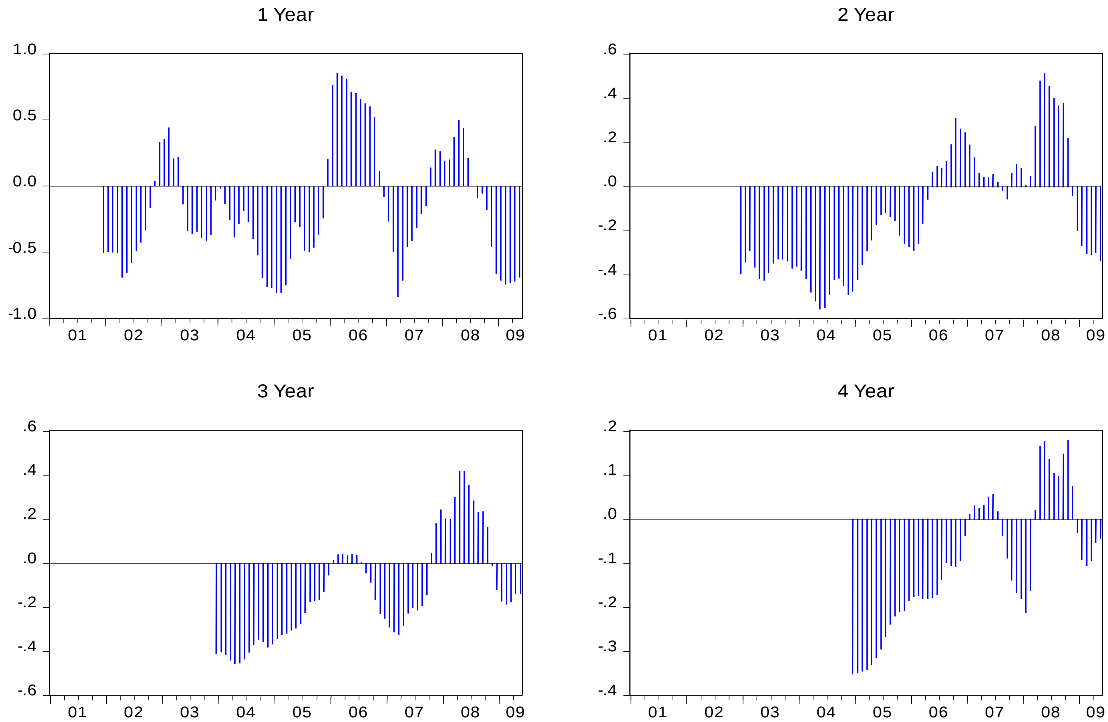
Source: Author's Calculation

Figure C2: Rolling Window Correlation (1980-2000)



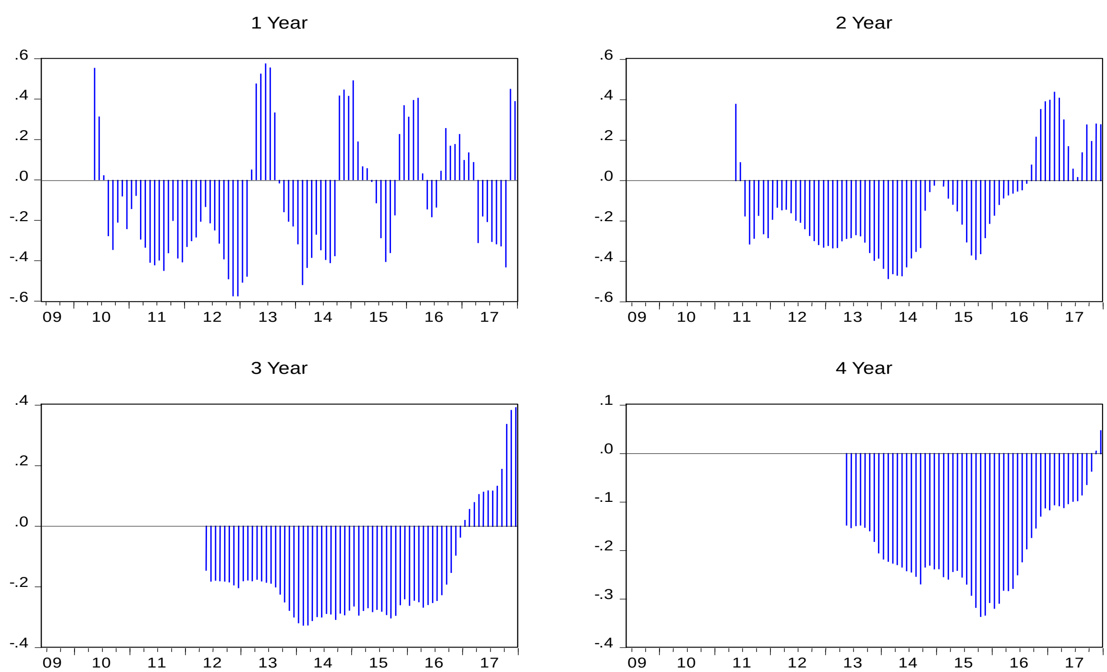
Source: Author's Calculation

Figure C3: Rolling Window Correlation (2001-2009)



Source: Author’s Calculation

Figure C4: Rolling Window Correlation (2009-2017)



Source: Author’s Calculation

Appendix D: The Persistence of the Variability of Output and Inflation to Demand and Supply Shocks

D1. Estimation of Aggregate Demand Equation

In order to estimate the aggregate demand equations as given in Equation 10, we first need to estimate a VAR model to identify the optimum number of lag to be used in the estimation. Using the optimum lag, we estimated the aggregate demand equations based on the Ordinary Least Square (OLS) method. The estimated equation would help to derive the aggregate demand shock. Finally, we estimated the IRFs to identify how the derived aggregate demand shock affected the variability of output and inflation. Table D1 presents the results of optimum lag that should be used under different lag order selection criteria. As in this study the selection of lag length is based on Schwarz Information Criteria (SIC), it is clear from Table D1 that the optimal lag that should be used is 2. Based on the lag length of 2, we estimated the aggregate demand equation. The results are presented in Table D2. Finally, we examined the impulse response function to identify how the variability of inflation and output moves in response to demand shock (see Figures D1 to D4). We follow this procedure for both full sample and sub-sample analysis.

Table D1: Selection of Optimal Lag Length in VAR (Full Sample)

Lag	LogL	LR	FPE	AIC	SIC	HQ
0	-7768.314	NA	9.47e+08	34.85791	34.90388	34.87603
1	-3331.997	8753.270	2.427457	15.07622	15.35203	15.18497
2	-3194.999	267.2397	1.469100	14.57399	15.07963*	14.77335*
3	-3170.461	47.31410	1.472304	14.57606	15.31154	14.86605
4	-3144.225	50.00274	1.464446*	14.57051*	15.53584	14.95112
5	-3124.621	36.92121	1.500788	14.59471	15.78987	15.06594
6	-3110.352	26.55504	1.575497	14.64283	16.06783	15.20468
7	-3095.749	26.84869	1.651743	14.68946	16.34429	15.34193
8	-3081.956	25.05039	1.738337	14.73971	16.62439	15.48281
9	-3062.476	34.94030	1.783832	14.76447	16.87898	15.59818
10	-3038.737	42.04886*	1.796358	14.77012	17.11448	15.69446

Note: * indicates lag order selected by the criterion, LR: sequential modified LR test statistic, FPE: Final Prediction Error, AIC: Akaike Information Criterion, SIC: Schwarz Information Criterion, HQ: Hannan-Quinn Information criterion (each test at 5% significance level), Endogenous variables: GDP_GAP CPI TBILL EXR OIL_GAP

Source: Author’s Calculation

Table D2: Estimated Aggregate Demand Equation (Full Sample)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.411959	0.159572	2.581651	0.0102
GDP_GAP(-1)	1.265111	0.045258	27.95307	0.0000
GDP_GAP(-2)	-0.390289	0.045494	-8.578975	0.0000
CPI(-1)	0.091889	0.035954	2.555720	0.0109
CPI(-2)	-0.092547	0.035905	-2.577518	0.0103
TBILL(-1)	-0.016266	0.030000	-0.542193	0.5880
TBILL(-2)	-0.010789	0.030055	-0.358964	0.7198
EXR(-1)	-0.024751	0.031554	-0.784402	0.4332
EXR(-2)	0.023749	0.031640	0.750590	0.4533
OIL_GAP(-1)	0.005189	0.007202	0.720448	0.4716
OIL_GAP(-2)	-0.005744	0.007147	-0.803710	0.4220
R-squared	0.871203	Mean dependent var		-0.002558
Adjusted R-squared	0.868296	S.D. dependent var		1.592883
S.E. of regression	0.578074	Akaike info criterion		1.765701
Sum squared resid	148.0371	Schwarz criterion		1.865478
Log likelihood	-389.8141	Hannan-Quinn criter.		1.805012
F-statistic	299.6532	Durbin-Watson stat		2.007162
Prob(F-statistic)	0.000000			

Note: Dependent Variable: GDP_GAP, Method: Least Squares
Source: Author's Calculation

D2. Estimation of Phillips Curve Equation

We followed the similar procedure as we used in Section D1. To estimate the Philips curve equation as given in Equation 11 in Section 3, we first need to estimate a VAR model to identify the optimum number of lag to be used in the estimation. Using the optimum lag, we estimated the Philips curve equation based on the OLS method and thereby derived the aggregate supply shock. Finally, we estimated the IRFs to identify how aggregate supply shock affected the variability of output and inflation. As the selection of lag length in this study is based on Schwarz Information Criteria (SIC), it is clear from Table D3 that the optimal lag length to be used to estimate the Philips curve equation is 2. The estimated Phillips curve equation is presented in Table D4. Finally, we inspected the impulse response function to identify how the variability of inflation and output moves in response to demand shock (see Figures D1 to D4). We follow this procedure for both full sample and sub-sample analysis.

Table D3: Selection of Optimal Lag Length in VAR

Lag	LogL	LR	FPE	AIC	SIC	HQ
0	-6700.371	NA	1.17e+08	29.93023	29.96688	29.94468
1	-2764.606	7783.679	2.944005	12.43128	12.61453	12.50351
2	-2631.528	260.8080	1.745641	11.90861	12.23846*	12.03864*
3	-2615.786	30.57023	1.747729	11.90976	12.38621	12.09758
4	-2593.233	43.39598	1.697472*	11.88050	12.50355	12.12611
5	-2577.213	30.53788*	1.697540	11.88041*	12.65006	12.18382
6	-2564.637	23.74781	1.724017	11.89570	12.81195	12.25689
7	-2554.021	19.85684	1.766421	11.91974	12.98259	12.33872
8	-2543.418	19.64484	1.810116	11.94383	13.15328	12.42061

Note: * indicates lag order selected by the criterion, LR: sequential modified LR test statistic, FPE: Final Prediction Error, AIC: Akaike Information Criterion, SIC: Schwarz Information Criterion, HQ: Hannan-Quinn Information Criterion (each test at 5% significance level), Endogenous Variables: CPI GDP_GAP EXR OIL_GAP

Source: Author's Calculation

Table D4: Estimated Phillips Curve Equation

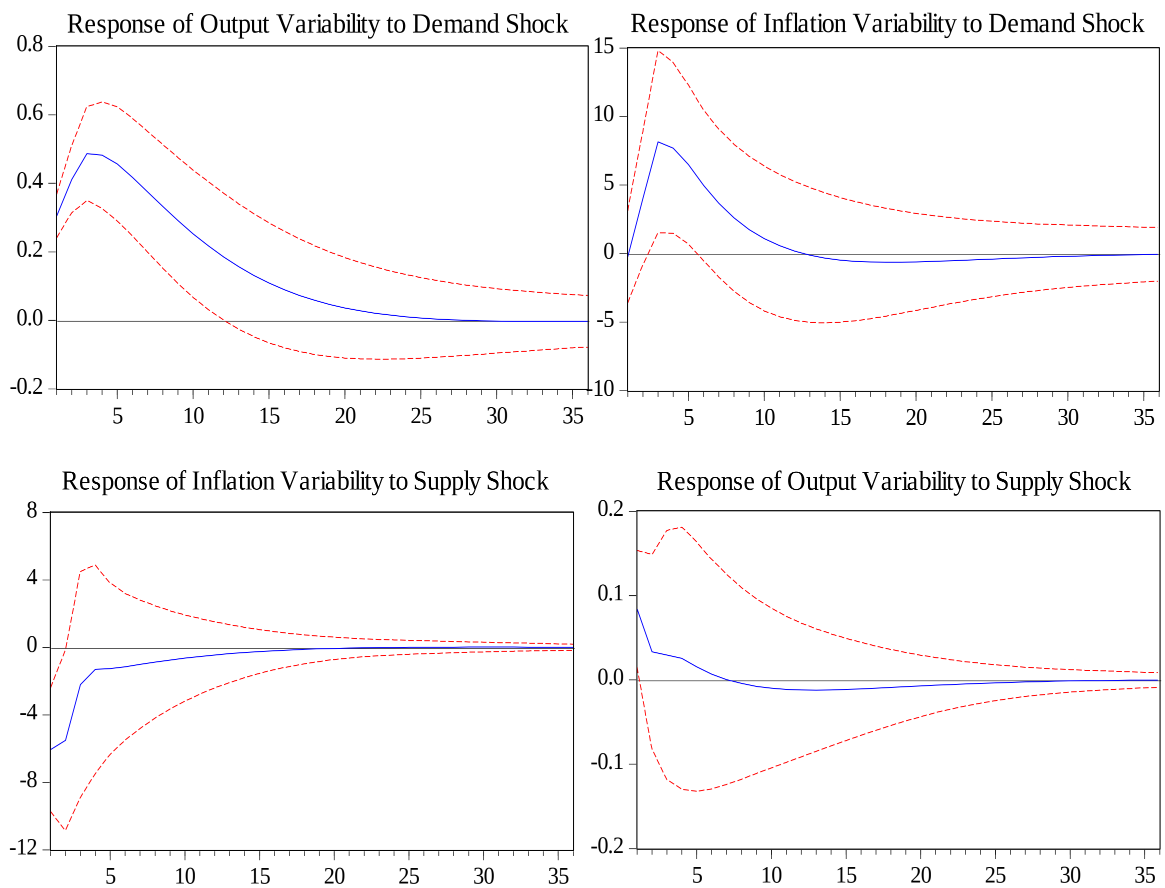
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.185688	0.104497	-1.776975	0.0763
GDP_GAP(-1)	-0.113763	0.058498	-1.944740	0.0524
GDP_GAP(-2)	0.157496	0.059082	2.665706	0.0080
CPI(-1)	1.155977	0.046373	24.92798	0.0000
CPI(-2)	-0.158940	0.046248	-3.436713	0.0006
EXR(-1)	-0.007356	0.040808	-0.180268	0.8570
EXR(-2)	0.017659	0.040923	0.431506	0.6663
OIL_GAP(-1)	0.052956	0.009373	5.650030	0.0000
OIL_GAP(-2)	-0.044303	0.009283	-4.772700	0.0000
R-squared	0.999857	Mean dependent var		69.88589
Adjusted R-squared	0.999854	S.D. dependent var		62.29469
S.E. of regression	0.752592	Akaike info criterion		2.289037
Sum squared resid	252.0456	Schwarz criterion		2.370674
Log likelihood	-510.6115	Hannan-Quinn criter.		2.321201
F-statistic	387908.2	Durbin-Watson stat		2.028123
Prob(F-statistic)	0.000000			

Note: Dependent Variable: CPI, Method: Least Squares

Source: Author's Calculation

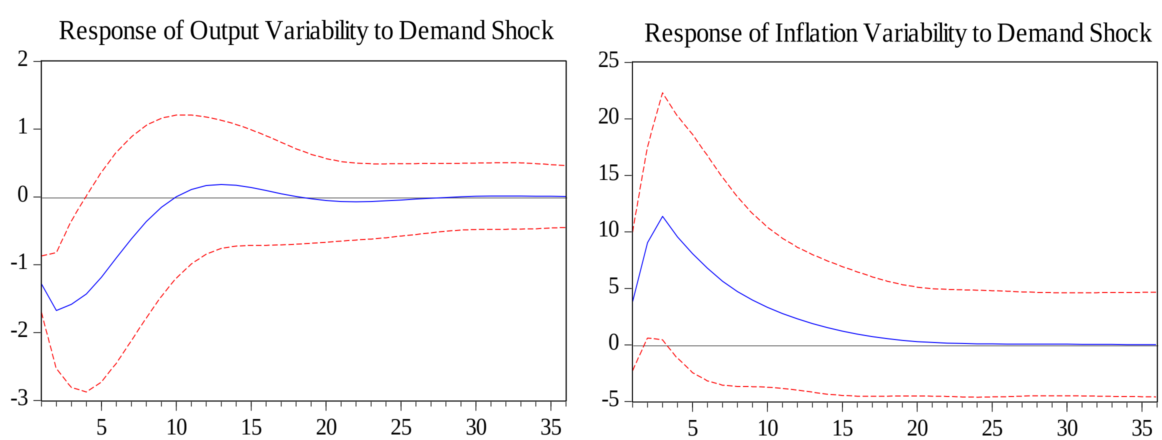
D3. The Persistence of the Variability of Output and Inflation to Demand and Supply Shocks

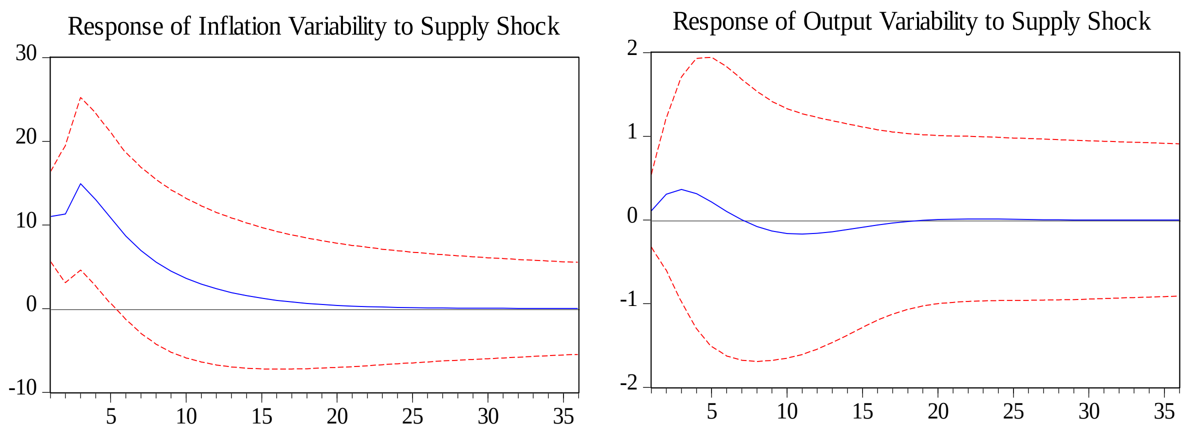
Figure D1: Responses of the Variability of Output and Inflation to Demand and Supply Shocks (1980-2000)



Source: Author's Calculation

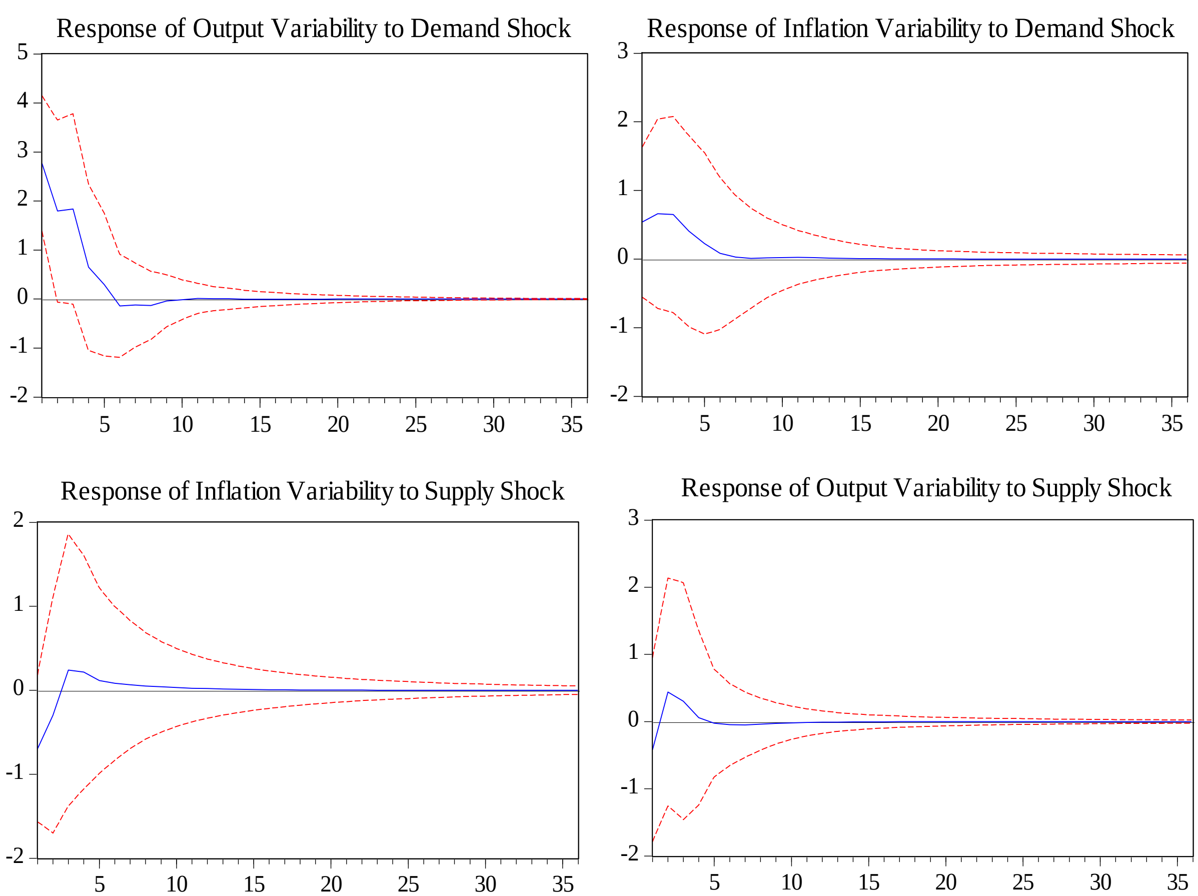
Figure D2: Responses of the Variability of Output and Inflation to Demand and Supply Shocks (2001-2009)





Source: Author's Calculation

Figure D3: Responses of the Variability of Output and Inflation to Demand and Supply Shocks (2009-2017)



Source: Author's Calculation