Decoding Policy Puzzles and Monetary Policy Transmission in Sri Lanka through Time-Varying Dynamics*

Sujeetha Jegajeevan†, W S Navin Perera‡ and K K C Sineth Kannangara§

Abstract

This study analyses the evolution of key macroeconomic variables and their linkages to understand and resolve some of the policy puzzles in Sri Lanka and to check whether responses to monetary policy shocks exhibit any time-variation over two decades employing time-varying parameter vector autoregression with stochastic volatility (TVP-SVOL). In addition, interest rate pass-through is also measured employing Autoregressive Distributed Lag (ARDL) method to update evidence on transmission of policy rates to other interest rates, including the periods that recognizes short term interest rate as operational target of the monetary policy. The findings from the interest rate pass-through analysis reconfirms the existing evidence of complete pass-through from policy interest rates to money market interest rates and sluggish pass-through from money market rates to other market interest rates, though the size and speed of adjustment are somewhat different from past findings. The time-varying analysis of macroeconomic dynamics leads to four main conclusions. Firstly, time varying mean did not show any substantial moderation in GDP growth trend over the years though a marginal moderation is observed recently. The level and volatility of inflation exhibit systematic moderation since late 2000s. The weaker linkages of money growth with GDP growth and interest rate evolve over the years, supporting the policy move to discontinue monetary targeting. Finally, the responses of growth and inflation to monetary policy shocks show time-dependence.

Key Words: TVP-VAR, stochastic volatility, monetary policy transmission, interest rate pass-through

JEL classification: C30, C32, E52, E58

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† Deputy Director, Economic Research Department, Central Bank of Sri Lanka (sujeetha@cbsl.lk)

‡ Senior Economist, Economic Research Department, Central Bank of Sri Lanka (navinperera@cbsl.lk)

§ Senior Economist, Economic Research Department, Central Bank of Sri Lanka (sineth@cbsl.lk)

1.0 Introduction

Central banks around the world are mandated to maintain price stability through appropriate monetary policy formulation. Policy formulation relies on several factors such as data on recent developments, projections of future path, understanding on the nature of linkages among macro-variables, evidence on how the economic variables respond to shocks and policies. It is crucial for the policymakers to regularly monitor and assess the nature of changes to these processes to obtain intended outcomes of their policies. Research in data-rich advanced economies aim to find evidence to accept or reject Great Moderation, change in dynamic linkages among key variables and evolution of transmission of shocks, including time-varying evidence of monetary policy transmission. Such evidences are eventually being considered in shaping important policy formulation. Kim and Nelson (1999), Primiceri (2005), Cogley and Sargent (2005), Benati and Mumtaz (2007), Baumeister et.al. (2010) and Akram and Mumtaz (2019) are some of these studies. No research has been done in Sri Lanka to assess the evolution of macroeconomic variables and dynamic linkages. However, a number of studies were carried out to identify key channels of transmission, speed and magnitude of transmission. Amarasekara (2005), Vinayagathasan (2013), Ghazanchyan (2014) and Perera (2016) are the key research done on monetary policy transmission in Sri Lanka. Some of these studies have limited their scope to interest rate pass through while others have extended the scope to study the full path of the transmission to the real economy. However, all these studies were based on samples limited to a period prior to 2012. The economy and its dynamics have evolved noticeably since then and monetary policy responses too have varied as a result. The most important change in the recent period is the gradual move away from a monetary aggregate based monetary policy regime towards a flexible inflation targeting regime. This was complemented by a more active monetary policy communication and advancement in the financial system. Moreover, inflation became broadly stable and low in the last decade, while linkages between key macroeconomic variables such as money-inflation; inflation-economic growth; money-economic growth, were found to be mixed in recent times. Further, the Central Bank of Sri Lanka (CBSL) has allowed for greater flexibility in the determination of the exchange rate in recent times. The three-decade long ethnic conflict ended in 2009. These have created several puzzles that cannot be explained with existing empirical evidences on the Sri Lankan economy.

This study aims to assess key macroeconomic variables to investigate changes in time series properties, such as trend, volatility and dynamic cross-correlations of these variables to

understand and resolve some of the policy puzzles and to identify possible changes to transmission of shocks. The evolution of key macroeconomic variables and the linkages among these variables are studied first employing time-varying parameter VAR with stochastic volatility (TVP-SVOL) to better understand the dynamics of the economy in an attempt to explain and resolve some of the questions that are puzzling the policymakers in Sri Lanka. This study also covers time-varying transmission of monetary policy to the target variables, such as inflation and economic growth, through the interest rate channel. For completeness, interest rate pass-through from policy rate changes to other market interest rates is also studied covering most recent data that includes the periods recognizing short term money market rates as operational target of the monetary policy.

Fixed coefficient models or time-varying models with constant volatility of shocks are not fully capable of capturing changes in the evolution of macroeconomic variables over time. The proposed methodology has two merits. While it allows coefficients to be time-varying, it also allows the volatility of the shocks also to be time-varying, a plausible assumption about the shocks in real times. TVP-SVOL was proposed by Primiceri (2005) to capture these dynamics in the model estimation. While the time-varying coefficient element of this model is important in estimating time-varying nature of the structural parameters, adding stochastic volatility to the model is also recognised as important in the recent literature as constant volatility raises a question that the estimated time-varying coefficients are biased due to ignoring possible variations of the volatility in disturbances. This model allows for time-variation in VAR coefficients as well as the covariance matrix, and therefore captures structural changes in the economy and dynamic relationship among the macroeconomic variables, while capturing dynamic nature of the shocks hitting the economy. The main purpose of this research is to address policy puzzles and to check whether transmission of monetary policy shock is time-dependent.

This paper contributes to the existing empirical literature on macroeconomic evolution and monetary policy transmission in Sri Lanka by adding evidence on the time-varying evolutions to resolve several policy puzzles. Further, the timing of this study is also appropriate as Sri Lanka is in transition to flexible inflation targeting. The findings with time-varying evidences would help to enhance the modelling and forecasting experience prior to Sri Lanka's official transition to a flexible inflation targeting regime.

The rest of the paper has been organised as follows. Section 2 briefly discusses related literature followed by a short description about puzzles encountered by the policymakers in Sri Lanka in Section 3. Descriptions about data and methodology are included in Section 4 and subsequently a detailed empirical analysis including time-dependent dynamics of the key macroeconomic variables, interest rate pass-through and time-varying nature of monetary policy transmission is presented in Section 5. The final section highlights the key findings along with some recommendations for future research.

2.0 Related Literature

Several research on the evolution of macroeconomic dynamics began with the advancement in econometric models that are capable of identifying structural breaks, time variations in parameters and the volatility of shock. Kim & Nelson (1999) study GDP growth stabilisation in the USA employing a Markov-switching model and found evidence of structural breaks in GDP growth. Primiceri (2005) is a pioneer study done on USA allowing for time-variation in coefficients and the variance covariance matrix. He found evidence to support changes in systemic and non-systemic monetary policy over forty years, aggressive response of interest rate to inflation and increasing role of non-policy shocks in explaining high inflation and unemployment in the USA. Benati and Mumtaz (2007) also studied the economic history of USA with TVP-SVOL identifying monetary policy, demand, supply and money demand shocks. They found that Great inflation was mainly driven by demand but non-monetary policy shocks. Akram & Mumtaz (2019), the research closely followed by this study, investigate time series properties of Norwegian macroeconomic variables employing TVP-SVOL and evidence of a fall in inflation persistence was observed during the inflation targeting regime, alongside time variation in the relationship among the key variables. Studies focusing on evolving macroeconomic characteristics in emerging and developing markets are very limited largely due to limitations in the availability of long data series. The improvement in econometric methodology, mainly the Bayesian approach, made it possible to study time variations in economic dynamics even with a limited sample. To our knowledge no such study has been carried out to understand the evolving nature of macroeconomic variables, their volatility and linkages using time-dependent methodology, though a number of recent studies, Jayawickrama and Perera(2013), Ehelepola (2015) and Jegajeevan (2016) attempt to understand idiosyncratic features of the economy.

Measuring monetary policy transmission has long been an area of interest among the policymakers and the academia. Friedman and Schwartz (1963), Bernanke (1986), Romer and Romer (1989), Bernanke and Gertler (1995), Mishkin (1996) and De Bondt (2005) could be mentioned as a few pioneering studies focused on the transmission of traditional interest based monetary policy. Bernanke (1986) provides two main conclusions. Firstly, he shows that credit shocks create significant impact on output and secondly, highlights the fact that money as well as credit have parallel and approximately equal forces on output. Romer and Romer (1989) proves that although monetary policy has large real effects, its persistence properties depends on the characteristics of the economy during the period. Further, Bernanke & Gertler (1995) show that credit, balance sheet and bank lending channels are effectively working for the US economy while stressing the effectiveness of the credit channel and Mishkin (1996) finds that asset prices channel without short term debt instruments is an important channel of monetary policy transmission. In the aftermath of the Great Financial Crisis, there were a growing number of research to study the transmission mechanism of unconventional monetary policy, i.e., quantitative easing (Borio and Disyatat, 2010, Joyce et al., 2012).

The literature discussing the monetary transmission of Sri Lanka is limited. Most of the existing literature are limited to interest rate pass-through (Amarasekara, 2005, Aazim et al., 2012, Ghazanchyan, 2014), whereas some of the recent studies include the analysis about the full transmission path (Amarasekara, 2008, Vinayagathasan, 2013, Perera, 2016). Amarasekara (2005), the pioneering study, examines the pass-through of monetary policy actions to market interest rates using the Repurchase rate (the Standing Deposit Facility Rate) and the Reverse Repurchase Rate (the Standing Lending Facility Rate). His findings suggest a complete and almost immediate (99.65 per cent) pass-through of policy rate changes to money market rates, but incomplete and sluggish pass-through from the call money market rate to commercial bank retail interest rates. Although Amarasekara (2008) use semi-structural VARs to estimate the impact of policy rate changes on economic growth and inflation in Sri Lanka, the sample period is restricted to 2004.

Using monthly data from 1978 to 2011, Vinayagathasan (2013) investigated the response of Sri Lanka's real economy to both domestic and foreign shocks, and found that the interest rate played a significant role in the monetary policy transmission in Sri Lanka. Using a seven-variable structural vector auto regression (SVAR) model, he found that movements in key macroeconomic variables were better explained by shocks to the interest rate than through exchange rate or money supply shocks. He also found no evidence of foreign monetary policy

shocks and world oil price shocks having an impact on the domestic economy. Ghazanchyan (2014) also studied the transmission of monetary policy in Sri Lanka considering interest rate, bank lending, exchange rate and asset price channels and found that the interest rate channel was the strongest and the quickest channel. The lending channel was also working with relatively longer lags, while the other two channels were found to be ineffective. Perera (2016) conducted a study on full transmission path of policy rate changes to real variables and found that the interest rate pass-through of Sri Lanka is sluggish and incomplete except for prime lending rates. Fixed deposit rates of commercial banks with 3 months' maturity and prime lending rates have a strong relationship with money market interest rates. He highlights that the most important transmission channel in Sri Lanka is the interest rate channel, whereas restrictive monetary policy shocks have an impact on real GDP and consumer price levels via other transmission channels. Further, he has used the 91-day Treasury bill rate as the proxy of money market rate.

The uniqueness of the current study is its extension compared to the previous studies by focusing on the time-varying nature of time series properties of key macroeconomic variables, their linkages and the responses of macroeconomic variables to monetary policy shocks, which is a compelling evidence to capture ongoing changes to the dynamics of the economy. It is very relevant, since Sri Lanka is facing several policy puzzles at present as discussed in the following section. Further, the monetary policy framework is in transition with several changes to the internal monetary policy formulation process and external communication. Thus, giving more attention to data of most recent years in the analysis have a definite advantage and would be useful for policymakers. Accordingly, this paper intends to contribute to the existing empirical literature on evolution of the economy and monetary policy transmission in Sri Lanka and give valuable insights to policymakers by adding evidence on the time-varying evolutions that would help to understand and resolve several policy puzzles.

3.0 Policy Puzzles in Sri Lanka: The Challenge for Policymakers

Sri Lanka, which has been operating monetary policy under a monetary targeting framework since the 1980s, observed a close, positive relationship between the growth of broad money supply (i.e. monetary expansion) and nominal growth of GDP (See Figure 3.1). However, the relationship between the growth of money supply and nominal GDP weakened during the recent periods, particularly since 2010. Several changes in the domestic and global arena, such as the end of the three-decade long ethnic war, onset of the Global Financial Crisis and its

spillover effects, the build-up of domestic financial sector vulnerabilities as well as advancements in financial sector activities (and instruments), could be attributed to these changes. Though simple graphical based analysis confirms such a break-down, this has not been proved scientifically based on in-depth research, thus making it difficult for policymakers to do informed policy making and policy communication.

Another possible reason for the weakening of the relationship between the growth of broad money supply and the growth of nominal GDP is the weakening relationship between the former and inflation (See Figure 3.2). While the ultimate objective of the Central Bank is to maintain price stability, i.e. low and stable inflation, on a sustainable basis, which was by way of controlling reserve money expansion under the monetary targeting framework, it increasingly became less useful as the relationship between the growth of reserve money and broad money, and thereafter inflation appeared to fade away. However, since the Central Bank has been implicitly targeting inflation particularly since the late 2000s, it has been successful in maintaining inflation at single digits for over a decade. While this has helped anchor inflation and inflation expectations, to a great extent, the contribution of monetary aggregates in stabilising inflation at low levels has been limited in these periods.

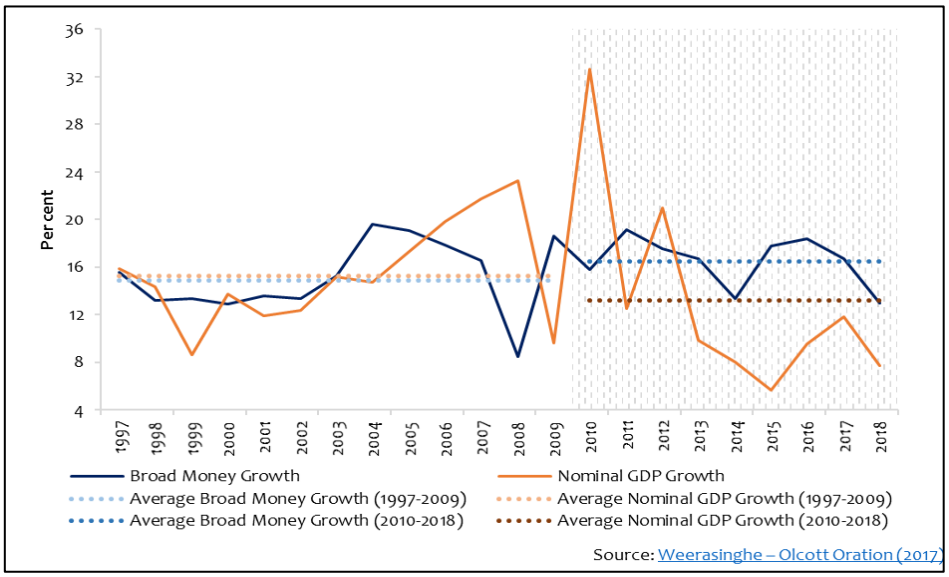

Figure 3.1: Nominal GDP Growth Vs. Broad Money Growth

Although Sri Lanka has had double digit episodes of inflation during most of the period prior to 2009, inflation has been maintained at single digit levels since then as a result of proactive monetary policy measures and improved communication strategies adopted by the Central

Bank supported by lower commodity prices in the international markets and timely intervention by the government at times of supply side disruptions. The achievement of single digit inflation, however, has failed to provide the required impetus to drive growth in the economy, particularly over the past few years. Average inflation slowed from 11.2 per cent during 2003-2009 to 5.3 per cent during 2010-June 2019, but this came alongside a relatively slow real economic growth rate of 5.5 per cent during this period, when compared to the growth of 5.9 per cent during 2003-2009. Although the economy was hit by several supply side shocks in the recent years, the aggregate demand side was also weaker regardless of low and stable inflation and high growth of money supply. This phenomenon of low and stable inflation providing a lesser than anticipated support in economic activities have been a major puzzle for policymakers of late.[1] Furthermore, discussions in roundtables as well as among academia highlight that the slowdown in the growth of the economy is possibly indicating a drop in the potential growth of the economy to a level of around 5.0 per cent or below, from its historical level of 6.0-6.5 per cent.

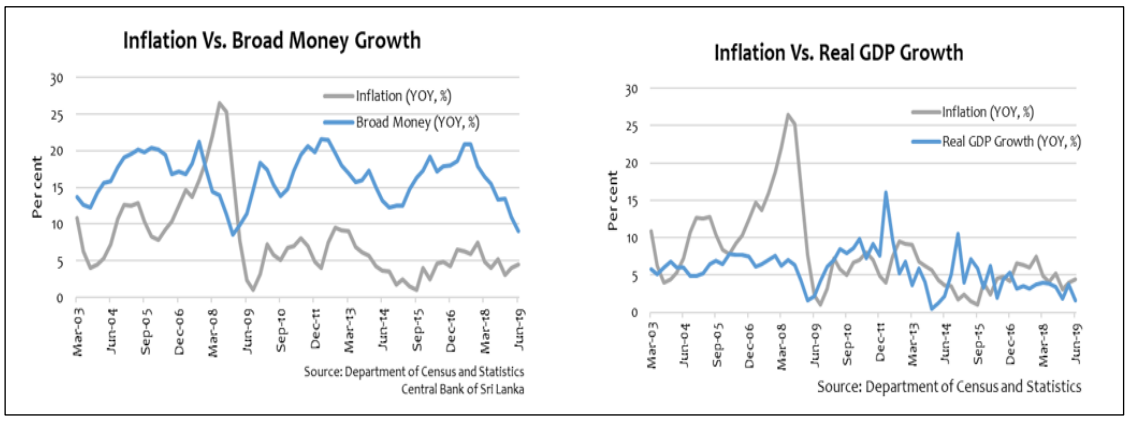

Figure 3.2: Disconnect between Key Macroeconomic Variables

Movements in policy rates indicate the stance of a central bank, but such changes only become effective if market interest rates, particularly lending rates adjust accordingly. It has often been observed that domestic retail lending rates have been rigid in responding to policy rate cuts than policy rate hikes, i.e. downward rigid. The asymmetric behaviour of lending rates to changes in policy rates, has therefore made it challenging for policymakers (i.e., the Central Bank) in their conduct of monetary policy, as the effectiveness of monetary policy decisions is centred around the response of commercial banks in adjusting their retail lending rates, given

[1] The slow growth of the economy could also be attributed to the possible underestimation of economy activity by the Department of Census and Statistics (DCS), driven largely by deficiencies in both the coverage of data as well as the quality in GDP compilation. (Central Bank of Sri Lanka, 2019)

the underdeveloped nature of the bond market in Sri Lanka. According to Figure 3.3, it is evident that Average Weighted Call Money Rate (AWCMR)[2], the operational target of enhanced monetary policy framework, was moving in line with the changes in the monetary policy stance, while the benchmark prime lending rate, the Average Weighted Prime Lending Rate (AWPR), which is also a short term retail lending rate, was broadly stagnant since 2016. The pass-through of policy rate changes on the Average Weighted Lending Rate (AWLR) is even low, when compared to AWPR. The sluggish response of market lending rates to policy rate adjustments necessitated the adoption of a suite of policy measures since late 2018 to support the Central Bank of Sri Lanka's monetary policy easing stance. Accordingly, alongside the downward adjustments to the policy interest rates, the Statutory Reserve Ratio (SRR) was also reduced with the view of reducing the cost of funds for commercial banks, which would support the reduction of their lending rates. Moreover, deposit rate caps were also introduced to contain the cost of funds incurred by banks when aggressively mobilising funds from the retail market. This was then followed by the imposition of lending rate caps so as to drive retail lending rates towards the intended levels. The need to impose a gamut of policy measures to drive market interest rates along the intended path highlights the challenges encountered by policymakers when implementing monetary policy.

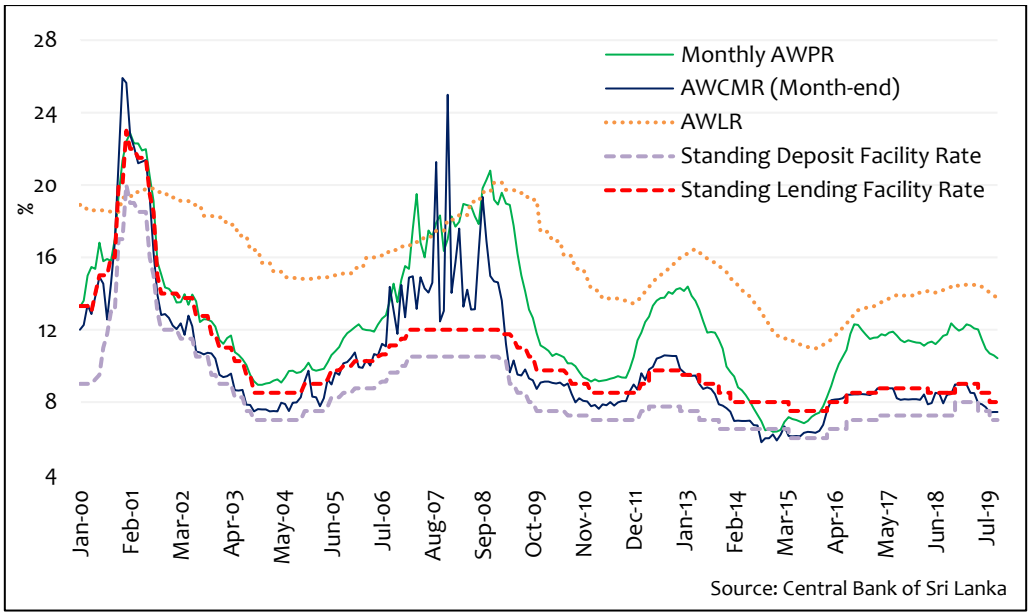

Figure 3.3: Movement of Selected Market Interest Rates

Also, the relationship between lending rates and credit has also waned over the years (See Figure 3.4). While an increase in lending rates are expected to dampen the growth of credit, Sri

[2] Further details of the interest rate used in this study are given in Table 4.2.

Lanka saw episodes such as that in 2016 where credit to the private sector surged to around 25 – 30 per cent in the backdrop of rising market lending rates, thus negating the anticipated outcome of adjustments to monetary policy stance.

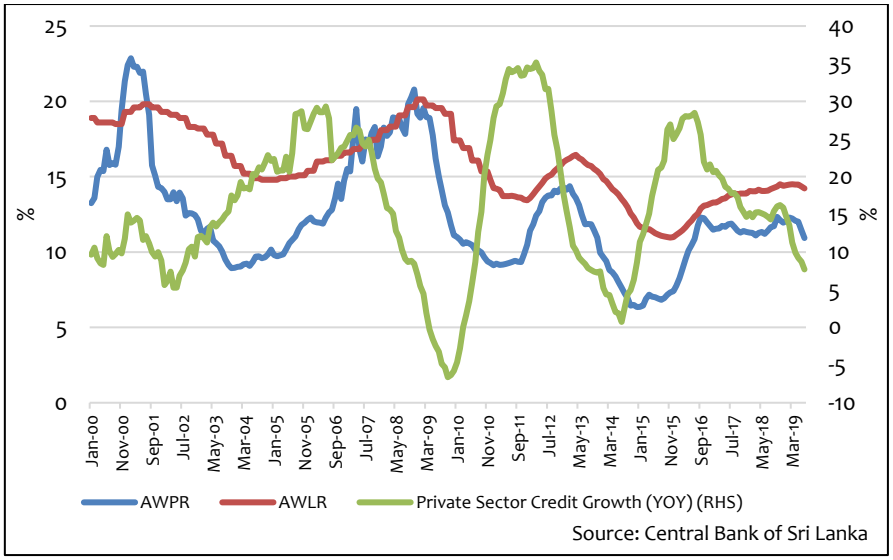

Figure 3.4: Disconnect between Lending Rates and the Growth of Private Sector Credit

Further to the disconnect between lending rates and the growth of private sector credit, Perera (2017) highlights that the response of output to credit impulses is unexpectedly low in the case of Sri Lanka, and this '*credit-GDP growth puzzle*' continues to remain a key challenge for policymakers as the relationship between private sector credit and economic growth appears to have been impeded since 2015, thus questioning the effectiveness of monetary policy in supporting real output (See Figure 3.5).

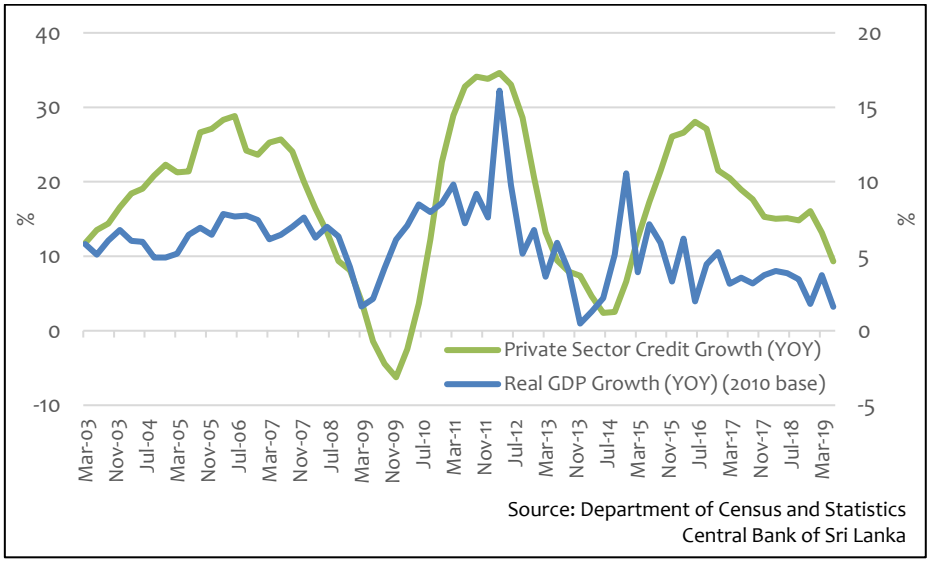

Figure 3.5: Private Sector Credit Growth Vs. Real GDP Growth

In summary, there are several policy related questions to be answered through empirical research. The following key questions are addressed in this research:

1. Has the relationship between money and inflation weakened in the recent years?
2. Has the relationship between money supply and economic growth weakened in the recent years?
3. Has the relationship between inflation and economic growth weakened in the recent years?
4. Has Sri Lanka's trend potential growth reached lower levels compared to the historical average?

4.0 Data and Methodology

This section gives a detailed description of the proposed models, the identification of restrictions and estimation method and the data.

4.1 Data

The study uses two sets of data samples. Monthly data samples covering 2001 January to 2019 June have been used for interest rate pass through analysis. Several interest rates have been selected sourced from the Central Bank as shown in Table 4.1. At the first stage of the discussion the magnitude of the pass-through from policy interest rate to money market rate is discussed. At the second stage, the pass-through from money market rate to other market rates is analysed.

For the analysis of time-varying dynamics and transmission of monetary policy changes to the real economy, quarterly data from 1996 March to June 2019 has been selected as quarterly GDP data is available from 1996. As discussed under methodology section, first 5 years of data has been used to compute initial value of the prior. Thus, data starting from 2002 has been used for inferences. The baseline model is a standard three variables approach, which includes GDP growth, inflation, and a short-term interest rate, with the objective of assessing the evolution of macroeconomic variables. This model is later extended by including money supply. AWCMR is chosen as the short-term interest rate, as it is currently recognised as the operational target of the monetary policy.

Table 4.1: Data Description

Variable	Definition
GDP Growth	Quarter-on-quarter growth
Inflation	Quarterly average inflation based on Colombo Consumer Price Index (CCPI)
Interest Rate	Average Weighted Call Money Market Rate (AWCMR): Both end value and monthly average are used
Money Growth	Quarter-on-quarter growth of M2b money supply
Exchange Rate	Quarterly change in US dollar- Rupee exchange rate (An increase indicates depreciation of Rupee)
Treasury Bill rate	Month end 91 days Treasury bill rate
Average Weighted Prime Lending Rate (AWPR)	AWPR is computed weekly, based on commercial banks' lending to their prime customers during the week, and its monthly figures are average values of the weekly rates
Average Weighted Lending Rate(AWLR)	AWLR is based on interest rates of all outstanding loans and advances of commercial banks. Monthly average is used
Average Weighted Deposit Rate(AWDR)	AWDR is computed based on all outstanding interest-bearing deposits held with commercial banks. Monthly average is used
Average Weighted Fixed Deposit Rate (AWFDR)	AWFDR is computed based on all outstanding interest-bearing time deposits held with commercial banks. Monthly average is used
The Standing Deposit Facility Rate (SDFR) and Standing Lending Facility Rate (SLFR)	SDFR is the deposit rate, while the SLFR is the lending rate of the Central Bank. The SDFR forms the lower bound and SLFR forms the upper bound of the Standing Rate Corridor (i.e. policy rate corridor)
Policy rate	Monthly average of SDFR and SLFR

4.2 Models and the Methodology

4.2.1 Methodology for interest rate pass-through

The fixed coefficient analysis of the pass-through uses the Auto Regressive Distribution Lag (ARDL) approach developed by Pesaran et al. (2001) to determine the short-run and long-run dynamics. Paying due attention on comparison of results, we use an ARDL(1,1) model to determine the pass-through dynamics. The ARDL approach is a standard way to determine the short-run and long-run dynamics and ARDL can be used for I(1), I(0) and as well as for a mix of I(1) and I(0) variables. It includes two main components in the regression; the auto regressive component considers the past values of the dependent variable as a function of the current values and the distributed lag component considers the current and past values of independent variables as functions of the dependent variable. The general, ARDL(p,q) model takes the following form,

$$ARDL_{p,q} = Y_t = \mu + \sum_{k=1}^{p} A_k \; Y_{t-k} + \sum_{j=0}^{q} B_j \; X_{t-j} + \varepsilon_t \qquad (1)$$

Where, $\sum_{k=1}^{p} A_k\ Y_{t-k}$ is the auto regressive component and $\sum_{j=0}^{q} B_j\ X_{t-j}$ is the distributed lag component. Accordingly, the ARDL(1,1) model will take the following form,

$$Y_t = A_0 + A_1 Y_{t-1} + B_0 X_t + B_1 X_{t-1} + \varepsilon_t; \text{ where } \varepsilon_t \text{ is the error term.}$$

Short-run dynamics are given by $\frac{\partial Y_t}{\partial X_t} = B_0$ and the long-run dynamics could be obtained by $\frac{\partial Y_T}{\partial X_t} = \frac{B_0+B_1}{1-A_1}$. The error correction form is as follows,

$$\Delta Y_t = A_0 - (1 - A_1)\, Y_{t-1} + B_0\, \Delta X_t + (B_0 + B_1)\, X_{t-1} + \varepsilon_t$$

$$\Delta Y_t = B_0\, \Delta X_t - (1 - A_1)\left[Y_{t-1} - \frac{A_0}{1 - A_1} - \frac{(B_0 + B_1)}{(1 - A_1)}\, X_{t-1}\right] + \varepsilon_t$$

$$\Delta Y_t = B_0\, \Delta X_t - \pi\, [Y_{t-1} - \alpha - \beta\, X_{t-1}] + \varepsilon_t$$

$$\Delta Y_t = B_0\, \Delta X_t - \pi\, ECT_{t-1} + \varepsilon_t; \qquad (2)$$

where π represents the speed of adjustment of short-run effects to long-run.

We also measure the time it takes for a complete pass-through of interest rate following an adjustment based on the mean adjustment lag approach adopted by Hendry (1995).

4.2.2 Time-varying parameter model with stochastic volatility (TVP-SVOL)

The methodology in this study closely follows the approach adopted by Akram and Mumtaz (2019).

The VAR model with time-varying coefficient is given below.

$$Y_t = c_t + \sum_{l=1}^{L} \emptyset_{l,t}\, Y_{t-l} + \vartheta_t \qquad (3)$$

Where Y_t contains GDP growth, inflation, short term interest rate and money supply growth in our model.

Based on Cogley and Sargent (2005) the covariance matrix has the following representation:

$$VAR(\vartheta_t) = R_t = A_t^{-1}\, H_t\, (A_t^{-1})' \qquad (4)$$

The time-varying matrices H_t and A_t are defined by

$$A_t \equiv \begin{pmatrix} 1 & 0 & 0 \\ a_{12,t} & 1 & 0 \\ a_{13,t} & a_{23,t} & 1 \end{pmatrix},\ H_t \equiv \begin{bmatrix} h_{1,t} & 0 & 0 \\ 0 & h_{2,t} & 0 \\ 0 & 0 & h_{3,t} \end{bmatrix} \qquad (5)$$

$h_{i,t}$ evolving as random walks. Following Primiceri (2005) matrix A_t includes non-zero and non-one elements to evolve as drift less random walks.

The (time-varying) matrix A_t is lower triangular with ones on the main diagonal while matrix H_t is defined as diag($h_{1,t}\, h_{2,t}\, \ldots . h_{N,t}$); $h_{i,t}$ evolves as a geometric random walk,

$$\ln h_{i,t} = \ln h_{i,t-1} + \tilde{v}_{t.}$$

Following Primiceri (2005), we postulate the non-zero and non-one elements of the matrix A_t, to evolve as driftless random walks:

$$\propto_t = \propto_{t-1} + \tau_t , \tag{6}$$

and we assume the vector $[v_t', \eta_t', \tau_t', \tilde{v}_t']'$ to be distributed as,

$$\begin{bmatrix} v_t \\ \eta_t \\ \tau_t \\ \tilde{v}_t \end{bmatrix} \sim N(0, V), \tag{7}$$

with

$$V = \begin{bmatrix} \Omega_t & 0 & 0 & 0 \\ 0 & Q & 0 & 0 \\ 0 & 0 & S & 0 \\ 0 & 0 & 0 & G \end{bmatrix} \tag{8}$$

and

$$G = \begin{bmatrix} \sigma_1^2 & 0 & 0 \\ 0 & \sigma_2^2 & 0 \\ 0 & 0 & \sigma_2^2 \end{bmatrix} \tag{9}$$

Prior distributions and starting values

The model is estimated using Bayesian approach employing Gibbs sampling algorithm that approximates the posterior distribution.

The initial conditions for the VAR coefficients $\emptyset_0$ are obtained via an OLS estimate of a fixed coefficient VAR with two lags using the first 20 observations of the data sample starting in 1996Q2.

Let $\hat{v}^{ols}$ denote the OLS estimate of the VAR covariance matrix estimated on the initial observations. The prior for the diagonal elements of the VAR covariance matrix is defined as $ln\ h_0 \sim$ N $(ln\ \mu_0, I_3)$ where μ_0 contains the diagonal elements of the Cholesky decomposition of $\hat{v}^{ols}$.

The prior for the off-diagonal elements A_t is A_0~ N ($\hat{a}^{ols}, V(\hat{a}^{ols})$) where $\hat{a}^{ols}$contains the off-diagonal elements of $\hat{v}^{ols}$, with each row scaled by the corresponding element on the diagonal. $V(\hat{a}^{ols})$ is assumed to be diagonal with the elements set equal to 10 times the absolute value of the corresponding element of $\hat{a}^{ols}$. The prior on Q is assumed to be inverse Wishart Q_0~ IW($\bar{Q}_0$, T_0) where Q_0 is assumed to be $var(\hat{\emptyset}^{OLS})$) x 10^{-4} x 3.5 and T_0 is the length of the sample used to for calibration. The prior distribution for the blocks of S is inverse Wishart: $S_{i,0}$~ IW($\bar{S}_i$, K_i) where i indexes the blocks of S. $\bar{S}_i$ is calibrated using $\hat{a}^{ols}$. Specifically, $\bar{S}_i$ is a diagonal matrix with the relevant elements of $\hat{a}^{ols}$ multiplied by 10^{-3}. Following Cogley and Sargent (2005) we postulate an inverse-gamma distribution for the elements of C, $\sigma_i^2 \sim IC\begin{pmatrix}10^{-4}, & 1\\ 2 & 2\end{pmatrix}$.

5.0 Empirical Analysis

5.1 Time-varying Dynamics of Macroeconomic Variables

In this section, we study the dynamic properties of the key macroeconomic variables and their co-movements to find out whether the correlation, volatility, trend of these variables have changed and whether the changes give any explanation to resolve the policy puzzles discussed in the earlier section. Prior to the detailed analysis, it is worth discussing the actual movements of the key macroeconomic variables to be discussed in this section. Figure 5.1 illustrates movements of 4 key macroeconomic variables namely quarterly growth of GDP, quarterly inflation, short term money market rate (AWCMR) and quarterly growth of money supply. An eyeball test of these charts reveal that GDP growth has been volatile at some periods in recent times, while inflation has become broadly stable. The money market rate was peaking at different time periods in the past. In contrast, money growth has been changing in positive range below 6.0 per cent over the sample period and it has exhibited relatively lower growth since last year.

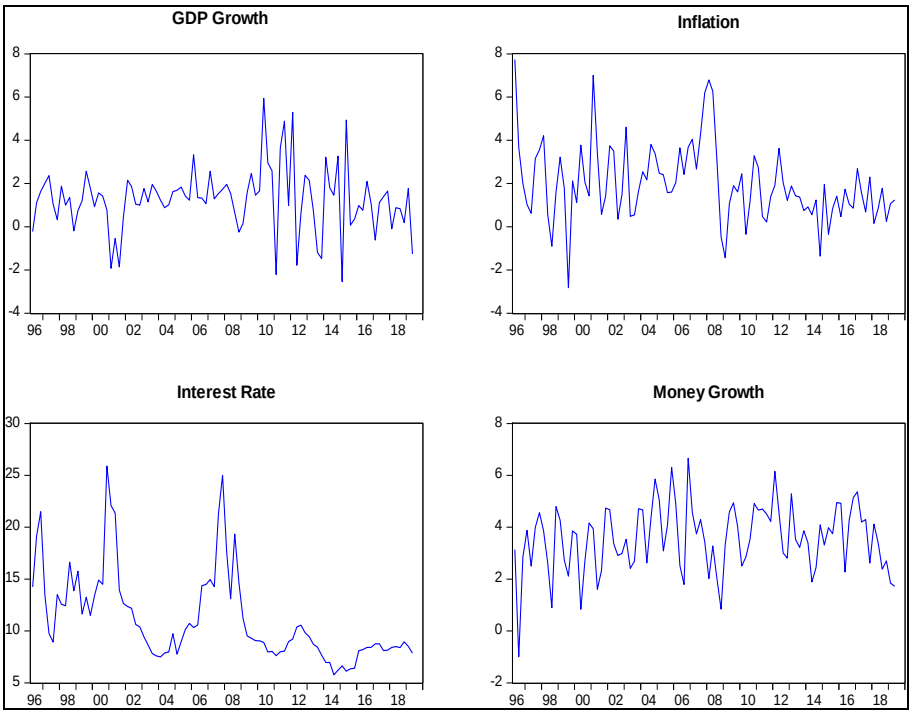

Figure 5.1: Movements of the Selected Variables

Prior to analysing the time-dependent variability, correlation and evolution of these variables, it is worth discussing the descriptive statistics of these variables and the relationship between them over the sample period. Table 5.1 highlights the key statistics to better understand these variables and their relationships with each other. It is clear from this table that analysing these statistics over the full sample period does not give any valuable insight to the policymakers. For instance, interest rate is the most volatile variable as it has the highest standard deviation. However, as per Figure 5.1 the volatility in interest rate has subsided for the last ten years. Thus, time-variant analysis is needed to understand and resolve policy puzzles to provide useful insights to the policymakers.

Table 5.1: Descriptive Statistics and Correlation Analysis of the Selected Variables

	Key Descriptive Statistics – 2002Q1-2019Q2			
	GDP Growth	**Inflation**	**Interest Rate**	**Money Growth**
Mean	1.40	1.88	9.84	3.74
Maximum	5.94	6.80	24.99	6.66
Minimum	-2.54	-1.44	5.77	0.84
Std. Dev.	1.55	1.61	3.47	1.20
	Correlation Analysis			
	GDP Growth	**Inflation**	**Interest Rate**	**Money Growth**
GDP Growth	1.00	-0.08	0.01	0.16
Inflation	-0.08	1.00	0.59	0.10
Interest Rate	0.01	0.59	1.00	-0.11
Money Growth	0.16	0.10	-0.11	1.00

Time-varying Trend

Time varying unconditional mean is estimated based on the methodology adopted by Akram and Mumtaz (2019). Baseline version with canonical three variable model is initially estimated and unconditional mean along with the data series is plotted in Figure 5.2[3] . The figure suggests that regardless of various structural and policy changes that took place the long term mean of the key variables did not change substantially and did not show any structural break, when GDP growth, inflation and interest rate are taken into consideration. This is further supported by a very narrow confidence band. Accordingly, the long term mean of quarterly GDP growth smoothly declined marginally to around 1.4 per cent. Similarly, the inflation moderation in the recent time is also gradual and does not show any structural changes. Accordingly, the long term mean of the quarterly inflation has decelerated from 2.0 per cent in 2000s to around 1.5 per cent in the recent years. The long-term interest rate movement has also been gradual and changing slightly in both directions, reflecting the monetary policy stance adopted by the Central Bank. The trend did not exhibit either upward or downward movement over the time. These findings, however, do not provide any valuable insights to understand and resolve some of the policy puzzles discussed earlier. Thus, the baseline model is extended further to include broad money supply growth that was the intermediate target of monetary policy until very recent periods and still considered as an indicative intermediate variable under the current enhanced monetary policy framework of the Central Bank. The same result based on the extended model is shown in Figure 5.3. The extended model provides more valuable information about dynamic changes in the time-dependent trend of the key macroeconomic variables. There is no evidence of systemic moderation in growth over the period though there is evidence of some moderation in growth in the most recent periods since 2018 that coincides with a slowdown observed in money supply growth. Long-term interest rate trend remains broadly stable and declines sharply in 2019. All these could lead to an understanding that recent moderation in growth and inflation could be linked to lower aggregate demand and slower economic activities in the economy.

[3] Actual movements of the endogenous variables are shown by blue lines. Red line shows median estimate of the long term mean, while the shaded area represents 68 % error bands.

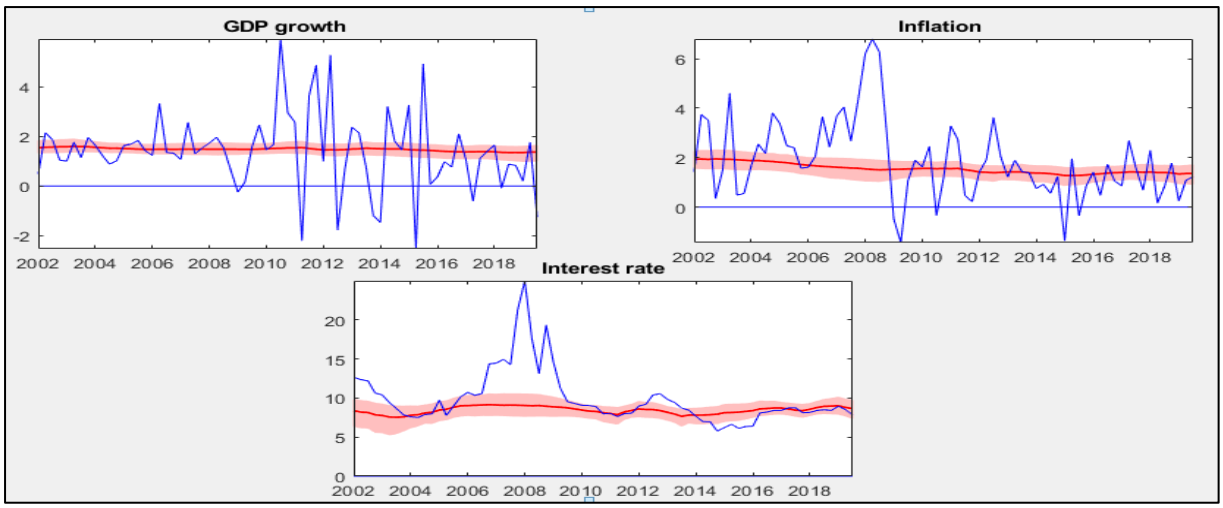

Figure 5.2 Time-Varying Trend of the Variables- Baseline Model

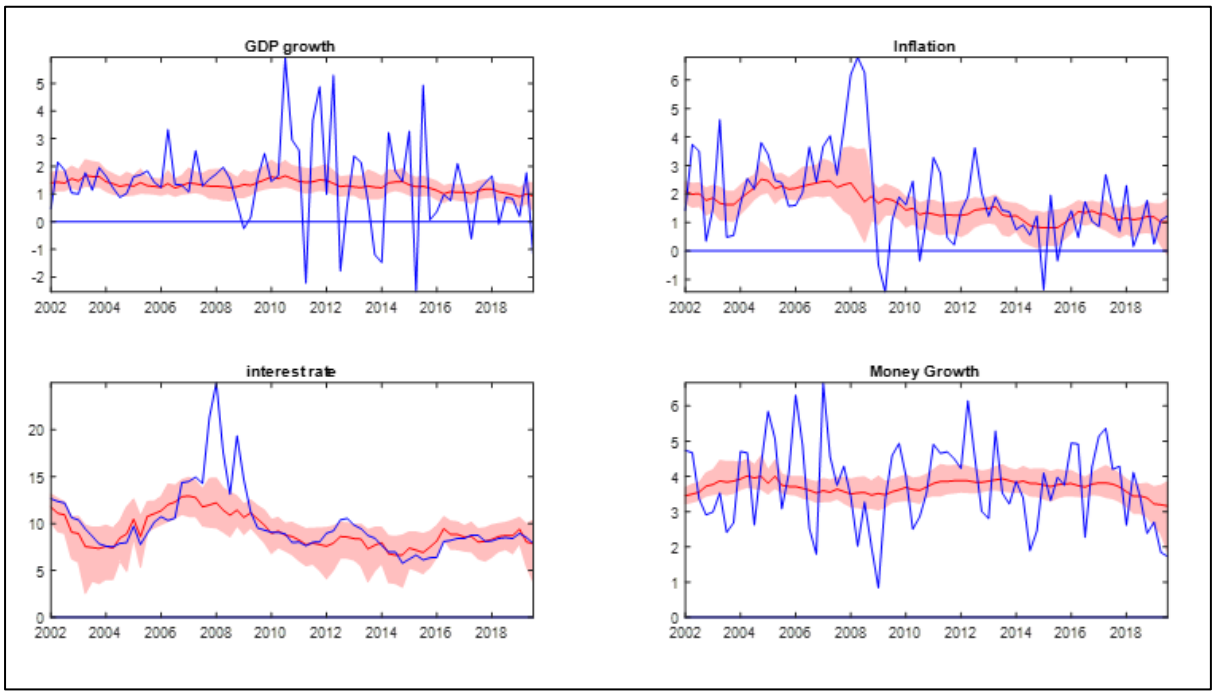

Figure 5.3 Time-Varying Trend of the Variables- Extended Model

Macroeconomic Volatility

Time-varying macroeconomic volatility is measured by the stochastic volatility of shocks. In Figure 5.4 the stochastic volatility of shocks is shown in the first panel and estimated unconditional standard deviation of the endogenous variables is shown in the second panel. It illustrates the comparability of the volatility of the endogenous variables and the volatility of shocks to these variables. If time-varying unconditional standard deviation of the variable move along with the volatility of shocks to that variable, then it is concluded that much of the variation in the variable is explained by the changing volatility of shock. Extended version of

the model is found to be useful in providing better insights, as discussed in the previous section, all the analysis will be based on the extended model going forward. As shown in Figure 5.4, GDP growth exhibits larger standard deviation that is explained by the stochastic volatility of shock during 2010-2015. The standard deviation during this period increased to over 6 per cent compared to near zero values in the other periods and the fixed standard deviation of 1.55 per cent reported for the sample of 2002Q1- 2019Q2. This highly volatile period coincides with the introduction of new series of GDP[4] as well as high public expenditure based infrastructure driven growth in the aftermath of end of civil war. Most interestingly the recent subdued growth since 2016 is not fully explained by the stochastic volatility, which is a useful insight for policy makers to take appropriate policies to revive the GDP growth by driving aggregate demand.

Another interesting finding is the gradual moderation of inflation since 2000, especially after 2010, as shown by continuous lowering of the standard deviation. Intuitively, this moderation in volatility of inflation is not mainly driven by the volatility in shock to inflation. Compared to the fixed standard deviation of 1.6 reported for the entire sample, the time-dependent standard deviation moderated from around 0.6 per cent in 2000s to less than 0.2 per cent in 2019. Volatility of shock is higher only in 2008- 2009, to our knowledge that is associated with large swings in oil price and some domestic economic shocks. This supports the claim of the Central Bank that its continuous initiatives to move to a more forward looking monetary policy framework by improving the internal processes and external communication has helped to anchor inflation and reduce the volatility in inflation. The attempts of the government to mitigate temporary supply side disturbances also complimented this effort. This evidence supports the argument for transition to the envisaged Flexible Inflation Targeting (FIT) framework.

Surprisingly, interest rate movements over the time did not show any notable stochastic volatility except for a shorter period of 2008-2009, which is largely attributed to the volatility observed in the money market during the period due to some disturbance to the domestic financial system as well as partly due to the GFC. This is a very valuable evidence, as in the absence of this time-varying analysis interest rate in Sri Lanka could be considered as highly volatile as shown by a relatively higher fixed standard deviation of 3.5 per cent for the sample

[4] The reliability of the new series is being widely questioned by many policy makers and the critics. This evidence could fuel such argument.

period. Money supply growth does not exhibit either substantial standard deviation or volatility of shock.

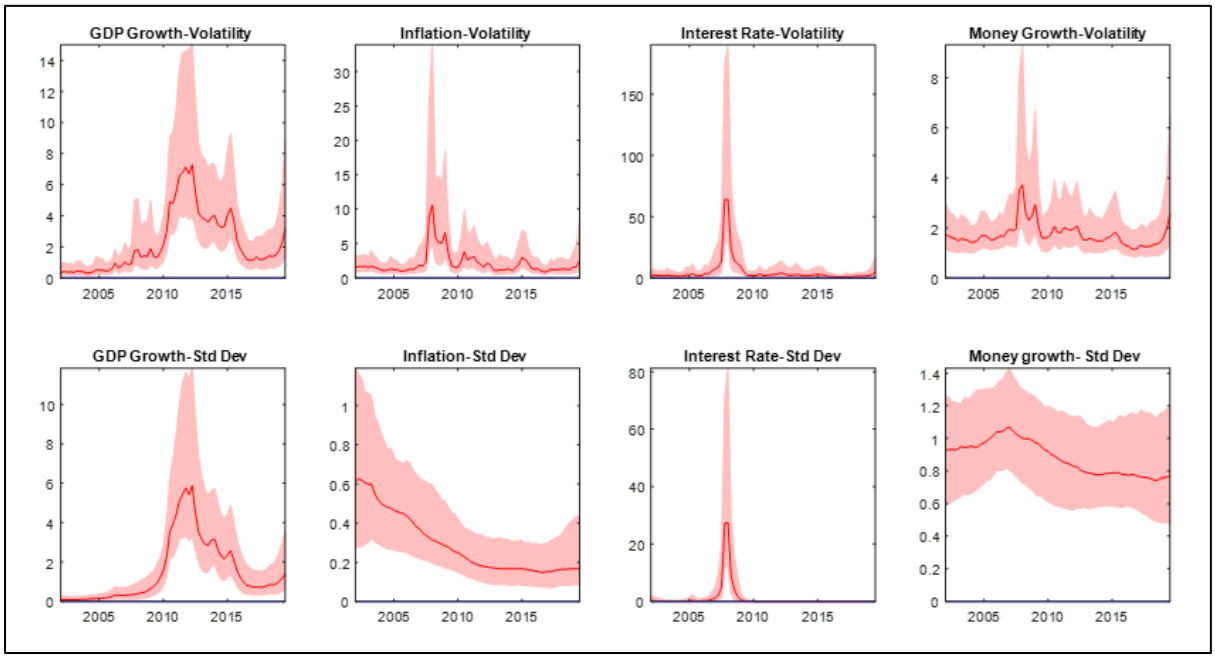

Figure 5.4 Time-Varying Stochastic Volatility and Unconditional Standard Deviation

Dynamic Correlations

Employing the methodology adopted by Akram and Mumtaz (2019) dynamic correlation between the pair of variables over business cycle frequency (three years) are measured and illustrated in Figure 5.5. Accordingly, the time-varying correlation of GDP growth- Inflation and GDP growth- Interest rate have been quite dynamic during some time periods, with median estimate of dynamic correlation between GDP-Inflation moving in both positive and negative territories and becoming more negatively correlated since 2010 with correlation coefficient of around -0.3. This is in comparison to a weak negative correlation of -0.08 recorded under the time-invariant analysis. Though negative relationship between GDP growth and inflation is puzzling such as puzzle is not new in the literature. Kydland and Prescott (1990) argue that supply side shocks are mainly responsible for such inverse relationship. There is also a view that even demand side shock under sticky price setting could explain such a relationship. The correlation between GDP-Interest rate has weakened to near zero levels since 2010. This is partly due to higher volatility associated with volatility in shocks observed in GDP growth during 2010- 2015 that is not driven structurally. This result is compared to the fixed correlation

of 0.01 reported in the fixed analysis. Correlation between GDP-Money growth also found to be weaker, though it tends to be in positive territory in some periods.

Interest rate- Inflation correlation has been broadly stable in the positive territory varying in a range of 0.2-0.4 per cent, compared to a higher fixed correlation of 0.6 per cent. Dynamic correlation between Inflation- Money growth is broadly stable at 0.2 per cent during most of the sample period, compared to a lower time-invariant full sample estimate of 0.1. Interest Rate- Money growth did not show any significant relationship during most of the period, expect for a negative correlation during a shorter period covering 2004-2010.

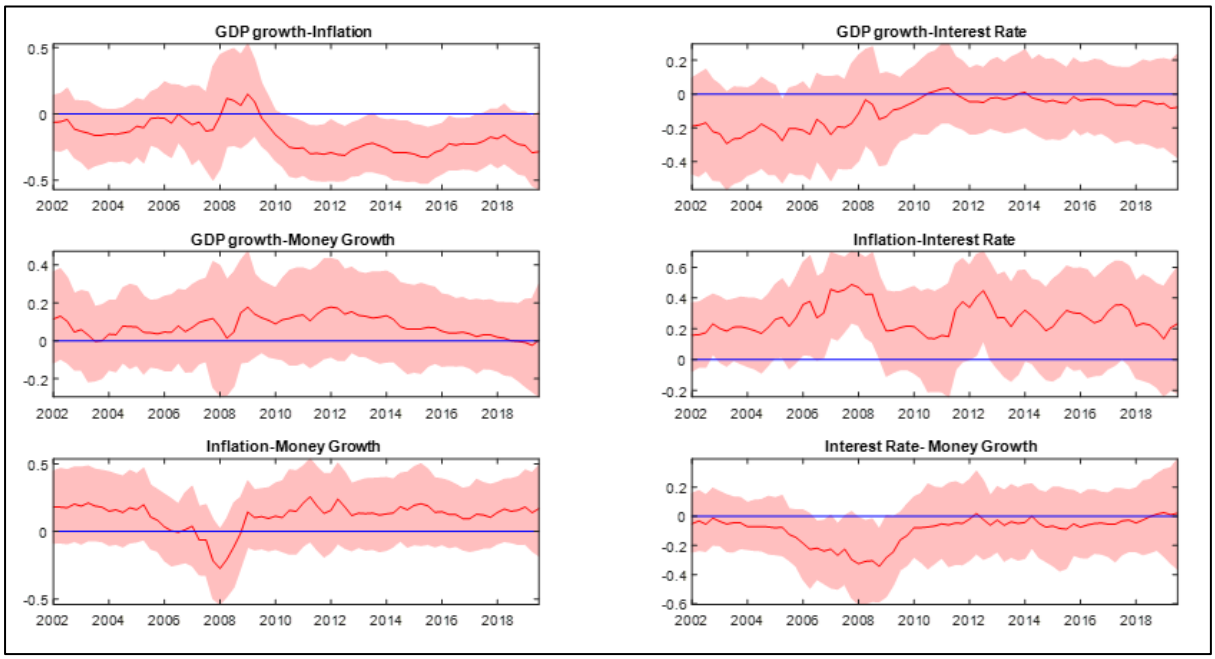

Figure 5.5 Dynamic Correlation between Pairs of Variables- Business Cycle Frequency

In Summary, the analysis of time-dependent time series properties provides some insights to better understand and explain some of the policy puzzles identified in this study. GDP growth exhibit time-varying relationship with other key macroeconomic variables mainly since 2010. This could be largely attributable to the changes in volatility of shock to GDP growth, rather than a systematic structural change. Also, there is no evidence of systematic and structural moderation in long-term mean of the GDP growth over a longer period, although a slight moderation is observed in the most recent periods. Such an evidence is valuable, as these cannot be captured through the observation of the growth series or filtering based estimation of trend of GDP growth. Figure 5.6 compares the outcome of HP filtered growth series and time-varying unconditional mean along with historical mean. Filtering based evidence suggest

notable improvement in trend during 2006-2013 while pointing to a notable dip in the trend since 2016. Such large swings in trend was not supported by time-varying estimation of the mean. Thus, there is no rationale to believe that the long term potential level of the GDP growth has shifted downward sharply. It can be concluded that the capacity for growth has somewhat slowed in most recent period, which is partly explained by recent deceleration in money growth. This warrant special attention of the policy makers to take timely and appropriate policy measures to revive the growth.

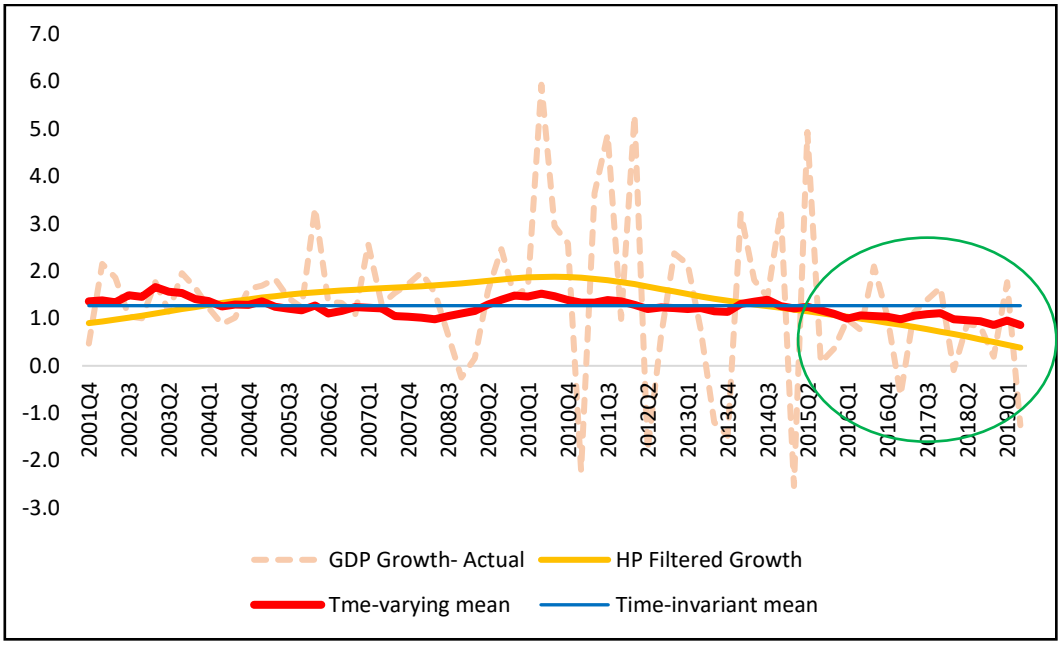

Figure 5.6: Comparison of Different Measures of GDP Growth Trend

Systemic moderation observed in the magnitude and the volatility of inflation since 2010 is also an important empirical evidence for the policy makers. Such moderation is not mainly driven by lower variations in shocks to inflation, as the volatility level of shock remain at the same level before 2008 and after 2010 as shown in the figures, except for higher volatility in inflation reported in 2008-2009 that is purely driven by volatility of shock. It is convincing that it could be policy driven and could be largely attributable to the efforts of the Central Bank to modernize the monetary policy process along with aggressive monetary policy communication with implicit target range for inflation to anchor inflation expectations.

However, there is no adequate evidence to show changing or weakening linkages among inflation, interest rate and money. The exception is the shorter period mainly between 2008-2010 that exhibited changes in volatility, unconditional mean and inter linkages. Near zero

correlation between Interest rate- Money growth estimated since 2010 confirms the Central Bank's gradual move away from monetary aggregate targeting.

5.2 Interest rate Pass-through of Monetary Policy

In the analysis of interest rate pass-through using fixed coefficient models (ARDL) we study interest rate pass-through via money market interest rate, Average Weighted Call Money Market Rate (AWCMR) considering the fact that current monetary policy target rate being the AWCMR. The purpose of this section is to examine whether existing evidence on interest rate pass-through in Sri Lanka has changed when most recent periods that explicitly recognise short-term interest rate as the operational target of the monetary policy is included in the sample. The analysis considers two stages of transmission; transmission from policy rate to short term money market interest rates (AWCMR) and then from market interest rates to retail interest rates (Lending and Deposit rates).

In this section, we analyse the pass-through from policy rates to AWCMR, and then assess the pass-through from AWCMR to other retail lending and deposit rates. Results of the short-run and long-run pass-through dynamics of AWCMR is summarised in Table 5.2.

As per the results in Table 5.2, the long-run pass-through from policy rates to AWCMR is more than complete with a one percentage point change in the policy rates translating into a 1.19 percentage point change in AWCMR. It is also observed that the contemporaneous change in AWCMR (i.e. the short-run pass-through) is around 1.09 per cent, with a speed of adjustment of 0.16 percentage points and a mean adjustment lag of 0.5 months. These findings on the short-run and long-run pass-through are consistent with the findings of Amarasekara (2005). In fact, the pass-through of policy rates to AWCMR in this study is higher than that reported in Amarasekara (2005).

Next, we examine the pass-through from AWCMR to retail lending and deposit rates. We find evidence of a higher than complete long run pass-through to AWPR, an almost complete long-run pass-through to AWFDR, but incomplete, yet high long-run pass-through to AWLR and AWDR. A one percentage point change in the call money market rate results in AWPR adjusting by 0.52 percentage points, contemporaneously, following which adjusts by around 0.08 percentage points towards the long run equilibrium. However, over the long-run, a one percentage point increase in the call money market rate results in a higher than complete pass-

through to AWPR (1.08 percentage points), demonstrating the effectiveness of monetary policy on short-term (lending) rates.

However, we observe incomplete long run pass-through for AWLR (0.84 percentage point change for a one percentage point change in AWCMR) almost exactly as in the case of Ghazanchyan (2014). Although we observe less-than-complete interest rate pass-through, it could still be considered high, particularly in the context of low contemporaneous pass-through of 0.4 per cent. This could be due to AWLR being compiled based on the outstanding stock of loans, which not only includes new lending but also loans granted in the past, thus making AWLR increasingly rigid. Nevertheless, the speed of adjustment is somewhat higher than the short-run response, although it takes around 1.5 years if there was to be complete pass-through of following a change in monetary policy.

The short-run pass-through of interest rates to retail deposit rates were dismal as per our findings. While the contemporaneous response of AWDR to a one percentage point change in the call money rates stood at 0.01 percentage points, the short run response of AWFDR was slightly higher at 0.02 percentage points. This finding is consistent with Ghazanchyan (2014), although remaining somewhat lower compared to Perera (2016)[5]. The speed of adjustment of deposit rates was also low at around 4-5 per cent.[6] However, the long-run pass-through is almost complete for AWFDR, albeit remaining incomplete, but comparatively high[7] for AWDR. The mean adjustment lag turned out to be around 19-24 months for the deposit rates.

[5] Perera (2016) reports a short-run pass-through of 0.07 percentage points and 0.10 percentage points to 1 percentage point change in the 91-day Treasury bill rate.

[6] Amarasekara (2005) report speeds of adjustment of 2.1 per cent and 8.0 per cent for AWDR and AWFDR, respectively, while Perera (2016) report somewhat higher speeds of adjustment of 9.4 per cent and 11.4 per cent, respectively, for the same.

[7] Ghazanchyan (2014) reports a long-run pass-through of 0.30 percentage points, compared to 0.76 percentage points in this study.

Table 5.2: Estimates of Long Run and Short Run Interest Rate Pass-Through of AWCMRAVG

	Mark up (A_0)		Long-run pass through (β)		Short-run pass through (B_0)		Speed of Adjustment (π)		Mean Adjustment Lags
	Coefficient	t-Value	Coefficient	t-Value	Coefficient	t-Value	Coefficient	t-Value	(in months)
Policy Rates to Short Term Money Market Rates									
AWCMRAVG	-0.9168	-0.6184	1.1889***	7.4782	1.0856***	6.3052	-0.1620***	-4.2608	0.5
AWCMRAVG to Retail Interest Rates									
Lending Rates									
AWPRAVG	1.1665	1.1938	1.0823***	11.8685	0.5217***	19.5073	-0.0847***	-4.9147	5.6
AWLR	6.8040***	6.2837	0.8392***	8.3942	0.0403**	2.5491	-0.0532***	-7.6920	18.0
Deposit Rates									
AWDR	0.1362	0.0869	0.7679***	5.1960	0.0109	0.6934	-0.0405***	-6.2589	24.4
AWFDR	0.4923	0.3153	0.9930***	6.7388	0.0215	0.9766	-0.0515***	-6.5659	19.0

Source: Authors' calculation

Note: ARDL(1,1) model is used in the estimation of model coefficients. $\boldsymbol{A_0}$ *indicates the mark-up (or mark-down) on the short-term money market rates and retail interest rates, while β provides a measure of the long-run pass-through from policy rates to the short-term money market rates, and thereafter from short term money market rates to the retail interest rates.* $\boldsymbol{B_0}$ *measures the short-run pass-through of interest rates, while* $\boldsymbol{\pi}$ *measures the short-run speed of adjustment towards the long-run equilibrium. Mean adjustment lag of a complete interest rate pass-through is measured as (1-*$\boldsymbol{B_0}$*)/* $\boldsymbol{\pi}$.

5.3 Monetary Policy Pass-through to Target Variables - TVP-SVOL

Impulse responses to monetary policy shock employing TVP-SVOL model using sign restrictions is discussed in this section. Given the background knowledge on the dynamics of the variables over time, the purpose of this section is to see whether impulse responses show evidence of variation over time. For simplicity, canonical three variable model has been used in this analysis. Monetary policy shock is identified by a positive shock to the short-term money market rate (AWCMR) and that is expected to have either zero or negative impact on the GDP growth and inflation under sign restriction based identification. If no significant deviation is observed in the responses of the target variables to the monetary policy shock, then it could be concluded that there were no substantial changes in the responses resulting from both policy changes and structural changes. In such instances, standard fixed coefficient models are sufficient to measure the monetary policy transmission mechanism, without giving due consideration to the time variations. If the responses vary notably over time, then the policy analysis and measurement of responses to shocks need to consider time variations. The previous section already has given evidence to show the presence of time variations in the trend, volatility and dynamic correlations. In this section we examine time-varying responses of macroeconomic variables to monetary policy shock.

Time- varying impulse response of monetary policy shock is shown in Figure 5.7. The size of impulse response is shown in x-axis and impulse horizon is shown in y-axis. The third dimension shows individual quarters from 2002Q1- 2019Q2. It is evident from the figure that the target variables demonstrate different magnitude of responses for the same level of increase (1 per cent) in the interest rate. The response of GDP growth to increase in interest rate was quite stable until 2010, but become substantially different in each period after that. In contract, inflation shows notably different responses throughout the sample period. The speed and the size of adjustment to interest rate after a 1 per cent increase on the impact also has changed substantially and highly time- variant since 2010.

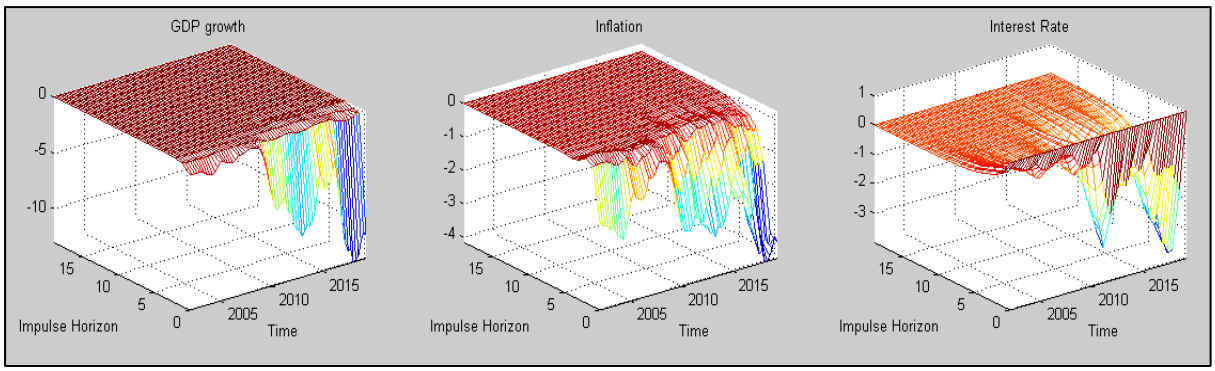

Figure 5.7: Impulse Responses of Monetary Policy Shock - Full Sample Period

It is therefore useful to extract impulse responses under two different sub-sample periods, i.e., prior to 2010 and post 2010, as shown in Figure 5.8. The first panel extracts the impulse responses during 2002- 2009, while the second panel includes the sample from 2010. Both the path and the size of the responses are different during the sub sample periods, supporting the application of time-variant models to study responses to monetary policy changes.

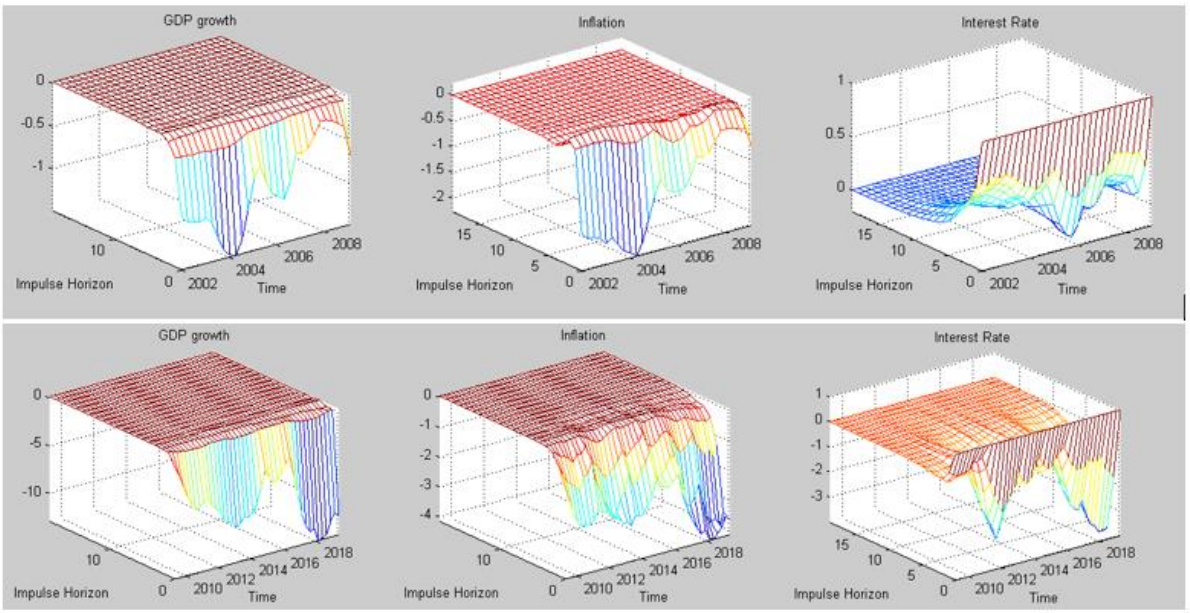

Figure 5.8 Impulse Responses of Monetary Policy Shock - Sub-Sample Period

6.0 Conclusion and Discussion

This research studies evolution of time series properties of key macroeconomic variables and the interlinkages to resolve some of the policy puzzles currently being faced by the policy makers in Sri Lanka. Further, traditional regression based method was employed to measure interest rate pass-through using data on monthly frequency to provide updated evidence on the interest rate pass-through covering most recent data. In addition, transmission process of monetary policy is studied to identify changes to the transmission process in the recent times and to see whether transmission exhibit time-dependent responses. TVP-SVOL has been employed to study time-varying macroeconomic dynamics and time-dependent monetary policy transmission. The key findings are summarised below.

Time-varying analysis of macroeconomic dynamics provides key findings that are valuable for policymakers in Sri Lanka. One important finding is that the key variables, such as GDP growth, inflation, short term interest rate and money growth, did not show any major structural break during the last two decades, since the long-term mean has evolved and changed smoothly. The result showing only marginal moderation of GDP growth in the recent times adds a strong evident against the recent arguments among the policy circle and the academia that Sri Lankan potential has declined to a new normal of around 4.0 per cent from around 6.0 per cent historical average. The findings suggest broadly stable long-term mean of quarterly GDP growth over the sample period with some moderation in the most recent years. Such moderation is smaller than the moderation exhibited by filtering technique driven trend. This finding will be a valuable insight for monetary policy formulation, since forward looking monetary policy rules partly rely on the measurement of output gap. Further, recent slowdown in growth momentum could be linked to the deceleration in money supply growth. Thus, policy maker's attention is sought for quick revival of the economic growth.

Further, systemic moderation in the magnitude and the volatility of inflation in the recent years is in favour of the Central Bank's transition to a robust and forward looking monetary policy formulation and communication. In addition, the long term mean of interest rate remaining broadly unchanged during past decades, regardless of gradual moderation in inflation and growth. Another important finding is lower correlation of money growth with GDP growth and interest rate over a decade. This matches with the Central Bank's gradual discontinuation of money targeting since mid-2000s. However, there is no substantial evidence to show breakdown of the relationship between Inflation- Interest rate and Inflation- money growth.

Analysis of volatility of the selected variables suggests that notable volatilities observed in GDP growth during 2010-2015, inflation during 2008-2009 and interest rate during 2008-2009 are largely driven by the stochastic volatility of shocks, rather than any structural changes. It should be noted that this provides a favourable evidence to the current debate that the revised GDP series based on 2010 base year is rather noisy and the volatility observed in this series during 2010-2015 is hard to be associated with the status of other key macroeconomic variables.

To gauge the magnitude and speed of interest rate pass-through in Sri Lanka, we conducted a two-staged analysis; firstly, testing for pass-through from policy rates to short term money market rates, namely AWCMR, and then assessing the pass-through from the money market interest rate to retail lending and deposit rates. The first stage analysis reported a more than complete short-run and long-run pass-through from policy interest rates to AWCMR. Next, based on the second-stage analysis, we found evidence of a more than complete pass-through (over pass-through) from AWCMR to AWPR in the long-run. However, the pass-through from AWCMR to AWLR in the short-run was substantially low when compared to the case of AWPR, with the long-run pass-through being somewhat high, though not complete. With respect to pass-through to market deposit rates, the short-run pass-through was poor with relatively low speeds of adjustment. However, long-run pass-through was almost complete for AWFDR, but comparatively lower for AWDR. As such, our findings are broadly consistent with the findings of Amarasekara (2005), Ghazanchyan (2014) and Perera (2016) albeit there being some differences in the magnitude and speed of adjustment, and the time it takes to achieve complete pass-through (mean adjustment lag). Our findings suggest that the interest rate pass-through to short term money market and retail lending rates (i.e., AWPR) is faster and higher, while the pass-through to other retail lending and deposit rates take time (around 1-2 years).

This paper also studied time-varying responses of target variables, such as inflation and growth, to a contractionary monetary policy stance employing TVP-SVOL. The findings confirm the presence of time-varying responses of growth and inflation to monetary policy shock. Findings support time-dependent responses of target variables to monetary policy, with clear distinction between the responses during 2002-2009 period and the period after that.

Finally, this study can be extended in many ways with future research. Due to time limitations, the scope of this paper on time-varying dynamics have been limited to traditional tri-variate

model with growth, inflation and interest rate and an extension with money growth. This model could be extended in the future to include exchange rate and fiscal variables, since these variables also play a significant role in shaping macroeconomic conditions. Further, in addition to sign restriction based identification used in this study, different identification methods could be employed to check the robustness of time-varying monetary policy transmission process found in this paper. Also, this study limits the interest rate-pass through analysis to time-invariant approach. There is recently emerging literature on time-varying interest pass-through employing time-varying cointegration analysis. An extension on this area is also recommended for future research. Finally, the time-varying transmission analysis in this paper is limited to finding out whether responses to monetary policy exhibit time-variations, rather than studying the transmission size, speed of adjustment and the underlying factors behind this time variation. This scope could be extended with future research.

References

Aazim, M.Z. and Cooray, N.S. (2012). Monetary Policy and Yield Curve Dynamics in an Emerging Market: Sri Lankan Perspectives. *South Asian Journal of Macroeconomics and Public Finance*, *1*(1), pp.25-56.

Akram, Q.F. and Mumtaz, H. (2019). Time-Varying Dynamics of the Norwegian Economy. *The Scandinavian Journal of Economics*, *121*(1), pp.407-434.

Amarasekara, C. (2005). Interest rate pass-through in Sri Lanka. *Staff Studies, Central Bank of Sri Lanka, Colombo*, 35(1&2), 1–32.

Amarasekara, C. (2008). The Impact of Monetary Policy on Economic Growth and Inflation in Sri Lanka. *Staff Studies, Central Bank of Sri Lanka*, 38(1&2), 2–44.

Baumeister, C., Liu, P. and Mumtaz, H. (2010). Changes in the transmission of monetary policy: Evidence from a time-varying factor-augmented VAR.

Benati, L. and Mumtaz, H. (2007). US evolving macroeconomic dynamics: a structural investigation.

Bernanke, B.S. and Gertler, M. (1995). Inside the black box: the credit channel of monetary policy transmission. *Journal of Economic perspectives*, *9*(4), pp.27-48.

Bernanke, B.S. (1986). Alternative explanations of the money-income correlation. *Carnegie-Rochester Conference Series on Public Policy*, 25, 1986, 49-100.

Borio, C. and Disyatat, P. (2010). Unconventional monetary policies: an appraisal. *The Manchester School*, *78*, pp.53-89.

Cogley, T. and Sargent, T.J. (2005). Drifts and volatilities: monetary policies and outcomes in the post WWII US. *Review of Economic dynamics*, *8*(2), pp.262-302.

Central Bank of Sri Lanka. (2019). The Impact of Frequent Large Revisions to National Accounts Estimates on Macroeconomic Indicators and Macroeconomic Policymaking, *Annual Report 2018*, pp.5-6.

De Bondt, G.J. (2005). Interest rate pass-through: empirical results for the Euro Area. *German Economic Review*, *6*(1), pp.37-78.

Ehelepola, K. (2015). An Estimated Open Economy New Keynesian DSGE Model for Sri Lanka with Monetary and Fiscal Rules. *Conference Proceedings, 08th International Research Conference (December 2015), Central Bank of Sri Lanka, Colombo*.

Friedman, M. and Schwartz, A. J. (1963a). A Monetary History of the United States, 1867-1960. *Princeton: Princeton University Press*.

Friedman, M. and Schwartz, A. J. (1963b). Money and Business Cycles. *Review of Economics and Statistics*, *45*:32-64.

Ghazanchyan, M.M. (2014). *Unraveling the monetary policy transmission mechanism in Sri Lanka* (No. 14-190). International Monetary Fund.

Hendry, D.F. (1995). *Dynamic econometrics*. Oxford University Press on Demand.

Jayawickrama, V. and Perera, R. (2013). Monetary Policy Rules in Practice: Evidence for Sri Lanka. *Conference Proceedings, 6th International Research Conference (December 2013), Central Bank of Sri Lanka, Colombo.*

Jegajeevan, S. (2016). Understanding Sri Lankan business cycles through an estimated DSGE model. *Conference Proceedings, 9th International Research Conference (December 2016), Central Bank of Sri Lanka, Colombo.*

Joyce, M., Miles, D., Scott, A. and Vayanos, D. (2012). Quantitative easing and unconventional monetary policy–an introduction. *The Economic Journal*, *122*(564), pp.F271-F288.

Kim, C.J. and Nelson, C.R. (1999). Friedman's plucking model of business fluctuations: tests and estimates of permanent and transitory components. *Journal of Money, Credit and Banking*, pp.317-334.

Kydland, F.E. and Prescott, E.C. (1990). Business cycles: Real facts and a monetary myth. Real business cycles, *a reader*, 383.

Mishkin, F.S. (1996). The channels of monetary transmission: lessons for monetary policy (No. w5464). *National Bureau of Economic Research*.

Perera, A. (2016). Monetary Transmission Mechanism in Sri Lanka: A Comprehensive Assessment with New Evidence. *Central Bank of Sri Lanka staff studies*, *43*(1-2).

Perera, W.S.N. (2017). Credit Intensity of Economic Growth–A Sectoral Analysis: Case of Sri Lanka. *Staff Studies*, *47*(1), pp.1-45.

Pesaran, M.H., Shin, Y. and Smith, R.J. (2001). Bounds testing approaches to the analysis of level relationships. *Journal of applied econometrics*, *16*(3), pp.289-326.

Primiceri, G.E. (2005). Time varying structural vector autoregressions and monetary policy. *The Review of Economic Studies*, 72(3), pp.821-852.

Romer, C.D. and Romer, D.H. (1989). Does monetary policy matter? A new test in the spirit of Friedman and Schwartz. *NBER macroeconomics annual*, *4*, pp.121-170.

Vinayagathasan, T. (2013). Monetary policy and the real economy: A Structural VAR Approach for Sri Lanka. *National Graduate Institute for Policy Studies*, *13*(13), pp.1-31.