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Liquidity Management and Monetary Transmission: Empirical Analysis for India

Vikas Charmal and Ashima Goyal

Indira Gandhi Institute of Development Research, Mumbai
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Email(corresponding author): ashima@igidr.ac.in

Abstract

A change in monetary operating procedures provides a natural experiment we use to evaluate first, whether Indian monetary policy transmission is better when durable liquidity is in surplus or when it is in deficit; second is it better with interest rates as the policy instrument or quantity of money or a mixture of the two. After showing our period of analysis can be divided into two liquidity regimes, we estimate separate structural vector auto-regressions for the financial and real sector, as well as SVARs for the whole period with alternative operating instruments. Monetary transmission from the repo rate was better during the period the liquidity adjustment facility (LAF) was in surplus with the central bank in absorption mode denoting excess durable liquidity. Pass through was faster and the repo rate had a greater influence on other variables. The impact of the rate on output gap exceeds that on inflation. The weighted average call money rate was found to outperform others as the operating target. Monetary policy has evolved so that policy rates are more effective in transmission compared to money supply, but best results are when durable liquidity is also in surplus. The results suggest keeping the LAF in deficit mode over 2011-19 was not optimal.

Keywords: Monetary transmission; liquidity deficit and surplus; repo rate; instrument; operating target

JEL Code: E52; E58; E65

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1. Introduction

The framework of Indian monetary policy has evolved over time. As the money market developed, the Reserve Bank of India (RBI) moved towards using the repo rate instead of monetary aggregates as the instrument of monetary policy after 2002. But critics continued to be skeptical about the possibility of transmission through the repo in a country like India with a large informal sector and use of cash. In this paper we show transmission does work through the repo. The repo does better than reserve money as the operating instrument but works best when durable liquidity is kept in surplus.

A liquidity adjustment facility (LAF) was introduced as part of money market development, to provide short-term liquidity (STL), to adjust for any imbalance between banks' demand for long-term liquidity (LTL), also known as durable liquidity, and its supply. Collateralized STL was supplied on banks' demand at the repo rate. Excess liquidity with banks was absorbed at the reverse repo rate. These rates defined a LAF band, within which the weighted average call money rate (WCMR), the overnight uncollateralized interbank borrowing rate, which was the operating target for policy (RBI 2011), was to stay. Banks and a few designated special primary dealers (SPDs) who had access to LAF borrowing were expected to meet the liquidity needs of the rest of the economy. The methodology of managing liquidity evolved with changes in operating procedures. There was continual adjustment in response to initial volatility in operating target and mismatch in liquidity management with monetary policy steps.

In 2016, India implemented a flexible inflation targeting (FIT) regime based on recommendations of an expert committee (RBI, 2014). In 2019 the repo rate was the policy rate, which was reviewed by the monetary policy committee (MPC) every two months. The final policy objective was keeping headline inflation within 4% and a band of (+/-) 2% while keeping in mind the objective of growth. The operating target was the benchmark for policy transmission. RBI had fixed a LAF corridor of 50 basis points with 25 basis points above the repo rate for marginal standing facility (MSF) and 25 bps below for reverse repo rate. While LAF provided STL, operations such as open market operations (OMOs), foreign exchange (FX) intervention, market stabilization scheme (MSS), cash reserve ratio (CRR) determined the LTL. The objective was for this to rise in line with nominal income growth.

Liquidity regimes can be classified into – surplus and deficit based on net absorption (-)/ injection (+) of bank reserves by RBI. If LTL is in surplus LAF is in absorption mode. It is in injection mode when LTL is in deficit. In the first decade after LAF was introduced, due to large inflows and high growth, liquidity was largely in surplus. In the second decade following a change in operating procedures LAF liquidity was kept in deficit regardless of monetary cycles. This switch provides a natural experiment to estimate and compare different aspects including speed and magnitude of policy transmission in different liquidity regimes.

Monetary policy transmission is the process through which the policy action of the monetary authority is transmitted to the ultimate objectives of stable inflation and growth, through various channels such as interest rate, credit, asset markets and expectations. From the operational point of view, transmission can be defined in three successive parts: (i) from policy rate to operating target; (ii) from operating target to intermediate target and (iii) from intermediate target to final objectives. Existing literature on monetary policy in India has analyzed all three parts for different periods with different techniques of analysis, but has not researched the issue of whether transmission is better under surplus or under deficit liquidity. It has also not compared alternative targets in the current framework.

We therefore address the following questions:

1. What is the response of financial sector variables to changes in monetary policy during surplus and deficit liquidity regimes?
2. What is the response of real sector variables to changes in monetary policy during surplus and deficit liquidity regimes?
3. Is 91 Day G-sec rate a better operating target than WACR?
4. Is repo rate or growth of reserve money a better policy instrument in the current operating framework?

Separate estimations for surplus and deficit liquidity regimes allow us to see if there are any significant differences in monetary policy transmission during these regimes.

The remainder of this paper is organized as follows: After a brief review of the relevant literature in section 2, section 3 gives stylized facts on liquidity. Section 4 describes variables used, data period and source, data compilation and transformation. Section 5 is a methodology section, which describes the basic structural vector autoregressive (SVAR) econometric model. Subsection 5.1 discusses the specific SVARs used to determine the transmission of monetary policy to financial sector, real sector and to compare different operating targets. Section 6 is subdivided into four sections. Section 6.1 and 6.2 describe empirical results of monetary policy transmission in surplus and deficit liquidity regimes to different sectors of the economy. Section 6.3 evaluates whether WACR or 91 day government securities (g-secs) is the better operating target. Section 6.4 compares whether repo rate or growth rate of reserve money is the better monetary policy instrument. Section 7 concludes

2. Review of Literature

Authors have applied time series tools to study all three parts of monetary transmission after the LAF became functional and operating systems changed.

Patra et al (2016) to study the first leg relationship between the policy rate (repo) and weighted average call money rate (operating target) divided the period from April 2008 to September 2015 into three segments based on the major changes in the monetary policy framework. Their autoregressive distributed lag based approach found the call rate to be closely aligned to the policy rate across the full sample as well as across regimes. After the 2014 monetary policy reforms the speed of adjustment increased as compared to earlier periods. The authors attributed this to intra-day fine-tuning operations, improving liquidity management by banks and rising efficiency in the money market. Fine-tuning is majorly done using variable rate term repo auctions as recommended by RBI (2014).

Volatility in the operating target would affect the second leg of transmission—its impact on the intermediate target. Volatility in WACR is defined in terms of its standard deviation. Higher volatility in WACR can create uncertainty about longer tenure rates. The rolling period standard deviations of the call rate for 7-90 days declined to 0.2% in 2015-16 from 4.6% in 2006-07 (Patra et al, 2016), implying better monetary policy efficiency.

Adding to the literature on this second leg of monetary policy, Kumar (2017) studied drivers of overnight inter-bank rate spread under the new liquidity management framework from July 2013 to December 2016. Spread here means the difference between the policy rate and overnight interbank rate. Applying OLS with Newey-West estimator and various GARCH models to daily data, the study found that liquidity conditions, such as, deficit, distribution and uncertainty impact the call money rate spread adversely. A moderation in the impact of liquidity uncertainty was, however, noticed after the introduction of fine-tuning liquidity management operations in September 2014.

Kavediya and Pattanaik (2016) found volatility in WACR to exert modest but statistically significant influence on volatility in daily change in other interest rates. In the credit market, a one percentage point increase in WACR volatility was estimated to cause about 26 basis points increase in bank lending rates.

Continuing the study of second leg monetary transmission in the financial sector from operating to intermediate targets, Prabu and Ray (2019) estimated the pattern of monetary transmission to financial markets over three different periods of regime shift in India using SVAR models. They used variables such as call money rate, 10-year g-secs rate, corporate deposit rate, rupee-dollar exchange returns and nifty returns to see transmission in money, g-secs, corporate debt, FX, and the equity segments of the Indian financial market respectively. Results showed that the impact varies across different segments of the financial markets as well as with different operating procedures of the monetary policy. Transmission was faster for call money and bond markets, but slower for the foreign exchange and stock markets. They also observed that monetary policy transmission in the financial sector significantly improved after fine-tuning of liquidity framework and the introduction of flexible inflation targeting regime.

In a further analysis of the first and second leg, Goyal and Agarwal (2019) compared the strength and efficacy of transmission of the policy rate and liquidity provision to market rates in India, using event window regression analysis. They found the interest rate transmission channel to be dominant, but the quantity channel had an indirect impact, increasing the size of the interest rate pass-through. They also compared transmission during periods when LAF was in surplus and in deficit but found little support for asymmetry in adjustment during tightening. However, pass-through was faster when liquidity and rate variables were aligned.

Moving to the third leg of monetary transmission to the real sector, Pandit (2006) employed a VAR framework to examine monetary policy transmission on variables such as index of industrial production (IIP), wholesale price index (WPI), commercial paper rate (CP) and broad money (M3). The results demonstrated that cash reserve ratio has a greater impact as an instrument of monetary policy, as compared to the bank rate, in the medium-term.

Khundrakpam and Jain (2012), used quarterly data for 1996-97:1 to 2011-12:1 in SVAR models to estimate the relative importance of various transmission channels of monetary policy to GDP growth and inflation in India. They found external exogenous factors delayed the impact of monetary policy transmission on GDP growth and inflation. Among the various channels of transmission, interest rate channel, credit channel and asset price channel were important, with the interest rate dominating, while the exchange rate channel was weak. A positive shock to policy rate led to a slowdown in credit growth with a lag of two quarters and subsequently impacted first GDP growth and then inflation negatively. A monetary policy shock reduced asset prices from the third quarter onwards.

Mishra and Mishra (2011) used a SVAR approach where the monetary policy instrument was set after assessing current values of inflation, to build a hypothetical case for inflation targeting in India. Results suggested demand effects of interest rate were stronger than exchange rate effects and supported shifting to a flexible inflation targeting framework.

The majority of authors have applied SVAR to different parts of the transmission process, using different variables. We follow this tradition. Once the repo is shown to affect financial variables, it is an adequate variable to capture the effect of financial variables on the real sector, since our objective is not to capture all minute details of transmission but to compare transmission across 2 periods in both the financial and real sectors.

No one has, however, applied SVARs separately to the periods of surplus and deficit liquidity and compared outcomes as we do. These periods are identified in the next section.

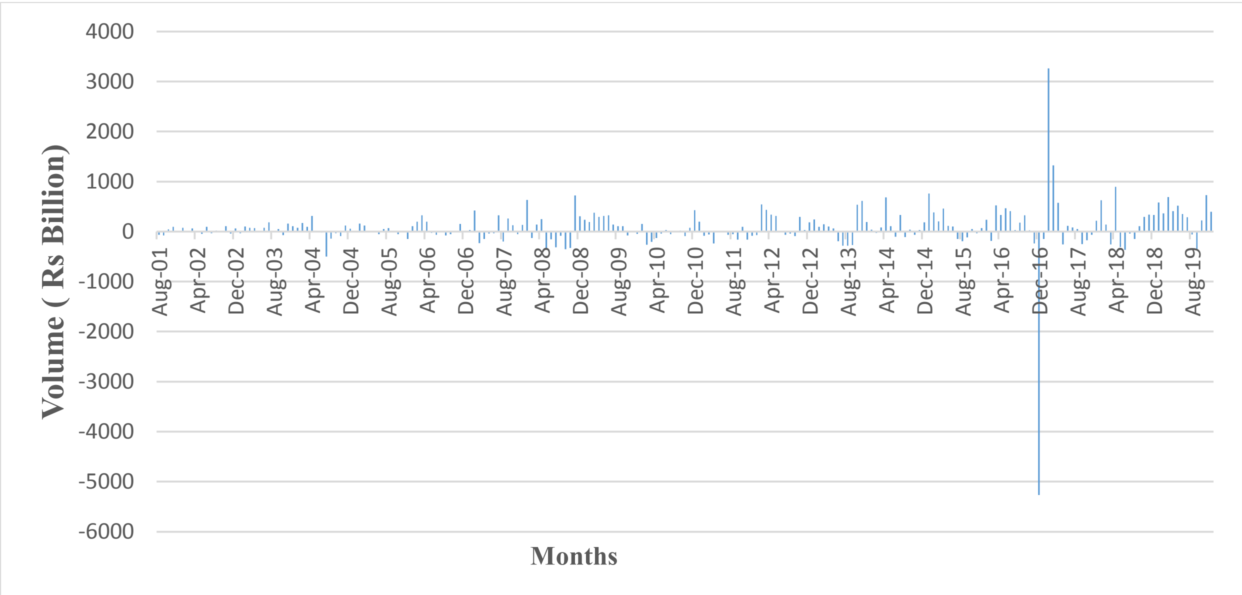
3. Central Bank Liquidity: Structural break

Stylized facts on liquidity show the division of our period into surplus and deficit liquidity. RBI's claims on banks, as well as LAF liquidity, show a break following the 2011 decision to keep LAF in the deficit mode. Outcomes for the operating target, as well as formal econometric tests, validate the break.

Long Term Liquidity: LTL is the sum of OMO, FX market intervention and changes in CRR and in MSS. RBI intervention in FX market is net purchase/sale of US dollar in rupee equivalent at contract rate (forward sales are not included). Change in CRR is calculated by taking month on month change in banker's deposits with the RBI. Change in MSS account deposits captures any liquidity injection or absorption through this scheme. An increase in deposits in CRR and MSS accounts are taken as absorption and therefore subtracted from a sum of net OMO and FX intervention. There is an injection (+) of LTL when net value is greater than zero and vice-versa. Chart 1 depicts monthly LTL for the period August 2001-April 2020. On average it is rising over time as it has to in order to keep pace with nominal income growth.

Large capital inflows during the global growth boom as well as the stimulus after the great financial crisis (GFC) kept LTL in surplus during 2002-2010. LAF remained in absorption mode to absorb this surplus. After 2010, however, LAF was consciously kept in deficit mode by the central bank after the recommendation in (RBI, 2011) that this improved monetary policy transmission, although the move to keep LAF in deficit had started in 2010 as part of tightening after the post crisis stimulus. Also after inflation targeting was formally adopted in 2016, the repo rate was the variable set by the monetary policy committee (MPC). It was regarded as important to keep the LAF in deficit at the upper end of the LAF corridor, so that the intermediate target, the weighted average call money rate, stayed close to the repo rate set by the MPC

Chart 1 - Long term liquidity



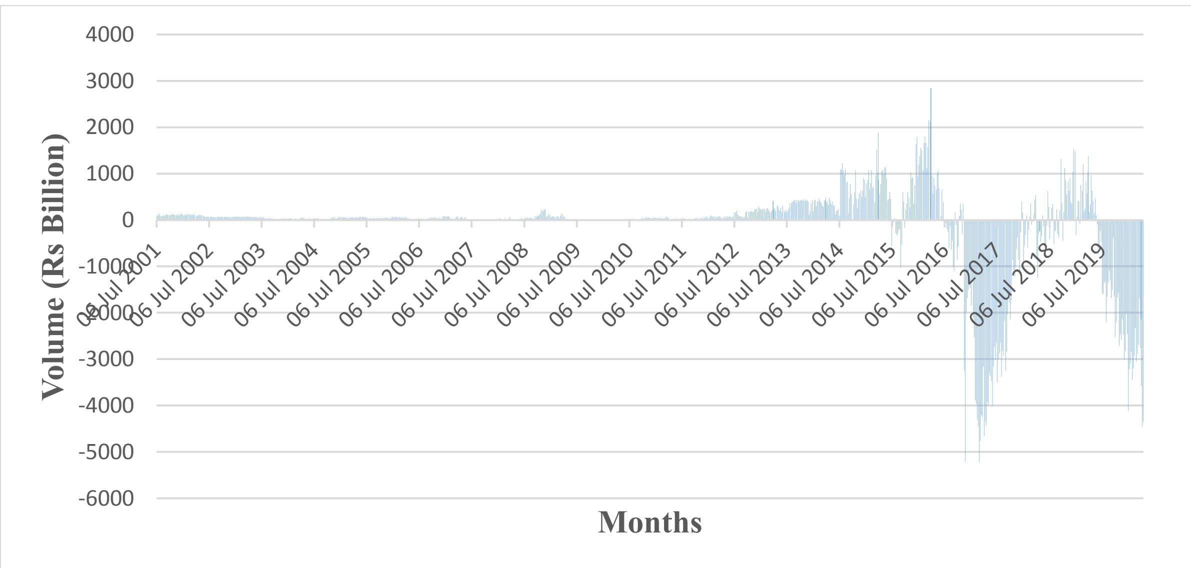
Source – Author's calculations based on data sourced from DBIE, RBI.

Because India is subject to large exogenous durable liquidity shocks due to foreign capital flows, currency leakages, and fluctuations in government cash balances, keeping LTL liquidity tight so that banks had to borrow at the LAF repo, sometimes led to too large a shortfall in LTL.

Reserve bank's claims on other banks: Chart 2 from the sources of reserve money, that is, from the asset-side of the RBI balance sheet, shows the shortfalls. It depicts the RBI's claims on banks including national bank for agriculture and rural development. Positive claims imply a liquidity shortage with banks so that they are borrowing from the RBI. Negative claims imply excess liquidity with banks that the RBI is absorbing. Thus there is an injection (+) of liquidity when net claims by RBI are positive and absorption of liquidity (-) when they are negative.

Bank borrowing the RBI used to be a minor positive amount prior to 2011, but after the move to keeping LAF in deficit it became significantly positive. The demonetization period of 2016-17 saw substantial RBI absorption, but then a return to deficits and injections over 2018-19 before liquidity became substantially surplus again by mid-2019. Demonetization was a shock that sharply raised banking liquidity, but it impact lasted for a limited period. Thus over most of the second half of our period was liquidity deficit.

Chart 2 - RBI's claims on banks

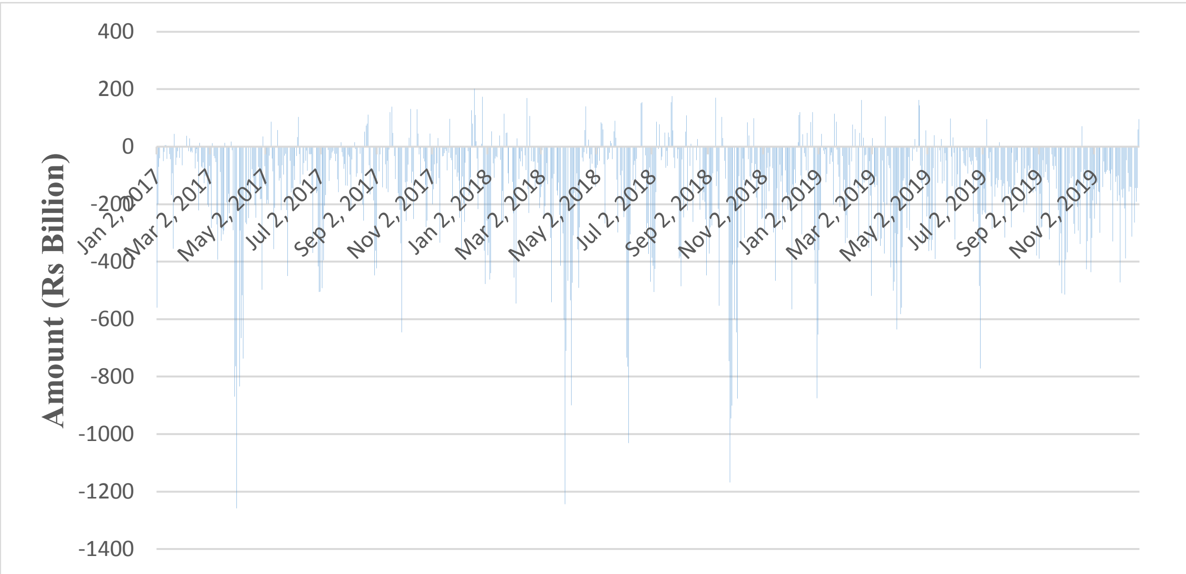


Source – Data sourced from DBIE, RBI

LAF liquidity: Banks need to borrow funds from the central bank to meet their reserve requirement, if it cannot be met from the inter-bank market and vice-versa. On a given day, if the banking system is a net borrower from the reserve bank under LAF, the system liquidity can be said to be in deficit. If the banking system is a net lender to the reserve bank, the system liquidity can be said to be in surplus. Injection of STL is required when LTL is less than banks' requirements.

LAF liquidity is calculated by subtracting total absorption during the day from total injection. Total injection during a day is the sum of fixed repo and term repo operations. Similarly, total absorption during a day is the sum of reverse repo and term reverse repo operations.
LAF injection (+)/absorption (-) = (fixed repo + variable rate repo) – (fixed reverse repo + variable rate reverse repo). Therefore LAF injections denote liquidity deficit. Chart 3 of daily LAF liquidity for the period 2017 to December 2019 shows even though LAF was largely in absorption mode, because of large cash deposited in banks after demonetization, there were many days over 2018-19 when banks were net borrowers from the RBI denoting liquidity deficit. Since only banks can borrow from the RBI, when banks were deficit in liquidity, the broader financial system was even more constrained (Goyal and Agarwal, 2019).

Chart 3 - Daily LAF liquidity

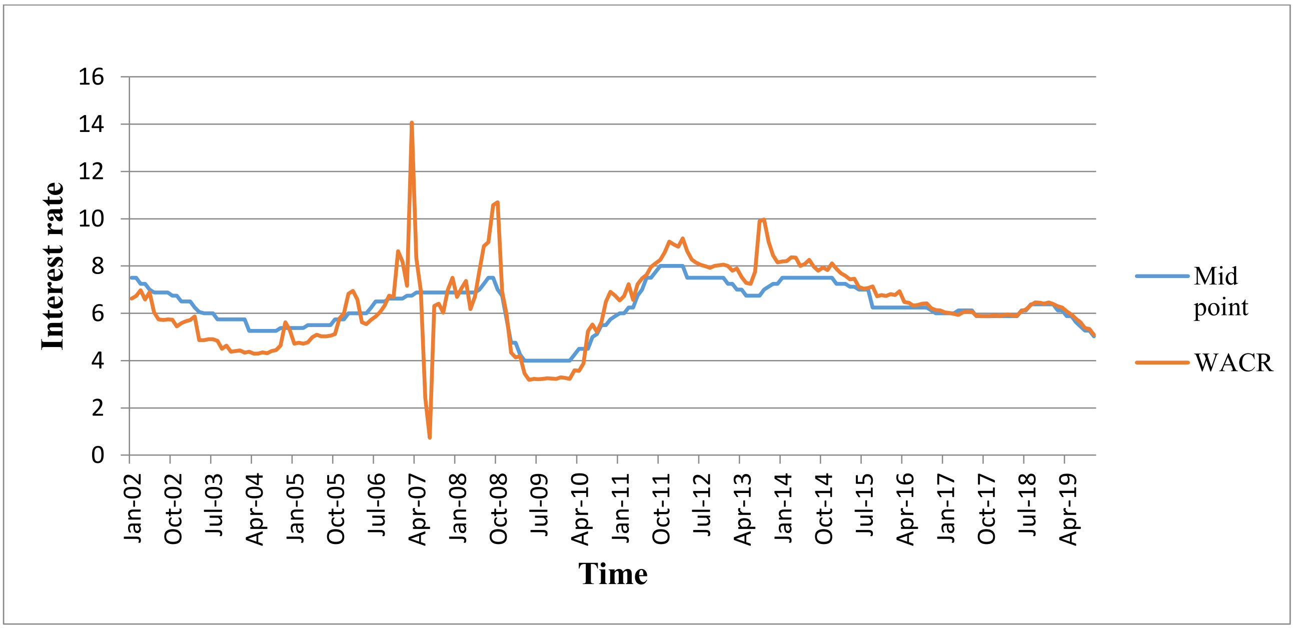


Source – Author's calculations based on data sourced from DBIE, RBI.

LAF injection (+)/absorption (-) = (fixed repo + variable rate repo) – (fixed reverse repo + variable rate reverse repo)

Impact on call rates: Chart 4 also points to a split of the period into two liquidity regimes as a result of RBI actions affecting its operating target, WACR. Mid-point series in the chart is calculated by taking mid-points of the corridor between repo rate and reverse repo rate. A WACR higher than the mid-point indicates liquidity deficit in the system as there is more demand for interbank borrowing raising WACR closer to repo rate. Similarly, a WACR lower than the mid-point indicates liquidity surplus. We can see that WACR series was below mid-point till 2010 and was above it after that.

Chart 4 - LAF deficit/surplus periods



Formal econometric tests:

Chow test rejects the null hypothesis of no structural break at January 2011 in the LAF monthly data series. F test done using a restricted model and unrestricted model with January 2011 as a breakpoint also shows that LAF behaves differently prior to and after the specified breakpoint. Zivot-Andrews unit root test identified May 2010 as the break point in the monthly LAF series, close to our beginning of the year January 2011 breakpoint (See appendix).

Hence choice of April 2001–2010 as LAF surplus and January 2011–June 2019 as LAF deficit period has a number of justifications. The main basis of our classification is the RBI's stated intention to keep liquidity in deficit, implemented in 2011 and reversed in 2019. While liquidity was affected by the large exogenous shocks India faces and reversed for short periods, the effects of the intention show up in the RBI's operating target, the WACR. Chart 4 clearly shows this be to below the mid-point of the LAF band before 2011 and above it after.

4. Data

The data for the domestic variables has been collected from the database on Indian economy, RBI, the EPW research foundation (http://www.epwrfits.in/PricesTreeview.aspx) and the Ministry of Statistics and Programme Implementation website (http://www.mospi.gov.in/data). Data for fed rates and global oil prices is taken from the Federal Reserve Bank of St. Louis (https://research.stlouisfed.org/). Data for world food price index is collected from International Monetary Fund website (https://www.imf.org/en/Research/commodity-prices).The period for analysis is from 2002 to June 2019 since the multi-phase transition from ILAF to full-fledged LAF started in 2001. It is divided into two sub-periods of surplus (2002–2010) or deficit (2011–2019) liquidity. The monthly frequency gives sufficient observations for time-series analysis.

Variables

In different regressions for the financial sector and the real sector, the model comprises of foreign block variables, policy variables and non-policy variables. Foreign block variables are federal funds rate, global oil prices and world food price index. Global oil prices are averages of three spot prices; West Texas intermediate, the Dubai Fateh and Brent crude oil. Fed rate is taken as a proxy for international interest rates and world food price index represents inflation in food prices globally. In examining monetary policy transmission, we focus on two policy variables: repo rate and reserve money. Domestic block non-policy variables in the financial sector include 91 day g-secs rate, 10 year g-secs yield, commercial paper rate, NEER (the weighted average nominal exchange rate against a basket of 6 other currencies) and nifty 50 returns. Variables used in the model for real sector were inflation (measured by consumer price index and wholesale price index log difference)), output gap (measured as a difference between (log of) index of industrial production (IIP) and its (log of) Hodrick-Prescott trend), money supply and credit growth. Repo rate was used as the policy variable. Credit is non-food credit data reported on database on Indian economy, RBI.

All data series are seasonally adjusted with X13 ARIMA before transforming them to a stationary series, since usage of non-stationary series can give spurious results. The augmented Dickey Fuller test for the presence of unit roots in the series suggests all the variables other than repo rate and WACR contain unit root. Therefore the first difference is taken of all variables except interest rates. As all the variables other than interest rate variables are converted to their natural logarithms, the resulting series give the growth rates after taking first difference.

5. Methodology

Variation in the policymakers' actions can be classified into two components, an accounted or systemic component and an unaccounted or shock component. The systematic component of monetary policy is defined by assuming that in any period'‘t’ monetary policymakers set the value of a policy instrument 'S_t' as a (linear) function of the variables in their information set Ω_t. It follows a following feedback rule of the form:

$$S_t = f(\Omega_t) + \sigma_s \varepsilon^s_t \quad (1)$$

Where 'f' is the reaction function that relates S_t to the information set Ω_t, containing contemporaneous and lagged variables in response to which the central bank sets the monetary policy instrument. The random variable '$\sigma_s \varepsilon^s_t$' is a monetary policy shock.

Structural vector auto-regression

Structural vector auto-regressions (SVARs) with short-run restrictions guided by economic theory are commonly used to identify monetary policy shocks in a simultaneous system. The short-run P^{th} order SVAR model can be written as:

$$B_0 Z_t = c^* + B_1 Z_{t-1} + B_2 Z_{t-2} + \ldots + B_p Z_{t-p} + u_t \quad (2)$$

Where, Z_t is an N x 1 vector with p lags for each variable. B_0 matrix gives a structure to the reduced form VAR model and u_t is a structural disturbance.

The underlying assumption is that u_ts are serially and mutually uncorrelated i.e.

$$E(u_t u'_\tau) = \{D \text{ for } t = \tau, 0 \text{ otherwise}\}$$

The number of restrictions to be imposed on the B_0 matrix can be obtained using the variance-covariance matrix Ω as follows:

$$\Omega = B_0^{-1} E(u_t u'_\tau)(B_0^{-1})' = (B_0^{-1}) D (B_0^{-1})' \quad (3)$$

Ω has N(N+1)/2 free parameters out of which N belong to the diagonal matrix D. The remaining N(N-1)/2 free parameters belong to the B_0 matrix. It implies that we have to impose N(N-1)/2 restrictions on the B_0 matrix for just identification.

Assumptions common in the literature are used to identify monetary policy shocks. There are a total of eight variables in each model: Two foreign and six domestic variables. The foreign variables are exogenous to the system, that is, domestic variables do not affect the foreign variables either contemporaneously or with a lag. The relatively small size of the Indian economy to the world economy justifies this assumption. Domestic block includes policy and non-policy variables.

5.1 Structure of the economic models

The SVAR models for estimating the impact of policy instruments on the economy are as follows:

Model 1 – Response of financial sector variables to impulse in monetary policy

$$B0*Zt=\begin{pmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ M21 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ M31 & M32 & 1 & 0 & 0 & 0 & 0 & 0 \\ M41 & M42 & M43 & 1 & 0 & 0 & 0 & 0 \\ M51 & M52 & M53 & M54 & 1 & 0 & 0 & 0 \\ M61 & M62 & M63 & M64 & M65 & 1 & 0 & 0 \\ M71 & M72 & M73 & M74 & M75 & M76 & 1 & 0 \\ M81 & M82 & M83 & M84 & M85 & M86 & M87 & 1 \end{pmatrix} \begin{pmatrix} \text{oilp} \\ \text{Fed rate} \\ \text{MP} \\ \text{91day gsecs} \\ \text{10yr gsecs} \\ \text{CP} \\ \text{NEER} \\ \text{nifty} \end{pmatrix} \quad (4)$$

The above matrix characterizes the restrictions placed on the contemporaneous relationships among variables. Here, 'Fed rate' is the federal fund rate and 'oil' is global oil price. 'MP' is the monetary policy instrument which could be 'repo rate' or 'reserve money growth rate'. ‘91 day g-secs’ is the yield of a short term debt instrument issued by the government; '10yr g-secs' is the yield of a long term government debt instrument; 'CP' is a yield on commercial paper; ‘NEER’ is nominal effective exchange rate returns and 'nifty' is the return on nifty 50 index.

While Fed rate and oil form the foreign block, MP form policy variables block and rest of the variables form domestic non-policy block. Restrictions in the above model are similar to those in the literature reviewed, in particular Prabu and Ray (2019). The small country assumption makes current international interest rates and oil prices exogenous. They are taken into consideration while setting the repo rate[1]. Innovations in 91 day g-secs are contemporaneously affected by foreign block variables and by the repo rate. Similarly, the 10 yr g-secs yield is contemporaneously determined by fed rate, oil, repo rate and 91 day g-secs. Commercial papers' yield, exchange rate return and nifty 50 index are the other variables that represent the financial sector and are directly or indirectly determined by the above variables. This model is run separately for deficit and surplus liquidity periods, which are then compared. The other variables also serve as controls capturing the difference in economic environment in the two periods.

Model 2 – Response of real sector variables to change in monetary policy

$$B0*Zt=\begin{pmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ M21 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ M31 & M32 & 1 & 0 & 0 & 0 & 0 & 0 \\ M41 & M42 & M43 & 1 & 0 & 0 & 0 & 0 \\ M51 & M52 & M53 & M54 & 1 & 0 & 0 & 0 \\ M61 & M62 & M63 & M64 & M65 & 1 & 0 & 0 \\ M71 & M72 & M73 & M74 & M75 & M76 & 1 & 0 \\ M81 & M82 & M83 & M84 & M85 & M86 & M87 & 1 \end{pmatrix}\begin{pmatrix} \text{Oilp} \\ \text{WFI} \\ \text{Fed rate} \\ \text{output gap} \\ \text{inflation} \\ \text{MP} \\ \text{credit} \\ \text{M3} \end{pmatrix} \quad (5)$$

The restrictions in (5) are similar to Khundrakpam & Jain (2012), Pandit (2006) and Mishra and Mishra (2011). Global oil prices (oil), world food prices (WFI) and Federal funds rate are foreign block variables[2]. They have a contemporaneous effect on all domestic policy and non-policy variables. Following the identification of monetary policy shocks proposed by Christiano et al (1999) the monetary policy instrument (MP) responds contemporaneously to

[1] The monetary policy process supports this structure. Any RBI monetary policy committee resolution available on the RBI website (see, for example, October 09, 2020: https://www.rbi.org.in/Scripts/BS_PressReleaseDisplay.aspx?prid=50479) shows they start with an assessment section taking up first the global economy, which includes discussion of oil price trends, to which India is very sensitive being largely dependent on oil imports. Next is a section on outlook where in the inflation outlook oil prices are brought up again. RBI (2014) finds oil prices are a major determinant of household inflation expectations.

[2] In the SVAR literature, what is called a 'price puzzle' is often noticed in models with inflation rates. That is, inflation rises with a rise in the policy rate instead of falling as it is expected to. One reason could be if supply shocks are simultaneously raising inflation. A central bank that responds by raising the policy rates sometimes fails to eliminate the inflationary effects of the supply shock (Balke and Emery 1994). The literature therefore suggests including exogenous commodity price series as a control variable in SVARs that have inflation as a variable. That is why we include the WFI variable in the set of models for the real sector transmission. It is specially required in the first period when world and domestic food price inflation was very high.

output gap and inflation but affects them with a lag[3]. M3 and credit respond to foreign and domestic variables contemporaneously[4].

Model 3: Is 91 day g-sec a better operating target than WACR?

This question is based on issues raised in RBI (2014) and in Goyal and Agarwal (2019). Along with the move to inflation targeting, the RBI (2014) expert committee had also recommended a shift in operating target from WACR to a 14-day term money rate. According to the committee, providing overnight liquidity on an enduring basis at an overnight repo rate jeopardized the growth of the term market. This is required for establishing market-based benchmarks for pricing of loans and deposits rates, which would make monetary policy transmission more effective. In line with this recommendation, the liquidity framework was fine-tuned in September 2014 with liquidity provided mainly through 14 - day term repo rate instead of unlimited accommodation at a given repo rate as earlier (Prabu A. and Ray, 2019). But Goyal and Agarwal (2019) found short term government securities yields to be most responsive to changes in policy rates in an event window analysis and advocated it as an operating target.

To compare 91 day g-secs rate and WACR to find which one is the better operating target we use WACR in (6) replaced 91 day g-secs rate in (4). The strategy of replacing substitute or closely related variables in the transmission chain, then estimating different SVARs and comparing them to decide which variable performs better was used in Mishra and Mishra (2011) and Khundrakpam and Jain (2012). It allows study of the interaction between different sets of variables.

[3] More recent sign restrictions and Bayesian methods avoid parameter restrictions but have strong author priors that may impose an implausible model on the data. They are useful where there is more simultaneity among variables, but not in isolating monetary policy, where institutional knowledge provides acceptable restrictions. Our objective is not to find the most efficient way of estimating details of monetary transmission but to compare it across the 2 periods. For this we need a robust scheme with minimal priors that do not change across the 2 periods.

[4] VAR Granger causality/block exogeneity Wald tests (available on request) show domestic non-policy variables are not affected by M3 and credit contemporaneously.

$$B0*Zt=\begin{pmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ M21 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ M31 & M32 & 1 & 0 & 0 & 0 & 0 & 0 \\ M41 & M42 & M43 & 1 & 0 & 0 & 0 & 0 \\ M51 & M52 & M53 & M54 & 1 & 0 & 0 & 0 \\ M61 & M62 & M63 & M64 & M65 & 1 & 0 & 0 \\ M71 & M72 & M73 & M74 & M75 & M76 & 1 & 0 \\ M81 & M82 & M83 & M84 & M85 & M86 & M87 & 1 \end{pmatrix} \begin{pmatrix} \text{oilp} \\ \text{Fed rate} \\ \text{MP} \\ \text{WACR} \\ \text{10yr gsec} \\ \text{CP} \\ \text{NEER} \\ \text{nifty} \end{pmatrix} \quad (6)$$

Model 4 –Does the repo rate or reserve money growth do better as the policy variable?

In order to test this we estimate two SVARs replacing repo rate with the growth rate of reserve money as the MP variable, for the entire period (2002-2019).The motivation behind this exercise is a persistent perception that the interest rate is not effective in monetary transmission in India so that the shift from money supply as the operating target to an interest rate target was premature. Mishra and Mishra (2011, Section 5.1) compared the growth rate of reserve money and call money rate as a monetary policy variable using a similar SVAR model. They found growth rate of reserve money worked better over 1985-1995, but call money rate did better over 1996-2005, concluding that monetary policy dynamics had changed with development and deepening of the money market. We repeat their test for a later period when LAF was well established. The SVARs are re-estimated with each set of variables and therefore capture the transmission from the variable of interest to other variables in the policy chain. This whole estimated transmission can be compared.

The exercise is done separately for the financial sector and the real sector, with SVAR estimation of equations (4) and (5) for the financial sector and the real sector respectively.

7. Empirical results and discussion

Akaike's information criterion (AIC) was used to determine the lag length of each VAR model. Number of lags is increased if residuals are auto correlated at that number of lags.

7.1 Response of financial sector variables to impulse in monetary policy

Using estimated SVARs, we compare monetary policy transmission to the financial sector in the period of LAF liquidity surplus with that in the deficit period.

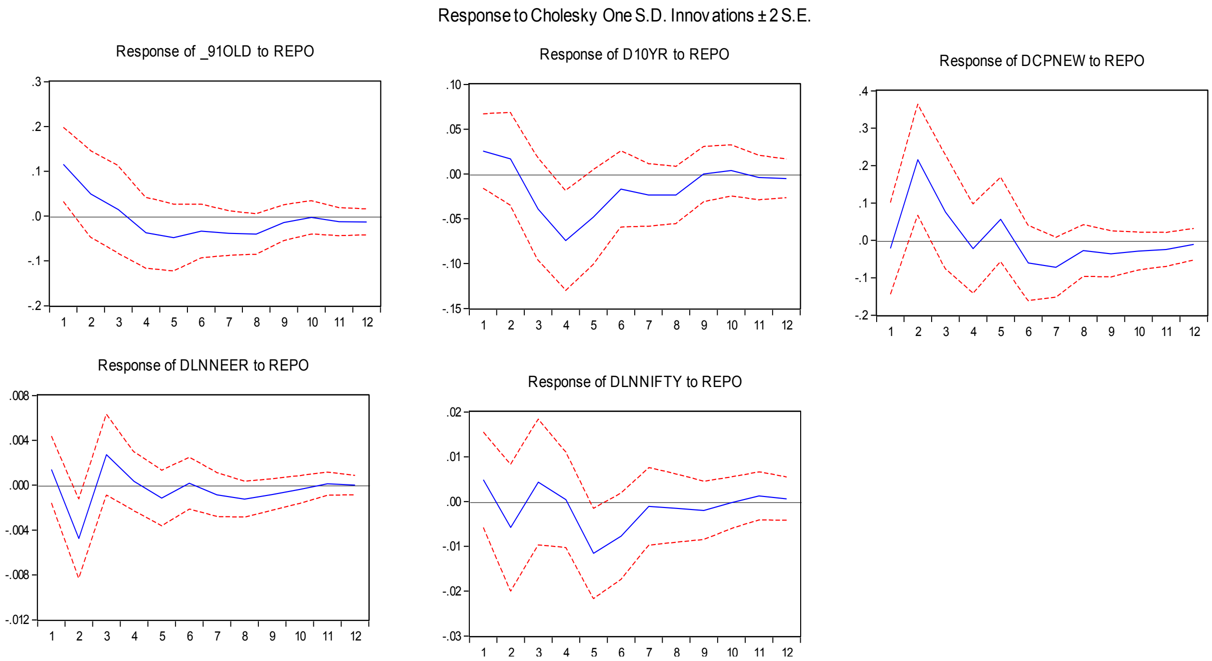
Chart 5 and 6 give impulse response functions (IRFs) of the domestic variables to one standard deviation positive shock to repo rate. 91OLD denotes change in 91 day g-secs, D10YR is change in 10 year g-secs yield, DCPNEW is change in commercial paper yield, DLNNEER is change in natural log of NEER and DLNNIFTY is a change in natural log of nifty 50 index.

IRFs of 91 day g-secs rate are consistent with theory. The short term g-secs rate instantaneously rises due to a positive innovation in repo rate, gradually reaching normal in the fourth month, in both the regimes. However, pass through is higher and quicker in the LAF surplus period implying transmission to 91 day g-secs was better in this period.

10 year g-secs yields also rise with a rise in the repo rate, gradually come to normal and turn negative after a lag of three months. Again, policy pass through is higher and faster in LAF surplus period.

The CP rate behaves similarly in the LAF surplus period, following a rise in the repo, reaching a peak in second month and then gradually coming to normal in the fourth month. But CP movement is inconsistent in the LAF deficit period. Therefore, the conclusion is again that policy transmission to CP rates was better during the LAF surplus period.

Chart 5 – Impulse response functions of financial sector variables [LAF surplus period (2002-2010)]

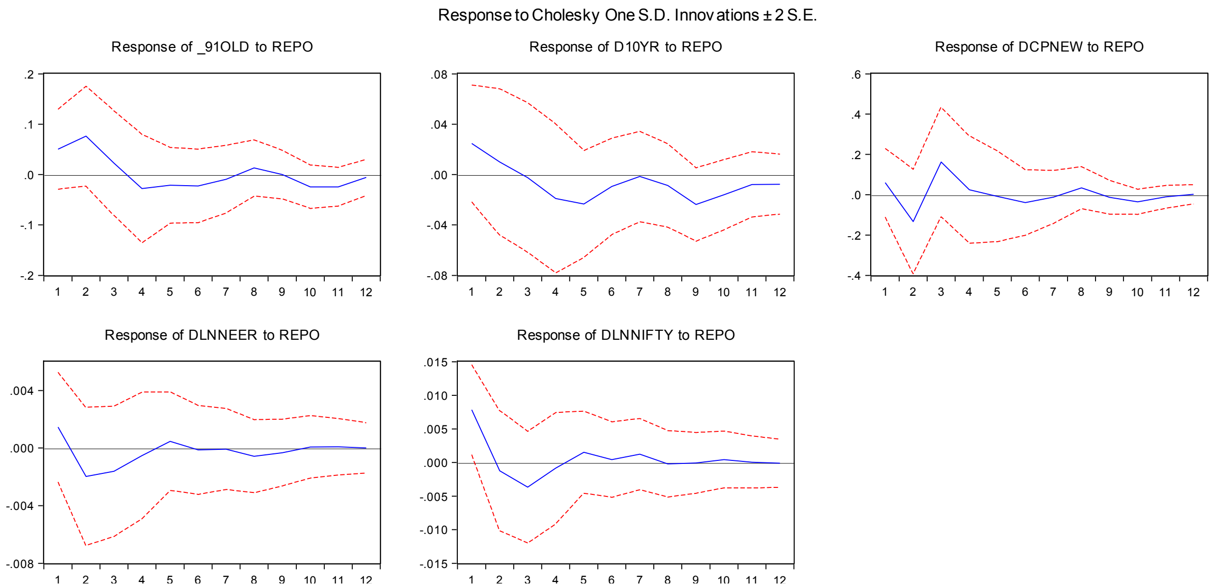


NEER is expected to appreciate due to a rise in the repo rate as capital flows in. But India does not yet have full capital account convertibility for debt inflows. Hence NEER has shown instantaneous but only marginal appreciation. Pass through is almost similar in the two liquidity regimes.

The nifty return is expected to fall due to a rise in the repo rate that contracts activity and the discounted value of future dividends in stock markets. The fall is higher in LAF surplus period.

Impulse response functions of variables representing financial sector in India show monetary policy transmission is better and faster in LAF surplus period as against the view of RBI (2011).

Chart 6 – Impulse response functions of financial sector variables [LAF deficit period (2011-2019)]



Forecast error variance decompositions (FEVDs) of financial sector variables:

Appendix tables A1 and A2 give estimated FEVDs for LAF surplus and deficit periods respectively, at 1, 3, 6 and 12 months. Domestic variables do not have a major influence on global oil prices (oil) and effective federal fund rates (Fed) confirming their causal priority. Repo rate results in LAF surplus period shows that oil and fed rate affect the domestic monetary policy rate. In the deficit regime, however, the effect of oil prices reduces and that of fed rate rises. India is a large net importer of oil; hence it is plausible for oil prices to impact domestic monetary policy. Policy was more responsive to commodity price shocks in the LAF surplus period, while after 2011 the benefits of a large fall in oil prices were not passed through in rate cuts under strict inflation targeting being followed then.

Money market instruments are responsive to changes in repo rate. But the influence is significantly lower in the LAF deficit regime. Repo rate explained 12% variation in 91 day g-secs in LAF surplus period which came down to only 4% over the horizon of one year in the deficit period. In case of 10 year g-secs, repo could influence 11% variation in LAF surplus regime, which reduced to 3% in deficit regime.

A similar pattern of higher influence of repo rate in LAF surplus period compared to deficit period shows in CP, NEER and Nifty FEVDs. Role of repo rate in variation of NEER came down to 2% in LAF deficit period from 10% in LAF surplus period. In case of CP, it came down to 3% from 13%.

IRFs and FEVDs both suggest that monetary policy transmission was better in LAF surplus compared to LAF deficit period.

7.2 Response of real sector variables to monetary policy impulse

Chart 7 and chart 8 depict IRFs of the domestic variables to one standard deviation positive shock to repo rate. In the charts, OUTPUT_GAP denotes output gap, DLNWPI and DLNCPI denote inflation in WPI and CPI respectively. DLNCREDIT gives non-food credit growth and DLNM3 gives change in broad money supply. IRFs of domestic variables used for real sector show complete contrasts in the two LAF liquidity regimes.

The price puzzle persists in the LAF surplus period despite the inclusion of the WFI variable, since world food inflation was very high in this period. Inflation is expected to fall with a rise in repo rate but IRF shows a slight rise in inflation after a contractionary monetary shock. It then turns negative after three months.

Price puzzle vanishes in the LAF deficit period. Inflation falls after one month, reaches a low in the second month and then gradually returns to normal.

IRF of output gap in LAF surplus period shows movement consistent with theory. Output gap starts declining with a lag of two months after increase in the repo rate. It bottoms out in the eighth month and then gradually starts recovering. In LAF deficit period however, output gap starts declining only after eight months.

Chart 7 – Impulse response functions of real sector variables (LAF surplus period)

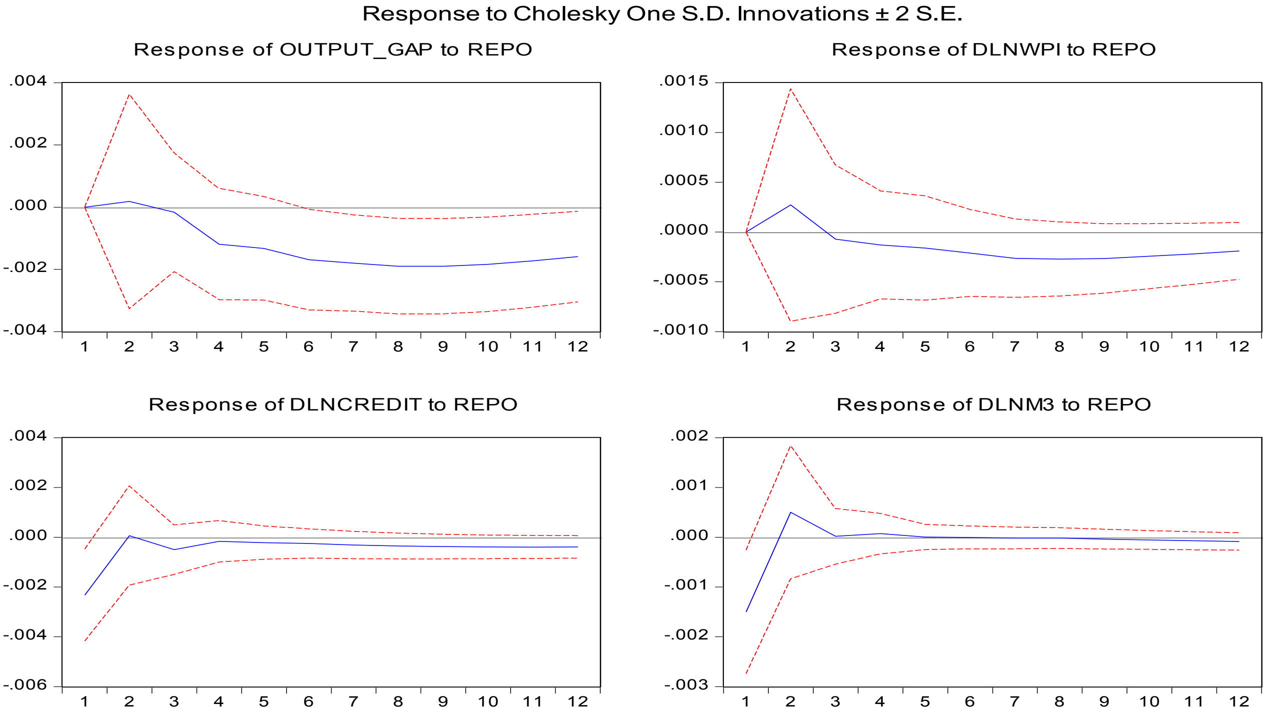
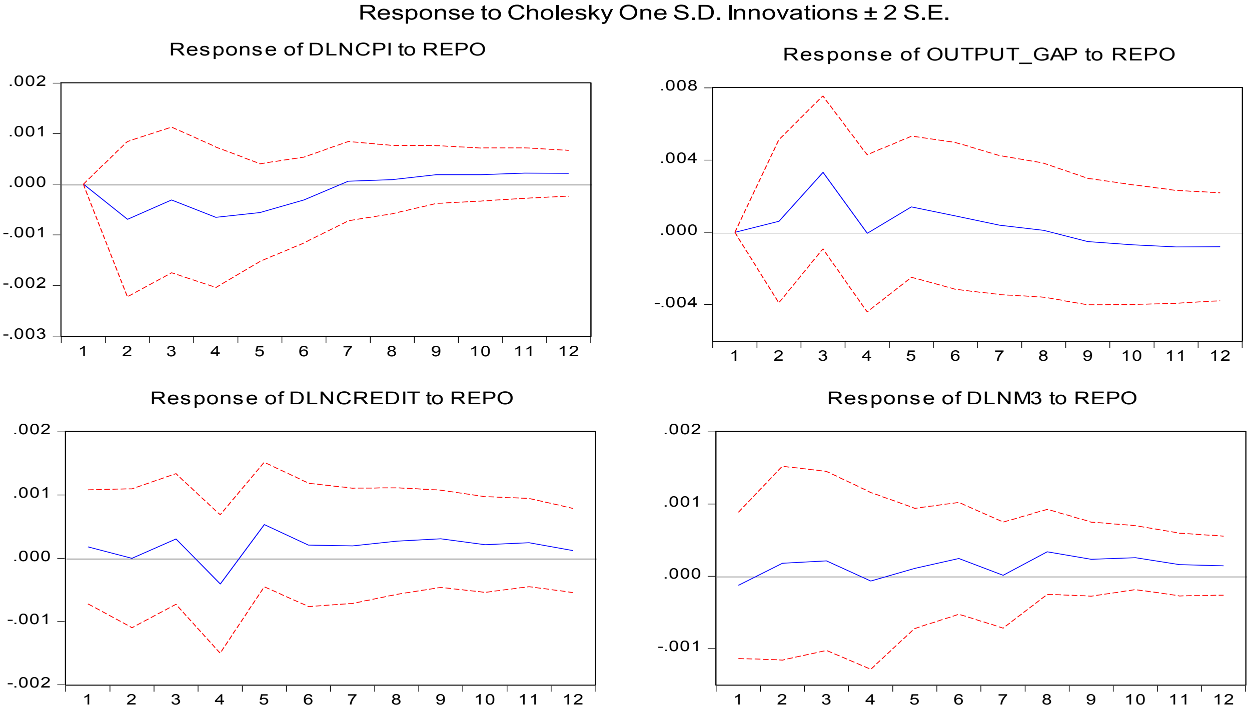


Chart 8 – Impulse response functions of real sector variables (LAF deficit period)



Credit growth is expected to fall following a rise in repo rate due to increased cost of borrowing. But IRF of credit growth shows such a movement consistent with theory in the LAF surplus period only. Similarly, a contractionary rise in repo rate resulted in a fall of money supply in the LAF surplus period only.

Hence from IRFs of output, credit growth and money supply it is observed that monetary policy transmission is more effective in the LAF surplus period.

Forecast error variance decompositions (FEVDs) of real sector variables in LAF surplus and deficit regimes:

FEVDs of real sector model for LAF surplus and LAF deficit regimes are presented in Appendix tables 3 and 4 respectively. Influence of repo rate on variation in inflation is very low in both the liquidity regimes. It explained only 1% variation in WPI inflation during the LAF surplus period and 3% in LAF deficit period. In the LAF surplus period, the largest impact on inflation came from commodity price shocks. This reduced considerably in the deficit period. The impact of repo on output gap is 5.4% compared to only 1% on WPI inflation after one year, in the LAF surplus period. Although repo responded the most to credit in LAF deficit period it had very little impact on it.

Influence of repo rate on output is higher in the LAF surplus period compared to the LAF deficit period. A similar pattern is observed in case of credit growth and money supply. This is indicative of better pass through of monetary policy in liquidity surplus period. But policy affects output more strongly than it affects inflation.

Robustness checks

To confirm our results, we did some robustness tests for both financial and real sector models. We estimated the SVAR model keeping foreign block variables completely exogenous to the system, so that domestic variables do not have any impact on foreign block variables contemporaneously or with a lag. The empirical results were not significantly different from original models. We also altered the order of variables in the SVAR. In the financial sector model the new order was oil prices, fed rate, 91 day g-secs, 10 year g-secs yield, commercial paper rate, Nifty returns and NEER. In the model used for the real sector, the order was oil prices, world food index, Fed rate, inflation, output gap, credit growth and money supply. The results were qualitatively similar to earlier models.

7.3 IRFs of 91 Day G-Sec and WACR to the policy variable

The estimation is based on equation (6) replacing 91 day g-secs with WACR, in order to examine which variable shows more speed and magnitude of monetary policy pass-through.

Chart 9 and 10 give the IRFs of WACR and 91 day g-secs respectively to a one standard deviation positive shock in the repo rate. IRFs of both the variables are consistent with theory, which says money market rates should increase following a rise in repo rate.

Although the pass through is similar in the first period, it is better and faster in case of WACR than 91 day g-secs rate in subsequent quarters. Forecast error variance decomposition (given in tables A5 and A6 in the appendix) also shows similar behavior. Repo rate explains 1.5% of WACR and 4.3% of G sec after one quarter but 29.70% variation in WACR after one year, whereas it is only 8.5% in case of 91 day g-secs rate.

These results are consistent with Goyal and Agarwal (2019) who find that short run g-secs yields are most responsive to changes in policy rates in 1 day and 10 days event windows. In their methodology, change in the repo rate is the main independent variable and change in different market rates were dependent variables. Data was collected for T and T ± 5 windows around periods of repo rate change. The finding that the coefficient of 91 day g-secs was significant whereas the coefficient of call money rate (CMR) was insignificant was attributed to the larger volatility in CMR. As it was estimated by a short-run event window, CMR was observed to be more responsive to changes in liquidity demand than to a change in repo rate.

But in our longer term analysis done using SVAR, we found WACR to be more responsive than short term government securities to the repo rate. Moreover, we used weighted CMR, which averages away the volatility. The response of WACR is found to increase and sustain in over a longer period compared to 91 day g-secs. Our conclusion, therefore, is that WACR is a better operating target.

We also did robustness check for the above exercise by adding growth rate of reserve money as a liquidity variable in the benchmark SVAR model after the Repo rate. The IRFs and FEVDs showed a similar pattern of results as in the original model of equation (6).

Chart 9 – Impulse response function of WACR to repo rate as policy variable.

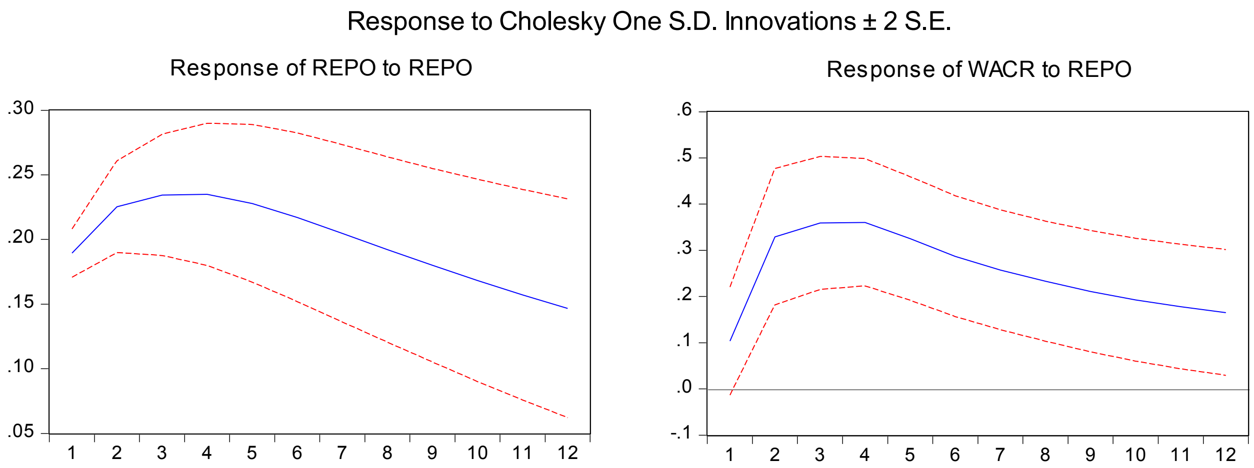
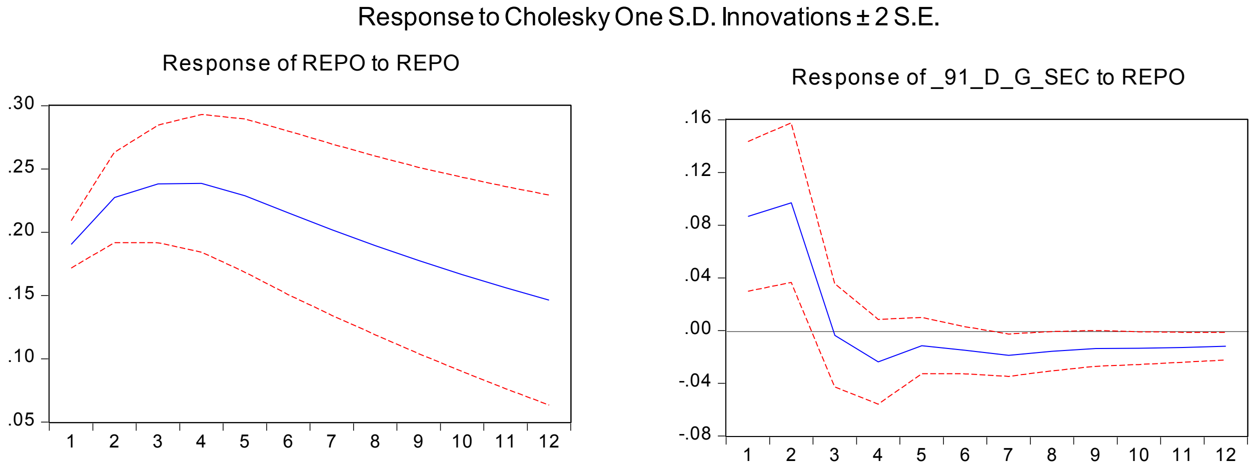


Chart 10 – Impulse response function of 91 day g-secs to repo rate as policy variable.



7.4 The repo rate and reserve money growth rate compared

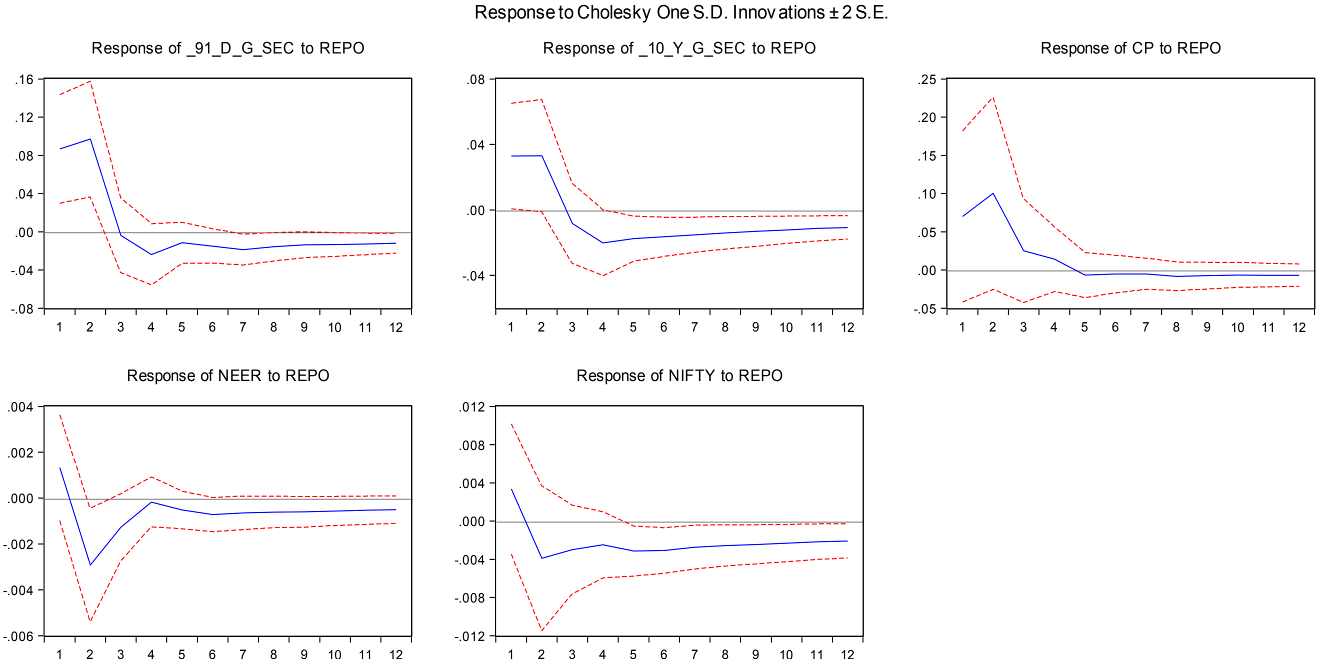
The SVAR models for this estimation are those in equations (4) and (5) respectively. The regressions are run for the entire period (Jan 2002 - June 2019).

1) Response of financial sector variables to impulse in monetary policy

Charts 11 and 12 give IRFs of financial sector variables to one standard deviation positive innovations in repo rate and the growth rate of reserve money respectively. Positive innovation in repo rate means monetary policy tightening and that in reserve money means expansionary monetary policy. IRFs of most of the variables are consistent with theory when repo rate is the policy variable, but not when reserve money is the policy variable.

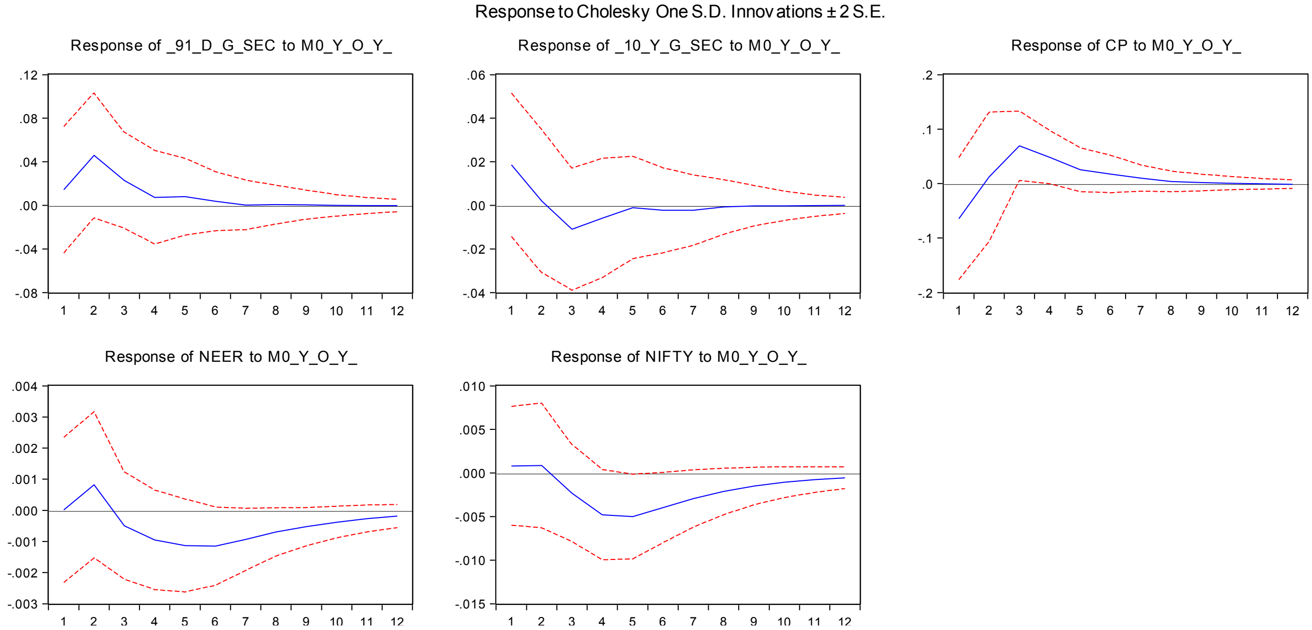
IRFs of 91 day g-secs, 10 year g-secs and commercial paper (CP in Chart 11) show positive movement following a monetary policy tightening (Chart 11). Money market rates are expected to follow the direction of change in repo rate as the central bank lends at this rate. In case of reserve money (M0_Y_o_Y in Chart 12) as the policy variable, money market rates are expected to fall due to a rise in money supply. Increased supply of reserves to banks reduces their borrowing requirements and thereby results in lower interest rates. IRFs of 91 day g-secs and 10 year g-secs in Chart 11 are not consistent with theory.

Chart 11 – Impulse response functions of financial sector variables when repo rate is the policy variable.



There is also a presence of the exchange rate puzzle when reserve money is the policy variable. NEER is expected to appreciate due to a rise in repo rate and depreciate due to a rise in money supply. IRFs show that there is initial appreciation in NEER after a policy shock and then it depreciates in both the cases of repo rate and reserve money. This means, IRF of NEER follows theory more accurately when repo rate is the policy variable. In case of nifty returns also, IRF is expected to rise due to rise in money supply however, it does not show movement consistent to theory. These IRFs suggest rate variables do better than quantity variable as the policy instrument.

Chart 12 – Impulse response functions of financial sector variables when growth in reserve money is the policy variable.



Forecast error variance decompositions (FEVDs) of financial sector variables

Tables A7 and A8 (in Appendix) gives FEVDs of financial sector variables when repo rate and the growth rate of reserve money are used as policy variables respectively. Repo rate explained 8.5% variation in 91 day g-secs and 5.3% variation in 10 year g-secs over the forecast period of one year. Influence of reserve money was 1.3% and 0.7% respectively. Same pattern is observed for commercial paper. Variation over the year is 1.9% with the repo rate but 1.5% when reserve money is the policy variable. Repo rate is more influential in case of NEER and nifty also. Therefore, from IRFs and FEVDs we can conclude that repo rate has higher pass-through as compared to reserve money.

2) Response of real sector variables to impulse in monetary policy

Chart 13 and 14 give IRFs of output gap, inflation and credit growth (CREDIT in charts 13 and 14) to one standard deviation positive shock in repo rate and the growth rate in reserve money respectively. Output gap is expected to fall due to a contractionary rise in the repo rate. It is expected to rise due to a positive innovation in reserve money. As the charts show, Output gap falls after a lag of three months when repo rate is the policy rate. That is the transmission takes place only after three months. The IRF showed immediate positive movement following a rise in reserve money, but falls again only after two months.

IRFs of inflation and credit show movement consistent to the theory in case of both repo rate and reserve money.

Chart 13 – Impulse response functions of variables used for real sector when repo rate is the policy rate.

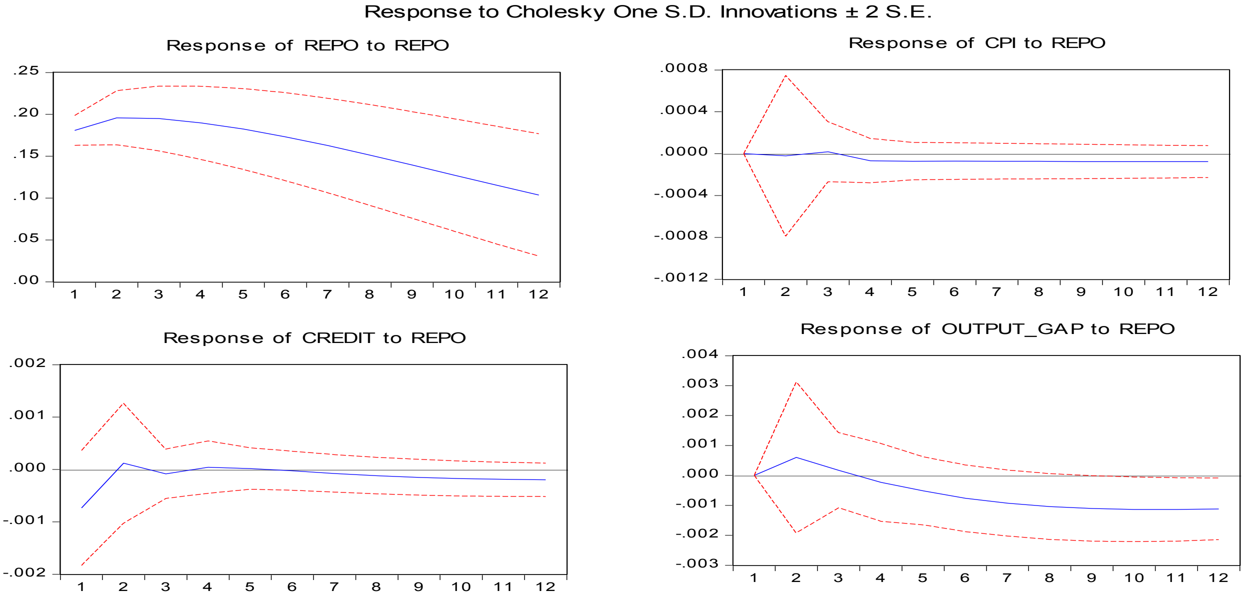
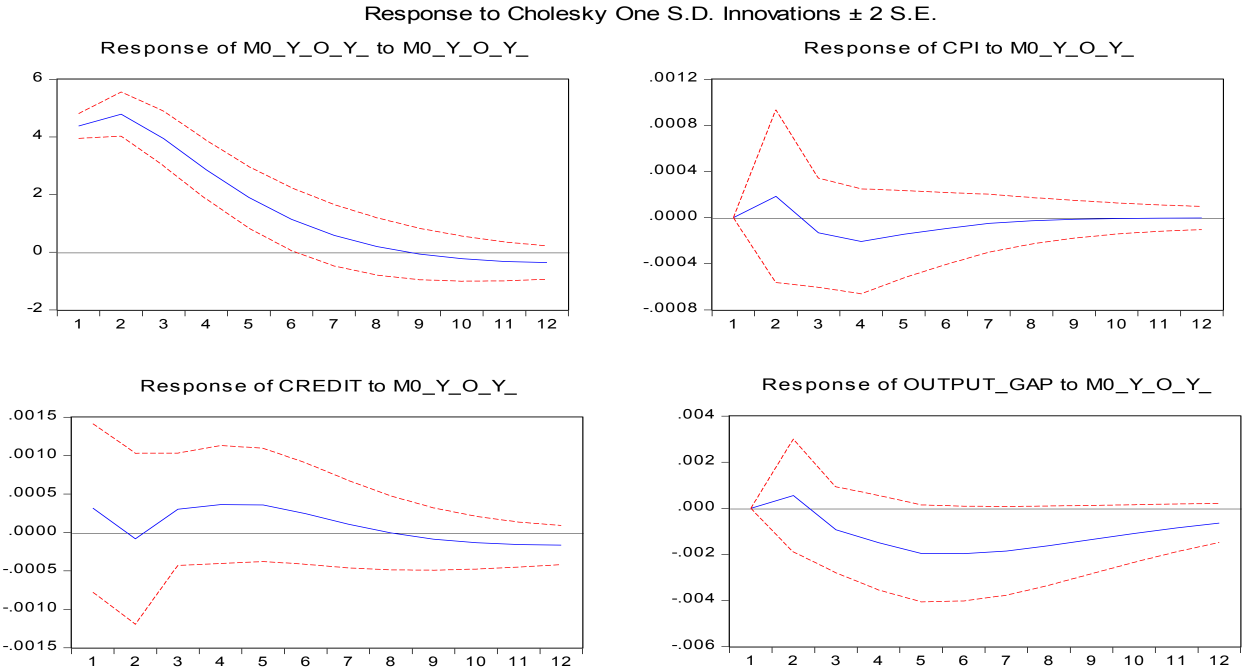


Chart 14 – Impulse response functions of variables used for real sector when growth in reserve money is the policy rate.



Forecast error variance decompositions (FEVDs) of real sector variables:

Tables A9 and A10 (in Appendix) give the FEVDs of real sector variables when policy variables are repo rate and the growth rate in reserve money respectively. Monetary policy variables have very low influence on real sector variables for the forecast period of one year. Repo rate explains only 1.8% variation in output gap and 0.15% in inflation. Reserve money growth has 4.3% and 0.4% influence on output gap and inflation respectively. In case of credit growth, repo rate has slightly higher influence than the reserve money.

The IRFs and FEVDs show repo rate works better as the policy variable. Transmission from the repo rate has become well established with the switch to the LAF system. However, money supply remains important since transmission is better when liquidity is in surplus.

8. Conclusion

Reserve Bank of India constituted a working group in 2010-11 to review the framework of the operating procedure of monetary policy in India. The group recommended LAF should be the key element in the operating framework of the RBI, and it should operate in deficit liquidity mode for optimal monetary transmission. This view that transmission would be better if banks were liquidity constrained was based on experience in advanced economies before the global financial crisis.

Repo rate was accepted as the single policy rate to unambiguously signal the monetary policy stance. The weighted average overnight call money rate was recommended as the operating target of the RBI. The operating objective was to contain this rate around repo rate within a corridor. The LAF framework was continued with reduction in corridor width from time to time.

The LAF deficit regime that came into effect in 2010-11, saw periodic complaints from the markets about shortages of liquidity (Goyal and Agarwal, 2019).

We use the natural division of the period after 2000 into two liquidity regimes to address the question whether monetary policy transmission was better in LAF deficit or in LAF surplus regime.

Different SVARs, with short run restrictions, were estimated for the financial sector and for the real sector respectively, with appropriate variables. Estimation results show monetary policy transmission was better and faster in the LAF surplus period compared to LAF deficit period, for both the financial and real sector. Pass through to money market rates was quicker and higher in the LAF surplus period. Output gap also showed quicker and higher pass through of monetary policy in LAF surplus period. IRFs of credit growth and money supply were consistent with theory in LAF surplus regime only. Although the influence of the repo rate on other variables was low in both regimes, it was slightly higher in LAF surplus regime.

An exercise comparing repo rate and reserve money as the monetary policy instrument, showed the repo rate to perform better indicating transmission is changing, with a greater role for interest rates. Monetary transmission from the repo rate exists and works better than that through liquidity variables alone. But liquidity remains important since transmission is better when durable liquidity is in surplus.

The repo, however, has a greater impact on the output gap than on inflation, suggesting an interest sensitivity of aggregate demand that should be factored into policymaking.

We also examine whether 91 day g-secs is a better operating target than WACR, using similar SVAR methodology with short run restrictions. IRFs and FEVDs showed that although the initial impact effect of a change in repo rate was more on 91 day g-secs, response of WACR is greater beyond the first quarter. Therefore WACR should continue to be the operating target. Money market weaknesses that create large intra-day volatility in the call money rate reduce the short-run impact. These could be addressed.

As the focus was on monetary policy shocks, we estimated SVAR with short run restrictions only. Estimation of models with long-run restrictions could be a useful extension, especially to examine impact on the real sector. Another extension is to examine whether, as in Goyal and Agarwal (2019), it is aligning the liquidity cycle with the rate change that improves transmission or liquidity should stay in surplus regardless of the monetary cycle.

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Appendix

***Tables for section 7.1**

Table A1 – Forecast error variance decompositions (FEVDs) of financial sector variables for LAF surplus period.

period	S.E.	oil	Fed rate	repo rate	91 Day g-sec	10 Year g-sec	CP	NEER	nifty
oil prices									
1	0.08	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.09	86.21	0.87	3.48	0.08	1.28	3.49	1.00	3.59
6	1.00	76.53	0.89	8.64	4.73	1.34	3.71	0.91	3.24
12	0.10	74.88	1.05	9.49	4.91	1.58	3.64	1.34	3.11
Fed rate									
1	0.14	5.39	94.61	0.00	0.00	0.00	0.00	0.00	0.00
3	0.37	9.58	86.62	1.88	0.97	0.03	0.13	0.34	0.45
6	0.0	6.22	81.61	9.34	0.36	0.05	0.43	1.10	0.89
12	1.22	2.21	76.19	17.79	0.12	0.27	1.38	1.01	1.02
repo rate									
1	0.20	2.72	1.73	95.55	0.00	0.00	0.00	0.00	0.00
3	0.45	18.81	2.03	71.62	5.88	0.45	0.42	0.79	0.01
6	0.71	35.08	1.91	53.86	7.04	1.02	0.30	0.75	0.03
12	0.82	43.72	4.87	42.97	5.79	0.98	0.53	0.82	0.33
91day g-secs									
1	0.43	1.15	0.27	8.30	90.27	0.00	0.00	0.00	0.00
3	0.50	10.19	0.49	9.42	67.53	7.08	2.68	2.58	0.02
6	0.51	9.99	0.48	10.13	64.94	7.66	3.07	2.72	1.02
12	0.53	11.21	0.53	12.61	61.36	7.51	2.93	2.77	1.08
10 year g-secs									
1	0.22	4.18	0.16	0.24	12.95	82.46	0.00	0.00	0.00
3	0.30	23.47	0.34	2.71	8.04	50.96	2.95	6.46	5.07
6	0.33	20.50	0.65	9.35	8.61	43.82	3.11	6.42	7.53
12	0.35	21.90	0.70	11.40	9.22	40.67	2.96	5.99	7.16
CP									
1	0.64	1.58E-05	0.04	0.02	13.98	0.21	85.75	0.00	0.00
3	0.77	0.48	4.91	11.72	12.35	0.29	67.37	2.14	0.75
6	0.81	4.00	4.67	11.36	12.07	0.80	61.20	4.51	1.39
12	0.82	4.55	4.52	13.21	11.95	0.91	58.96	4.44	1.45
NEER									
1	0.02	0.00	0.68	1.06	0.10	1.10	6.83	90.23	0.00
3	0.02	0.59	0.61	10.20	1.06	2.12	8.40	76.43	0.60
6	0.02	1.89	2.26	9.81	1.25	2.26	7.86	73.93	0.73
12	0.02	2.43	2.31	10.45	1.25	2.32	7.83	72.66	0.74
nifty									
1	0.06	5.61	8.30	0.54	3.31	0.72	12.14	4.67	64.72
3	0.07	4.57	7.46	1.43	3.16	1.18	12.97	5.95	63.28
6	0.07	6.80	6.50	5.84	9.11	2.62	11.77	5.51	51.85
12	0.08	8.31	6.44	6.39	9.00	2.77	11.47	5.72	49.91

Table A2 – Forecast error variance decompositions (FEVDs) of financial sector variables in LAF deficit period.

period	S.E.	oil	Fed rate	repo rate	91 day g-sec	10 year g-sec	CP	NEER	nifty
oil prices									
1	0.08	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.09	94.42	0.53	1.10	0.83	1.35	1.35	0.04	0.37
6	0.09	88.32	2.34	1.26	0.94	1.39	3.00	1.53	1.23
12	0.10	84.24	3.07	3.11	1.79	1.66	3.12	1.72	1.29
Fed rate									
1	0.04	1.04	98.96	0.00	0.00	0.00	0.00	0.00	0.00
3	0.09	5.09	86.84	0.11	1.11	0.18	6.47	0.13	0.07
6	0.16	2.89	90.05	1.26	0.99	0.41	4.02	0.06	0.32
12	0.29	2.63	81.01	11.82	0.67	0.19	3.31	0.15	0.23
repo rate									
1	0.17	1.54	0.09	98.36	9.74E-35	5.28E-34	1.14E-31	0.00	0.00
3	0.33	0.54	0.31	97.31	0.03	0.96	0.22	0.18	0.46
6	0.54	0.52	3.50	88.90	0.08	4.04	0.77	2.01	0.19
12	0.75	0.38	12.54	78.13	0.06	4.46	1.41	2.87	0.15
91 day g-sec									
1	0.41	3.88	1.31	1.54	93.28	0.00	3.27E-31	0.00	0.00
3	0.48	4.73	1.44	3.80	80.35	5.43	0.03	3.73	0.49
6	0.53	4.73	1.22	3.81	67.35	11.96	0.10	8.77	2.06
12	0.55	5.43	1.97	4.02	63.98	12.18	0.57	9.48	2.35
10 year g-sec									
1	0.23	0.06	1.40	1.13	0.97	96.44	6.25E-30	0.00	0.00
3	0.27	8.07	1.06	0.96	1.25	82.36	0.60	5.35	0.35
6	0.29	8.59	1.54	2.09	2.10	77.38	0.88	5.48	1.94
12	0.29	8.37	2.66	3.16	2.29	73.95	1.64	5.76	2.17
CP									
1	0.87	0.05	6.04	0.47	0.31	0.91	92.22	0.00	0.00
3	1.20	0.26	5.58	3.29	0.43	1.34	85.43	0.93	2.74
6	1.24	1.46	7.68	3.23	0.73	1.51	80.87	1.05	3.46
12	1.26	2.05	8.24	3.32	0.82	1.56	79.32	1.24	3.44
NEER									
1	0.02	0.25	0.00	0.60	4.24	5.28	1.81	87.82	0.00
3	0.02	0.74	1.18	2.03	5.13	9.56	1.60	76.83	2.93
6	0.02	1.14	1.55	1.91	6.46	11.22	2.23	69.93	5.57
12	0.02	1.71	2.61	1.95	6.58	11.11	2.23	68.10	5.70
nifty									
1	0.04	4.20	10.09	4.68	4.55	0.41	1.70	37.84	36.51
3	0.04	4.77	12.39	5.17	6.44	2.49	1.67	34.58	32.49
6	0.04	5.24	13.99	4.63	6.85	5.45	4.40	30.75	28.69
12	0.04	5.19	15.59	4.58	6.74	5.53	4.30	30.00	28.07

***Tables for section 7.2**

Table A3 – Forecast error variance decompositions (FEVDs) of real sector variables in LAF surplus regime.

period	S.E.	oil	WFI	Fed rate	output gap	WPI inflation	repo rate	credit growth	money supply
oil prices									
1	0.08	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.09	79.46	9.66	0.18	1.91	3.18	0.44	4.44	0.72
6	0.09	76.30	10.19	0.76	2.25	4.53	0.96	4.31	0.69
12	0.09	74.55	10.91	0.78	2.69	4.43	1.75	4.17	0.73
WFI									
1	0.03	6.39	93.61	0.00	0.00	0.00	0.00	0.00	0.00
3	0.03	5.71	83.70	3.01	3.35	3.09	0.03	0.34	0.77
6	0.03	6.18	80.01	3.02	4.40	4.37	0.38	0.81	0.83
12	0.03	6.43	78.91	3.06	4.51	4.37	1.04	0.79	0.87
Fed rate									
1	0.14	8.21	3.15	88.64	0.00	0.00	0.00	0.00	0.00
3	0.37	11.79	1.97	82.85	0.46	0.12	1.40	0.04	1.37
6	0.66	11.44	0.79	75.88	1.33	1.17	5.55	0.02	3.82
12	1.13	6.88	1.54	65.79	4.13	2.62	13.32	0.02	5.69
output gap									
1	0.02	0.00	0.05	0.03	99.91	0.00	0.00	0.00	0.00
3	0.02	0.94	3.68	0.09	90.33	0.67	0.02	1.57	2.70
6	0.02	1.48	4.53	0.26	86.17	2.02	1.43	1.69	2.41
12	0.02	3.09	5.84	0.38	78.48	2.82	5.39	1.59	2.41
WPI									
1	0.01	7.74	0.25	0.41	0.37	91.24	0.00	0.00	0.00
3	0.01	18.18	1.19	2.49	1.96	69.35	0.18	4.59	2.06
6	0.01	18.03	3.86	3.75	4.41	62.17	0.34	4.97	2.46
12	0.01	18.85	4.42	3.90	4.54	60.04	1.04	4.82	2.40
repo rate									
1	0.20	0.16	0.03	3.73	2.64	2.81	90.64	0.00	0.00
3	0.39	9.83	6.15	5.66	1.49	7.78	68.18	0.66	0.24
6	0.62	20.73	17.65	4.40	5.54	5.17	45.80	0.46	0.24
12	0.80	22.40	24.20	5.40	12.76	3.38	31.34	0.31	0.22
credit growth									
1	0.01	0.02	2.39	0.85	0.11	0.74	5.61	90.29	0.00
3	0.01	6.02	3.60	3.43	0.34	4.00	4.87	75.38	2.35
6	0.01	7.87	4.44	4.07	1.05	4.30	4.69	70.89	2.69
12	0.01	7.79	4.53	4.29	1.22	4.64	5.26	69.51	2.76
money supply									
1	0.01	0.12	0.43	1.96	1.94	0.04	5.16	23.31	67.04
3	0.01	0.98	0.71	2.01	2.68	3.74	5.24	23.00	61.63
6	0.01	1.06	0.79	2.22	2.80	3.71	5.21	23.04	61.15
12	0.01	1.23	0.80	2.92	2.82	3.69	5.19	22.80	60.54

Table A4 – Forecast error variance decompositions (FEVDs) of real sector variables in LAF deficit period.

period	S.E.	oil	WFI	Fed rate	output gap	WPI inflation	repo rate	credit growth	money supply
oil prices									
1	0.08	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.09	89.56	1.50	0.86	0.50	2.72	0.57	2.86	1.42
6	0.09	81.86	1.63	2.89	0.89	2.74	0.82	6.62	2.56
12	0.10	78.07	2.79	2.99	0.98	2.63	2.72	7.17	2.64
WFI									
1	0.02	11.47	88.53	0.00	0.00	0.00	0.00	0.00	0.00
3	0.02	11.96	80.77	1.00	0.47	0.69	1.18	1.73	2.21
6	0.02	11.81	70.59	2.27	2.17	1.45	2.72	2.92	6.06
12	0.03	12.17	66.28	2.53	2.46	1.86	3.07	3.14	8.49
Fed rate									
1	0.04	1.43	0.00	98.57	0.00	0.00	0.00	0.00	0.00
3	0.09	4.35	0.06	91.15	0.14	0.45	0.49	0.23	3.12
6	0.15	2.12	0.71	93.39	0.26	0.68	0.43	0.22	2.17
12	0.26	3.80	0.28	83.05	1.41	0.38	4.38	3.77	2.94
output gap									
1	0.02	2.73	5.72	0.97	90.58	0.00	0.00	0.00	0.00
3	0.02	2.55	4.41	2.28	81.07	3.18	2.37	1.93	2.21
6	0.03	5.48	8.75	7.04	66.06	4.46	2.27	2.08	3.86
12	0.03	6.80	8.86	8.86	61.27	4.37	2.42	2.84	4.59
inflation									
1	0.01	0.86	0.12	0.73	2.94	95.35	0.00	0.00	0.00
3	0.01	1.53	1.09	1.74	6.27	79.24	1.19	8.47	0.47
6	0.01	1.94	1.30	2.30	7.39	72.39	2.67	9.88	2.14
12	0.01	2.12	1.68	2.88	7.91	70.45	2.92	9.72	2.32
repo rate									
1	0.16	2.37	0.86	0.00	18.65	0.04	78.08	0.00	0.00
3	0.31	0.63	7.71	0.12	13.57	0.08	74.16	2.77	0.94
6	0.51	1.17	11.63	1.33	14.12	1.34	60.46	9.03	0.92
12	0.70	1.79	10.66	2.53	17.50	2.01	46.51	18.30	0.70
credit growth									
1	0.00	0.34	1.53	0.36	2.63	4.01	0.15	90.99	0.00
3	0.01	2.76	4.66	5.42	5.72	6.81	0.42	74.20	0.00
6	0.01	3.55	8.02	9.23	10.98	6.34	1.62	59.20	1.05
12	0.01	3.70	9.43	9.92	12.83	6.29	2.17	52.53	3.13
money supply									
1	0.01	2.69	0.11	2.20	11.36	0.31	0.05	8.92	74.37
3	0.01	5.29	0.63	2.83	10.49	1.42	0.25	9.67	69.41
6	0.01	7.27	1.37	3.45	12.63	2.89	0.39	9.17	62.83
12	0.01	7.67	1.95	3.67	12.90	3.19	1.01	9.23	60.39

***Tables for section 7.3**

Table A5 – FEVD of WACR when WACR is the operating target.

period	S.E.	oil	Fed rate	repo rate	WACR	10 Y g-sec	CP	NEER	nifty
1	0.08	0.25	0.28	1.50	97.97	0.00	0.00	0.00	0.00
3	0.08	0.80	1.03	16.03	80.12	1.12	0.04	0.45	0.40
6	0.09	3.75	3.17	24.73	64.08	2.21	0.05	1.42	0.58
9	0.09	5.56	3.97	27.94	57.82	2.38	0.05	1.65	0.63
12	0.09	6.53	4.21	29.70	54.78	2.42	0.05	1.68	0.64

Table A6 – FEVD of 91 day g-sec when 91 day g-sec is the operating target.

Period	S.E.	oil	Fed rate	repo rate	91 day g-sec	10 Y g-sec	CP	NEER	nifty
1	0.08	2.49	0.43	4.28	92.81	0.00	0.00	0.00	0.00
3	0.09	6.59	1.40	7.78	80.03	0.53	1.67	1.49	0.52
6	0.09	6.51	1.43	8.03	78.55	0.60	2.38	1.56	0.93
9	0.09	6.61	1.44	8.34	78.13	0.60	2.38	1.57	0.94
12	0.09	6.67	1.45	8.53	77.87	0.61	2.37	1.56	0.94

***Tables for section 7.4:**

Comparison between repo rate and reserve money growth rate as the policy variable.

Table A7 – Forecast error variance decompositions (FEVDs) of finance sector variables for repo rate as policy variable (2002- 2019)

period	S.E.	oil	Fed rate	repo rate	91 D g-sec	10 Y g-sec	CP	NEER	nifty
oil prices									
1	0.08	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.09	96.24	0.01	0.47	0.23	0.34	0.91	0.10	1.70
6	0.09	94.48	0.16	1.79	0.32	0.42	0.91	0.14	1.78
12	0.09	93.08	0.24	3.06	0.34	0.44	0.89	0.18	1.77
Fed rate									
1	0.10	2.11	97.89	0.00	0.00	0.00	0.00	0.00	0.00
3	0.29	1.73	96.43	0.34	0.40	0.06	0.83	0.05	0.16
6	0.50	1.07	94.24	2.63	0.16	0.06	1.39	0.06	0.39
12	0.77	0.77	85.06	11.36	0.12	0.04	1.76	0.03	0.84
repo rate									
1	0.19	0.62	1.80	97.58	0.00	0.00	0.00	0.00	0.00
3	0.42	9.13	4.26	83.58	1.64	0.75	0.50	0.13	0.02
6	0.65	16.80	7.12	71.78	1.77	1.29	0.25	0.59	0.40
12	0.86	20.08	9.69	65.61	1.58	1.48	0.14	0.94	0.46
91 day g-sec									
1	0.42	2.49	0.43	4.28	92.81	0.00	0.00	0.00	0.00
3	0.47	6.59	1.40	7.78	80.03	0.53	1.67	1.49	0.52
6	0.47	6.51	1.43	8.03	78.55	0.60	2.38	1.56	0.93

12	0.47	6.67	1.45	8.53	77.87	0.61	2.37	1.56	0.94
10 year g-sec									
1	0.24	3.40	0.88	1.91	5.29	88.51	0.00	0.00	0.00
3	0.27	15.20	1.64	2.96	4.29	70.74	0.60	3.08	1.49
6	0.28	14.92	1.62	4.13	4.33	68.75	0.64	3.02	2.60
12	0.28	15.10	1.81	5.28	4.26	67.37	0.62	3.00	2.56
CP									
1	0.81	0.02	0.38	0.75	4.04	0.00	94.80	0.00	0.00
3	0.91	0.22	0.61	1.88	3.93	0.02	90.70	0.07	2.57
6	0.92	0.47	0.81	1.88	4.07	0.07	89.95	0.19	2.55
12	0.92	0.48	0.83	1.92	4.08	0.07	89.88	0.20	2.55
NEER									
1	0.02	0.02	0.57	0.64	1.17	2.45	0.92	94.22	0.00
3	0.02	0.14	0.70	3.75	1.72	3.69	1.15	86.66	2.18
6	0.02	0.19	0.86	3.97	1.78	3.90	1.17	85.91	2.21
12	0.02	0.41	0.87	4.55	1.78	3.87	1.16	85.13	2.21
nifty									
1	0.05	4.49	2.74	0.44	3.70	1.22	1.84	14.36	71.23
3	0.05	4.37	3.91	1.18	4.08	1.30	2.06	14.94	68.16
6	0.06	4.53	3.94	2.00	4.24	1.31	2.05	15.07	66.87
12	0.06	4.86	3.92	3.07	4.19	1.33	2.02	14.84	65.78

Table A8 – Forecast error variance decompositions (FEVDs) of finance sector variables for reserve money as policy variable (2002- 2019)

oil prices									
period	S.E.	oil	Fed rate	reserve money	91 D g-sec	10 Y g-sec	CP	NEER	nifty
1	0.08	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.09	95.02	0.32	0.33	0.36	0.51	1.36	0.42	1.68
6	0.09	94.67	0.39	0.34	0.42	0.56	1.39	0.44	1.80
12	0.09	94.61	0.43	0.34	0.43	0.57	1.39	0.44	1.81
Fed rate									
1	0.11	3.11	96.89	7.39E-30	0.00	0.00	0.00	0.00	0.00
3	0.30	3.72	94.54	0.12	0.35	0.09	0.87	0.14	0.17
6	0.55	4.12	92.87	1.27	0.14	0.08	1.14	0.05	0.33
12	0.90	3.60	90.45	4.14	0.05	0.04	1.08	0.03	0.61
reserve money									
1	4.17	0.97	0.90	98.13	0.00	0.00	0.00	0.00	0.00
3	8.27	1.14	0.27	91.35	0.15	3.51	3.49	0.00	0.09
6	9.70	2.11	0.23	88.49	0.23	5.24	3.25	0.07	0.39
12	9.91	2.50	1.71	86.43	0.24	5.33	3.25	0.08	0.47
91 day g-sec									
1	0.42	2.59	0.34	0.11	96.96	0.00	0.00	0.00	0.00
3	0.47	7.47	2.14	1.29	84.52	1.13	1.97	0.79	0.69
6	0.48	7.43	2.29	1.31	82.34	1.24	3.46	0.80	1.13
12	0.48	7.43	2.29	1.31	82.31	1.25	3.47	0.81	1.13

10 year g-sec									
1	0.24	3.92	1.02	0.59	7.76	86.71	0.00	0.00	0.00
3	0.28	17.88	2.72	0.59	6.46	68.52	0.83	1.55	1.44
6	0.29	17.51	2.98	0.63	6.65	67.03	0.97	1.62	2.61
12	0.29	17.50	2.98	0.63	6.66	67.02	0.97	1.62	2.61
CP									
1	0.81	0.14	0.45	0.64	5.62	0.04	93.12	0.00	0.00
3	0.91	0.36	0.84	1.10	5.24	0.07	90.01	0.06	2.32
6	0.92	0.59	1.01	1.47	5.43	0.16	88.93	0.11	2.30
12	0.92	0.60	1.04	1.49	5.43	0.16	88.87	0.11	2.30
NEER									
1	0.02	0.07	0.95	0.00	1.45	2.30	0.76	94.47	0.00
3	0.02	0.13	1.25	0.29	1.91	3.93	1.05	88.61	2.83
6	0.02	0.23	1.72	1.36	2.02	4.24	1.07	86.49	2.87
12	0.02	0.23	1.88	1.93	2.01	4.25	1.07	85.76	2.87
nifty									
1	0.05	5.77	3.01	0.02	3.46	1.08	1.45	14.89	70.32
3	0.06	6.36	4.77	0.22	3.90	1.15	1.68	15.19	66.73
6	0.06	6.21	5.26	2.24	3.89	1.16	1.66	15.01	64.57
12	0.06	6.17	5.41	2.76	3.86	1.23	1.65	14.88	64.04

Table A9 – Forecast error variance decompositions (FEVDs) of real sector variables when repo rate is the policy variable (2002- 2019)

output gap								
period	S.E.	oil	WFI	Fed rate	output gap	CPI	repo rate	credit growth
1	0.08	0.13	0.25	0.50	99.12	0.00	0.00	0.00
3	0.08	0.77	1.93	0.67	95.98	0.11	0.09	0.44
6	0.08	1.16	2.66	0.64	94.70	0.11	0.29	0.45
12	0.09	1.48	2.76	0.83	92.53	0.11	1.80	0.49
CPI								
1	0.03	0.01	0.23	1.66	0.03	98.06	0.00	0.00
3	0.05	0.82	2.06	2.05	1.73	91.66	0.00	1.68
6	0.08	0.98	2.42	2.37	1.75	90.73	0.05	1.70
12	0.11	0.98	2.82	2.62	1.74	90.01	0.15	1.68
repo rate								
1	0.10	0.24	0.00	3.51	0.22	0.04	95.99	0.00
3	0.28	8.18	2.98	8.55	1.43	0.04	77.82	1.00
6	0.48	16.48	8.06	10.35	5.94	0.02	57.90	1.26
12	0.74	20.35	14.14	9.75	12.24	0.04	42.36	1.12
credit growth								
1	0.02	0.01	2.49	1.55	0.04	1.95	0.81	93.16
3	0.02	3.94	3.13	1.94	1.21	3.50	0.73	85.55
6	0.02	5.32	3.03	2.85	2.19	3.49	0.71	82.40
12	0.02	5.31	3.47	3.68	2.38	3.42	0.88	80.86

Table A10 – Forecast error variance decompositions (FEVDs) of real sector variables when growth in reserve money is the policy variable (2002- 2019)

period	S.E.	oil	WFI	Fed rate	output gap	CPI	reserve money	credit growth
output gap								
1	0.08	0.03	0.19	0.54	99.25	0.00	0.00	0.00
3	0.09	1.51	2.36	0.80	94.44	0.10	0.28	0.52
6	0.09	2.67	3.55	0.91	89.91	0.10	2.33	0.53
12	0.09	2.77	3.66	1.17	87.41	0.11	4.33	0.55
CPI								
1	0.03	0.00	0.21	1.50	0.02	98.27	0.00	0.00
3	0.06	1.16	2.27	1.76	1.56	91.24	0.16	1.86
6	0.08	1.44	2.74	1.89	1.60	90.07	0.38	1.87
12	0.12	1.54	3.33	1.93	1.60	89.36	0.39	1.85
reserve money								
1	0.11	0.99	0.00	1.49	0.39	0.15	96.98	0.00
3	0.29	0.97	0.00	0.57	5.81	0.25	92.07	0.32
6	0.52	1.51	0.26	0.45	15.67	0.35	80.76	1.01
12	0.83	2.77	1.11	1.82	20.17	0.35	72.70	1.07
credit growth								
1	0.02	0.01	2.44	1.59	0.09	2.08	0.15	93.64
3	0.02	3.59	3.28	1.98	1.13	3.69	0.26	86.06
6	0.02	5.06	3.15	3.01	2.45	3.70	0.65	81.98
12	0.02	5.04	3.39	4.12	3.04	3.61	0.75	80.04

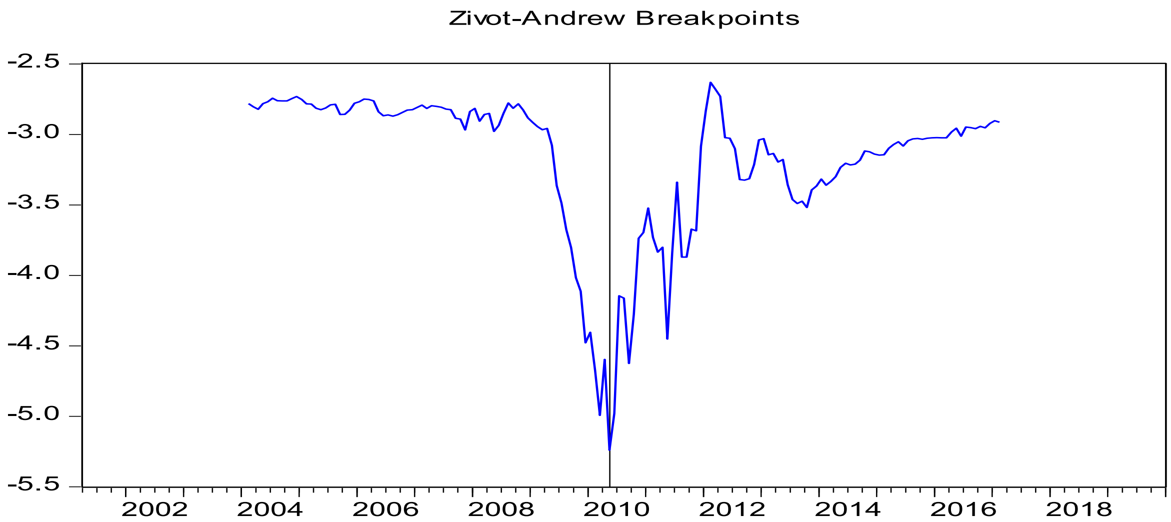
Structural break tests results:

1. Zivot-Andrews unit root test – We ran this test to identify a break point in the series. The null hypothesis is that LAF has a unit root with a structural break in both the intercept and trend. The results as presented in Table A10 and Chart 15 shows that the test identified May 2010 as the break point in the monthly LAF series, which is close to our beginning of the year January 2011 breakpoint.

Table A10: Zivot-Andrews unit root test

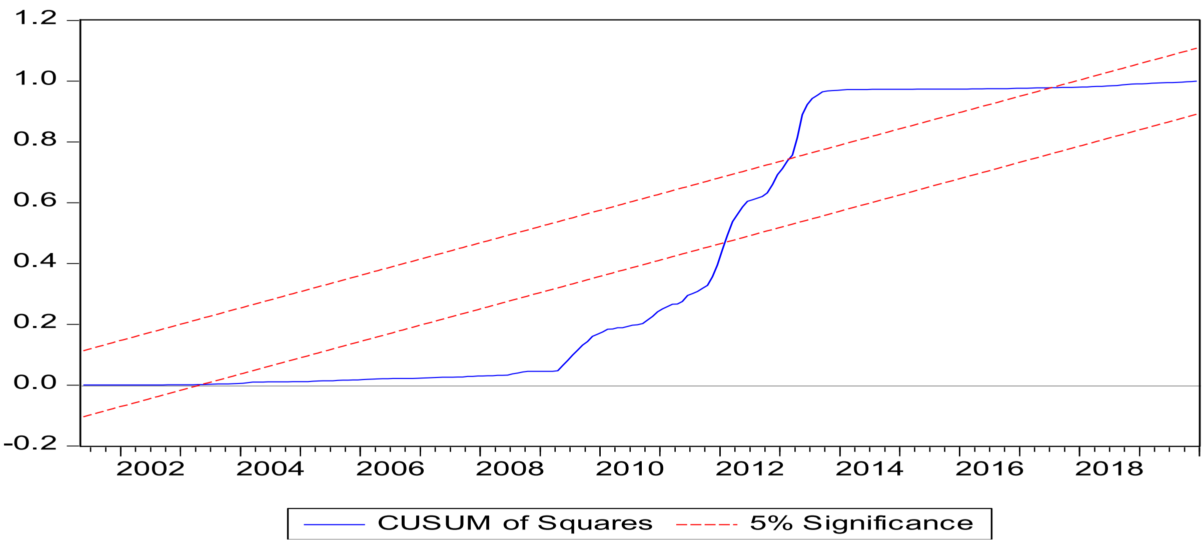
Chosen lag length: 0 (maximum lags: 4)		
Chosen break point: 2010M05		t-Statistic
Zivot-Andrews test statistic	-5.239786	5.70E-05
1% critical value:	-5.57	
5% critical value:	-5.08	

Chart 15: Zivot-Andrews breakpoints



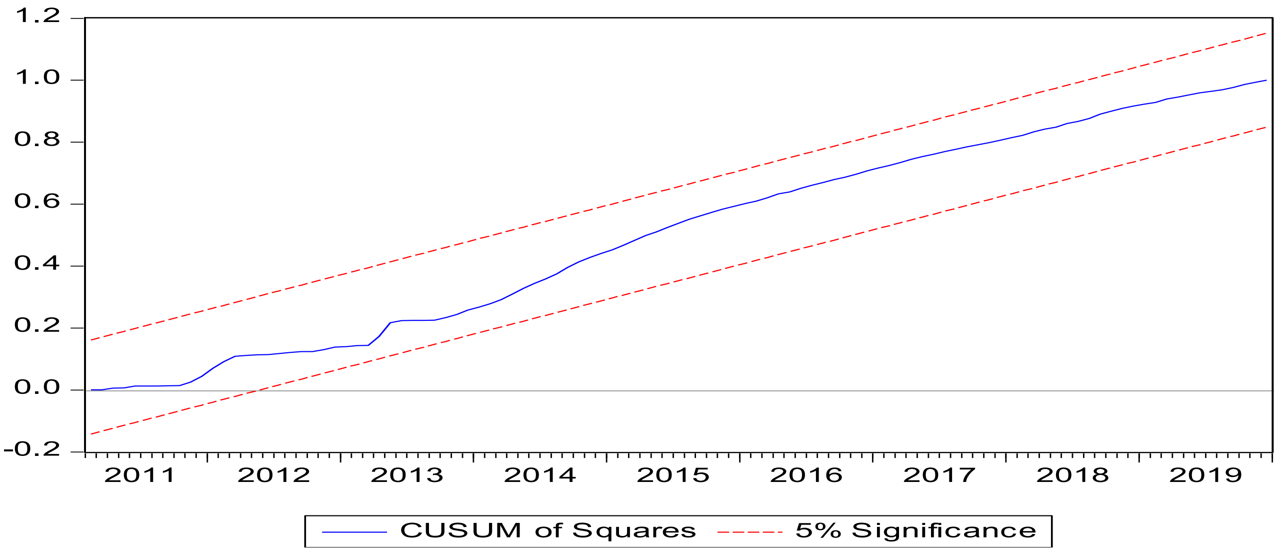
2. CUSUMSQ test of stability analysis: Monthly LAF is regressed on a constant using OLS for the period April 2001 to June 2019. Stability analysis shows the deviation of CUSUM of Squares line from 5% level of significance (Chart 16). This is the evidence of structural break in the data.

Chart 16 - Stability analysis of the model using CUSUMSQ Test



3. Test results using dummy variable to distinguish between the periods: We regressed monthly LAF variables for the same period on a constant and a dummy variable. The dummy variable took value 'zero' for observations prior to January 2011 and 'one' after that. Stability analysis done using CUSUMSQ test shows that CUSUMSQ plot falls within 5% significance level after using a dummy variable for our specified breakpoint.

Chart 17 - Stability analysis of the augmented model using CUSUMSQ Test



4. To further validate our decision of starting the LAF deficit period from January 2011, we did a Chow breakpoint test with January 2011 as a break point. The null hypothesis is no breaks at specified breakpoint. Test results (Table A11) show that we reject the null hypothesis at 5% level of significance, implying there is a structural break in LAF liquidity data at January 2011. Details of the test are presented in Table 2.

Table A11 – Chow Break Point Test: 2011M01

F-statistic	60.19711	Prob. F(1,223)
Log likelihood ratio	53.76856	Prob. Chi-Square(1)
Wald Statistic	60.19711	Prob. Chi-Square(1)
F-statistic	60.19711	Prob. F(1,223)
F-Critical	3.88	

5. We also calculated F value using Chow test of restricted and unrestricted model to show that there is a structural break in LAF series. Here, we reject the null hypothesis of no structural break if estimated F value is greater than F table value at given degrees of freedom.

F={[(RSSr-RSSu)/q]/[RSSu/(n-k)]}

Where,

RSSr – residual sum of squares of restricted model

RSSu – residual sum of squares of unrestricted model q- Number of restrictions

n – Total number of observations

k – Number of parameters in unrestricted model

A. Unrestricted Model

Monthly LAF = c + dummy + e

Where,

Monthly LAF: Dependent variable with monthly LAF values for April 2001–June 2019

C: Constant

Dummy: Dummy variable which takes as 'zero' for observations prior to January 2011 and 'One' for others.

e: residual

B. Restricted model

Monthly LAF = c + e

Table A12: Chow Test results with restricted and unrestricted model

Particulars	Values
RSSr	3.73E+11
RSSu	2.94E+11
Q	1
N	225
K	2

$F_{estimated}$ = {[(3.73E+11- 2.94E+11)/1]/[2.94E+11/(225-2)]}

$F_{estimated}$ = 3.54E+08

$F_{critical}$ = 3.883496539

Since $F_{estimated} > F_{critical}$ hence we reject the null hypothesis of no structural break