Money and Business Cycle: Evidence From India

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Abstract

In this paper we take a New Keynesian model with non-separable money in utility to Indian data using maximum likelihood. The identification problem in isolating the effect of money on output and inflation is solved by adjusting real balances for shifts in money demand. Estimates with an extended model with relevant features like partial indexation in prices, markup shock and time varying inflation target, show that real balances do affect output and inflation even after correcting for money demand unlike results for the United States and Eurozone. A regression estimate and multivariate structural vector autoregression give similar results. Types of money matter. Reserve money has the largest impact, pointing to the importance of the informal sector. The estimated income elasticity of narrow money is more than twice that of broad money, pointing to the dependence of firms on banks. Interest semi elasticity of money demand is close to one. Responsiveness of output to real interest rate is high. We find that interest rate setting is quite persistent. Coefficient of lagged interest rate varies from 0.71 to 0.95. We conclude that there is a significant asymmetry in the role of money in India (an emerging economy) in comparison to United States and Eurozone (advanced economies).

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1 Introduction

Money played a big role in the Great Depression as documented by Friedman and Schwartz (1963) but New Keynesian models developed by Rotemberg and Woodford (1997) and McCallum and Nelson's (1999) assign minimal role to the stock of money. In none of these models do changes in the nominal or real quantities of money directly affect the dynamic behaviour of other variables. Later models developed in the New Keynesian tradition a la Clarida et al. (1999) have no money. Even if there is money in the utility function as in Ireland (2004a) separable utility removes any explicit role for money. Ireland (2004b) suggests that post 1980s US data seem to prefer the standard specification, in which real balances are absent from the IS and Phillips curves so that previous studies are justified in their minimal treatment of money's role in the monetary business cycle. Andres et al. (2006) also find no direct effect of money upon inflation and output in Eurozone.

Poole (1970) showed that if money demand shock is the prominent shock in the economy then setting the interest rate is the optimal strategy since then money supply responds endogenously to the shock. New Keynesian models have largely followed this argument by including interest rate setting rule based on Taylor (1993). In New Keynesian models central banks satisfy the demand for money at the existing interest rate. Monetary transmission is expected to occur through the interest rate only. In a sense they have understood the message of Friedman and Schwartz (1963). Although central banks do not directly control the quantity of money they still influence the amount of money through their interest rate setting. The model widely used by central banks for policy making does not have any explicit role of money.

Recently, India also adopted inflation targeting as the monetary policy framework. Inflation targeting is usually implemented through some kind of interest rate rule. In a traditional IS specification, output is determined by the interest rate only and therefore an interest rate based monitory rule works. If output is affected by money supply too, the interest rate alone would be an inadequate intermediate target. The new monetary policy framework requires a clear understanding of monetary transmission. For example, can we rely only on the interest rate or do we need to take money into account as well? If, as our results show, money affects output and inflation even after correction for money demand shocks then a purely interest rate based rule would be suboptimal. The existence of a large informal sector in India and structural differences in money markets, the role of money may be asymmetric to that obtained in the US. Therefore exploring the role played by money in the Indian business cycle is important.

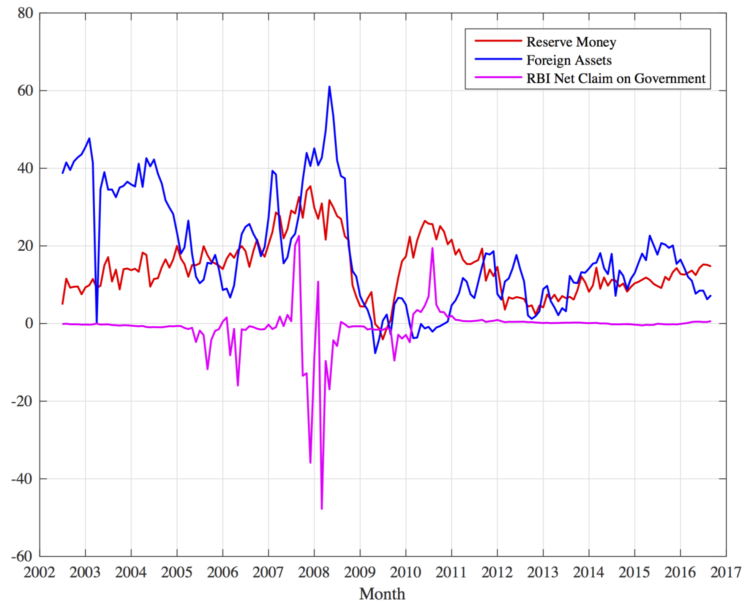

Figure 1: Share of net RBI claim on government, Growth of Reserve Money and Foreign Assets

Notes: Both Reserve money growth and RBI's holding of foreign assets are on year on year basis between June 2002 to Sep 2016 and are in % whereas net RBI claim on government is a proportion of reserve money. Data has been taken from Reserve Bank of India website.

Moreover, volatile capital flows make money supply volatile in India, so that it is not fully endogenous. Even in case of sterilisation there is never 100 percent sterilisation. Figure 1 gives year on year growth of reserve money and of RBI's holding of foreign assets. The correlation between them is 0.3469. Under foreign outflows it can be very difficult to compensate for the decline in reserve money. As one can see from the graph when there was a large amount of capital outflow in the aftermath of financial crisis, reserve money contracted sharply. Fluctuations in Government cash balances, which are a part of RBI credit to government are another source of large exogenous shocks. Share of RBI credit to government in reserve money goes as high as 54% and as low as -20% during the period June 2002 to September 2016. The correlation between year on year growth of reserve money and net credit to government is -0.16 during the same period.

Second, cash and therefore reserve money may have a greater role in the still large informal sector. The ratio of currency to GDP (gross domestic product) is around 5 per cent in most economies. In India it is high. It averaged 8.4 per cent during 1975-2000, crossed 10 per cent for the first time in 2002-03 and remained above this level since then. The average rose to 10.8 per cent in the last decade. There was a sharp rise in currency held in 2010-11, over 2014-16, and again in 2017-18 after a contraction associated with demonetisation in 2016-17. Table 1 shows when both short- and long-run liquidity are tight there is a growth in currency held by the public. The hypothesis follows that informal interest rates rise and more cash leaks into the informal sector, in such conditions. Therefore money supply is likely to affect output independently of formal sector interest rates. Second, since cash is a component of reserve money, the latter can be expected to have a greater effect compared to other types of money.

In the US and UK keeping overnight liquidity in the deficit mode is believed to help transmission. RBI's decision to follow this practice led to a switch to the liquidity adjustment facility (LAF) upper band in 2010. The same year rate of growth of currency held by the public increased sharply. In October 2013 in a bid to develop term money markets, short-term liquidity was tightened. Over 2014-16 currency growth rose sharply again (Table 1), reversing the negative trend of the previous three years. As leakages of cash increased, rate of growth of broad money (M3) also fell. The rate of growth of short and long-term liquidity was also sharply negative in these periods. As liquidity was tightened after the 2016 demonetisation to take out the excess liquidity associated with deposits flooding into banks, currency held by the public grew sharply again.

Table 1: Rates of Growth of Money Supply and Liquidity

	Currency with the Public	M0	M1	M3	Long-Term Liquidity	Short-Term Liquidity
2005-06	15.7	16.9	27.2	21.1	26.9	-485.8
2006-07	17.2	23.9	17.1	21.7	38.3	-6.5
2007-08	17.7	31.0	19.4	21.4	46.0	-37.0
2008-09	17.1	6.4	9.0	19.3	89.3	-127.0
2009-10	15.3	17.0	18.2	16.9	-91.4	-5113.6
2010-11	**18.8**	**19.1**	**10.0**	**16.1**	**251.1**	**-134.0**
2011-12	12.3	3.6	6.0	13.5	314.8	146.2
2012-13	11.5	6.2	9.2	13.6	-11.3	10.1
2013-14	9.2	14.4	8.5	13.4	-27.5	-45.7
2014-15	**11.3**	**11.3**	**11.3**	**10.9**	**14.4**	**-66.4**
2015-16	**15.2**	**13.1**	**13.5**	**10.1**	**10.5**	**-53.9**
2016-17	-20.9	-12.9	-3.4	7.3	-62.3	-685.0
2017-18	**39.2**	**27.3**	**22.1**	**9.5**	**157.7**	**-6.2**

Notes: Currency with the public is currency in circulation minus cash with banks. Reserve money (M0) is currency in circulation + other deposits with RBI+ bankers deposits with RBI. Narrow money (M1) is currency with the public + other deposits with RBI + demand deposits. Broad money (M3) is M1 plus time deposits. Short term liquidity is Net Injection (+)/Absorption (-) calculated as a difference between Repo (purchase), Reverse Repo (sale) for both Spot and Term in the LAF, as well as Marginal Standing Facility (MSF). Long Term Liquidity comprises: (i) Net Injection (+)/Absorption (-) from OMO (the difference between purchase and sale of government securities) (ii) from Foreign Currency Assets (increase injects liquidity and decrease absorbs liquidity. Data on Forex Assets proxies for RBI forex market intervention) (iii) from change in Bankers' Deposits with RBI (used as a proxy for liquidity injection or absorption from Cash Reserve Ratio (CRR) operations. There is liquidity injection when deposits in RBI decrease and vice versa) (iv) from deposits in Market Stabilisation Scheme (MSS) account (proxies for liquidity injection or absorption through MSS. An increase in deposits is taken as absorption and vice versa.)
Source: Calculated from Reserve Bank of India, Handbook of Statistics on Indian Economy and Weekly Statistical Statement.

It is often argued that monetary transmission does not work in an economy like India's with a large informal sector. But the correct combination of rate and quantity changes could be effective. It maybe that tight liquidity itself reduces transmission. First, it is difficult to compensate for large exogenous shocks, such as foreign outflows and changes in government spending, which lead to excessive tightening. Second, as liquidity available to the informal sector falls, informal sector rates of interest may rise. This may raise leakage of cash to the informal sector, and growth of currency held, reducing broad money growth and transmission to the formal sector.

It follows that even with correct identification money may be found to affect output and the impact of narrow and of broad money could differ. Monetary transmission would work better if liquidity and rates move in the same direction. Goyal and Agarwal (2017) find support for the latter. They examine the strength and efficacy of transmission from the Indian policy rate and liquidity provision to market rates, using event window regression analysis. The interest rate transmission channel is dominant, but the quantity channel has an indirect impact on the size of interest rate pass through. It increases the size of coefficients.

We first estimate a reduced form regression on the lines Meltzer (2001) and Nelson (2002) in section 3, finding a weak link from money growth to output. But a reduced form exploration of the effect of money on output and on inflation is problematic due to the identification issue. It is difficult to separate the change in money supply, independent of change in money demand. Therefore, we estimate a structural vector autoregression in section 4 which gives strong evidence of money affecting output. We estimate three models with three monetary aggregates, reserve money, narrow money and broad money.

Finally, to resolve identification issues, we take the model of Ireland (2004b) with money in utility where money is not separable from consumption. We augment it with a supply shock as supply shocks play an important role in emerging economies like India. We also allow for partial indexation in prices to get a New Keynesian Phillips Curve (NKPC) which is both backward and forward looking. Since for most of the period of analysis there was no inflation target in place, we augment the model with a time varying inflation target. Therefore, we estimate four models with three monetary aggregates, reserve money, narrow money and broad money. Our first model is Ireland (2004b), second model is Ireland (2004b) augmented with a time varying inflation target, third model is Ireland (2004b) augmented with a markup shock and fourth model is Ireland (2004b) augmented with both a markup and a time varying inflation target. Our estimation also allows us to explore the impact of a money supply shock on inflation and on output. Finally, our estimated results allow us to see whether money's role in the business cycle differs in advanced and in emerging economies.

We solve the model using Blanchard and Kahn (1980) and obtain state space representation. Thereafter, we estimate the model using Kalman filter based likelihood estimation in Matlab.The estimated parameters suggest that income elasticity of narrow money is more than two times the income elasticity of broad money in case of India. Interest semi elasticity of money demand is close to one. There is also evidence of high real interest rate responsiveness of output. After including relevant features of Indian economy, the real balance does affect output and inflation, even after correcting for money demand shocks. Evidence on the relationships between real money balance and other macroeconomic variables in India over the business cycle from cross-correlations, a simple aggregate demand regression and impulse responses from a multivariate structural vector autoregression to identify the impact of money supply shocks also support a role for money, and a differential impact of its components.

The rest of the paper is structured as follows: Section 2 gives brief overview of the data used. Section 3 gives evidence from a simple regression; Section 4 from structural vector autoregression; Section 5 discusses the model; while Section 6 gives and discusses estimated parameters obtained from the New Keynesian model and Section 7 concludes the paper. An appendix at the end gives graphs of data being used in the estimation and impulse responses. An online appendix gives the bootstrap distribution of parameters.

2 Data

The model is estimated using log of real gross domestic product[1,2], log of real money supply (narrow and broad money deflated using wholesale price index), consumer inflation and interest rate (15-91 days treasury bills rate) for 1996Q2 to 2016 Q3[3]. Real gross domestic product and money supply have trends reflecting secular growth during the period of analysis. One way to capture these trends in variables is to add a trend to the productivity variable z_t. The model then implies that all real variables grow at the same rate $z = g$. This is the idea of balanced growth generally used in estimating DSGE models. Data on output and money supply make this approach problematic as these variables grows at different rates. Therefore in the model each of these variables fluctuates around a constant mean as we use a stationary productivity shock. Therefore we de-trend the log of real gross domestic product and log of money supply with their respective linear trend before estimation. Real GDP, money supply and inflation are seasonally adjusted using X-13 ARIMA. Interest rate is not seasonally adjusted.

Table 2 gives the correlation among variables. Measures of money supply have strong correlation among themselves. Reserve money has very high and significant correlation with output while that with inflation is much lower. The correlation of broad money with inflation and output, however, is low and is not significant. That the correlation between private consumption and all measures of money supply are positive but not significant, suggests the major impact of money supply comes through production in the informal sector. There is a positive correlation between inflation and output.

[1] Ideally it should be in per capita terms, but since we could not find any source for quarterly data on working population we used real gross domestic product only.

[2] We have data from three base years (1999-00, 2004-05 and 2011-12). We use retropolation (Fuente, 2009) to create a uniform series. Suppose we have two series for a economic variable of interest. We calculate the log difference between the old and new series (when the new series starts and we have data for both series) and add this difference to old series to create a uniform series thus preserving the growth rate of the old series. The implicit assumption is that the "error" contained in the older series remains constant over time that is, that it already existed at time 0 and that its magnitude, measured in proportional terms, has not changed between 0 and the time new series starts.

[3] Garcia-Cicco et al (2009), criticise the use of short quarterly data particularly due to the inability to characterise non-stationary shocks using a short span of data. But we are limited by the availability of the quarterly data set.

Table 2: Correlation between Money, Output, Consumption and Inflation

	Reserve Money Money	Narrow Money Money	Broad Money Money	Output	Consumption	Inflation
Reserve Money	1					
Narrow Money	0.7487*	1				
Broad Money	0.6314*	0.7778*	1			
Output	0.7291*	0.2702*	0.1195	1		
Consumption	0.1170	0.1563	0.1216	0.0422	1	
Inflation	0.2584*	0.157	0.129	0.3186*	0.1229	1

Notes: All measures of money supply, output and consumption are in log and linearly de-trended. Inflation is Q-o-Q consumer price inflation. * represent significance at 5% level.

3 Evidence From A Simple Regression

Following Meltzer (2001) and Nelson (2002), we estimate empirical aggregate demand specifications in which a measure of de-trended real output, $DTGDP_t$, is a function of its own lags, a measure of the real interest rate, RR_t, and lags of RR_t, and lags of real money growth, MG_t. Real money has been obtained by deflating nominal money by wholesale price index. We de-trend output using a linear trend. We estimate the model using three measures of money stock: Reserve money (Model 1), narrow money (Model 2) and broad money (Model 3). The estimated model is:

$$DTGDP_t = \delta_0 + \sum_{i=1}^{4} \alpha_i DTGDP_{t-i} + \sum_{i=0}^{3} \beta_i RR_{t-1} + \sum_{i=1}^{4} \gamma_i MG_{t-1} + \epsilon_t$$

Where RR_t us calculated as

$$RR_t = \sum_{i=0}^{3} \left[\left(1 + \frac{i_t}{100}\right)^{0.25} - 1 \right]_{t-i} - \frac{P_t - P_{t-4}}{P_{t-4}}$$

Where i_t is 15-91 days treasury bills rate and P_t is consumer price index.

We estimate three models using quarterly data from 1996: Q2 to 2016: Q3. We do not use data beyond 2016: Q3 because in November 2016, government of India announced demonetisation of 500 and 1000 rupee notes. It was certainly an extraordinary period including which in our sample can bias our estimates. Gross domestic product at constant prices is the measure of real output. It was seasonally adjusted using X-13 ARIMA. Similarly, consumer price index and wholesale price index were seasonally adjusted. Table 3 gives the regression results. The coefficients have the expected signs: Positive for lag of output gap, negative for real interest rate and positive for the lag of money growth. We are interested in the estimated coefficients associated with money growth. Lag 1 of reserve money growth coefficient is significant at 5% significance level. From here one can infer the lag of reserve money significantly affects the output gap and therefore a contraction in reserve money is expected to lead to a contraction of output.

Narrow money and broad money coefficient did not turn out to be significant individually. Therefore we conducted a joint F test for sum of the coefficients, $\sum_{i=1}^{4} \gamma_i = 0$. The F statistics and related p value is given at the bottom of the table. Null of $\sum_{i=1}^{4} \gamma_i = 0$ is rejected at 5% significance level for reserve money and for narrow money it is rejected at 10% significance level. At 13% significance level one can reject the null of $\sum_{i=1}^{4} \gamma_i = 0$ even for broad money. Based on the above evidence we can conclude that money in general matters for aggregate output determination, especially reserve money. In terms of model fit also, the model with reserve money has highest R^2. This makes sense as the largest component of reserve money is cash in circulation and this should be an important determinant of aggregate consumption and output in an economy like India, which is largely cash based, and has a large informal sector.

Table 3: Regression Results with Linear Trend in Output

	M0	M1	M2
	$DTGDP$	$DTGDP$	$DTGDP$
$DTGDP_{t-1}$	0.895***	0.940***	0.951***
	(0)	(0)	(0)
$DTGDP_{t-2}$	0.0158	0.0188	0.0479
	(0.932)	(0.918)	(0.792)
$DTGDP_{t-3}$	0.0378	0.07	0.0425
	(0.836)	(0.698)	(0.814)
$DTGDP_{t-4}$	-0.032	-0.107	-0.146
	(0.799)	(0.38)	(0.213)
RR_t	-0.0988*	-0.0784	-0.0739
	(0.036)	(0.109)	(0.134)
RR_{t-1}	0.0585	0.0488	0.0725
	(0.395)	(0.498)	(0.314)
RR_{t-2}	-0.00318	0.000869	-0.044
	(0.964)	(0.991)	(0.566)
RR_{t-3}	-0.0444	-0.059	-0.0412
	(0.361)	(0.268)	(0.446)
MG_{t-1}	0.128*	0.0747	0.0156
	(0.014)	(0.104)	(0.778)
MG_{t-2}	0.0686	0.0382	0.0744
	(0.219)	(0.408)	(0.181)
MG_{t-3}	-0.0243	0.00359	0.0587
	(0.648)	(0.935)	(0.286)
MG_{t-4}	0.00837	0.0291	-0.00453
	(0.874)	(0.5)	(0.935)
Constant	0.726*	0.683*	0.920**
	(0.02)	(0.038)	(0.004)
F	109.3	99.4	99.12
R^2	0.955	0.951	0.95
Sum of Real Money Growth Coefficients	0.18067	0.14559	0.14417
F Test for Sum Zero	5.92	3.07	2.36
P Value	0.0179	0.0848	0.1293

p-values in parentheses * p<0.05 ** p<0.01 *** p<0.001

4 Evidence from SVAR

In addition, multivariate structural vector auto regressions were also estimated to identify the impact of shocks to different types of money. We used quarterly treasury bills rate, de-trended money, de-trended output and quarter on quarter inflation. The same data was used to estimate the New Keynesian model of the next section too. Three models were estimated using reserve, narrow and broad money. We choose one lag based on SBIC criteria. Other criterion also suggest one lag in most of the cases. Ordering of the variable was inflation, de-trended output, treasury bills rate and de-trended money. We use Cholesky decomposition for identification. Our identification assumes that inflation is an exogenous variable and money supply contemporaneously responds to all variables. This identification, which imposes the NKE interest rate rule, allows us to control for money supply response to money demand shocks. Figure 2 gives the impulse response from the structural vector autoregression model with reserve money. Impulse response from the structural vector autoregression of other two models are given in Appendix (figure 6 and figure 7).

Both reserve and narrow money supply shock significantly increase output, although in case of broad money the evidence is weak. All measures of money supply increase inflation in a significant way. Positive shock to reserve money significantly decreases interest rate. Impulse responses gives strong evidence of the role played by money in Indian business cycles[4].

Figure: 3 gives forecast error variance decomposition (FEVD) of output and inflation from the model with reserve money. Reserve money explains around 50% of FEVD of output over 40 periods. FEVD from other two models are given in Appendix (figure 8 and figure 9). As it's clear from these figures, reserve money explains highest amount of

[4]We estimate another SVAR mode for robustness. In that ordering of the variable was treasury bills rate, de-trended money, de-trended output and inflation. This identification assumes that interest rate is an exogenous variable and it affects only money supply contemporaneously. Output is affected by both interest rate and money supply contemporaneously and inflation is affected by all three of them contemporaneously. SVAR results are similar with this identification too. We don't report these results and are available on request

variation in output. Broad money explains least variation in output. Therefore, not only money is important but different type of money has different role in business cycle.

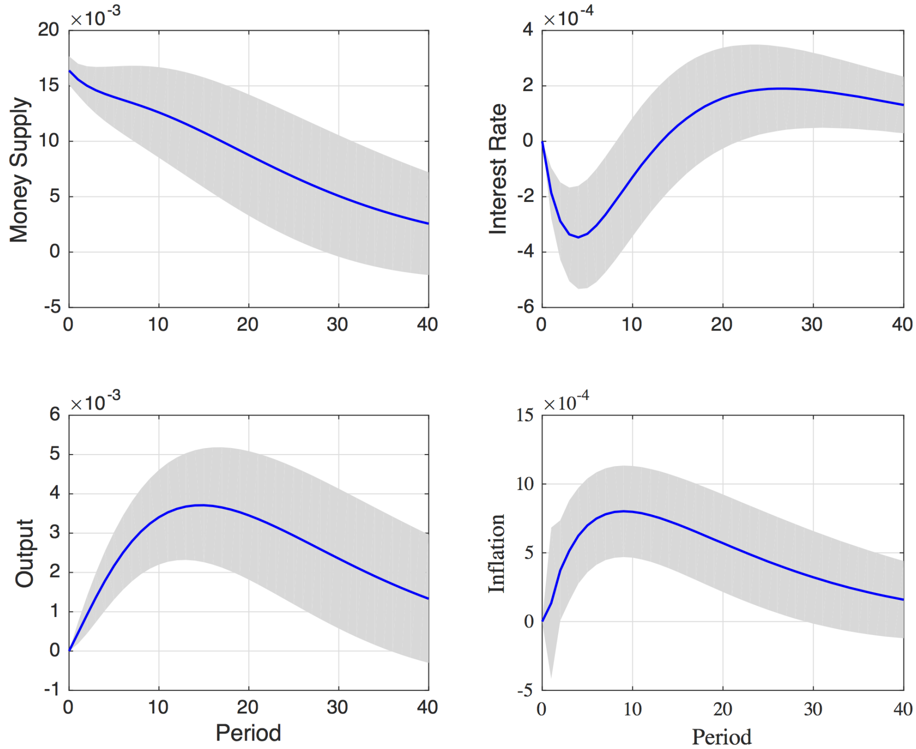

Figure 2: Impulse Response: One Standard Deviation Shock to Reserve Money

Notes: Shaded area gives 68 percent confidence band for responses.

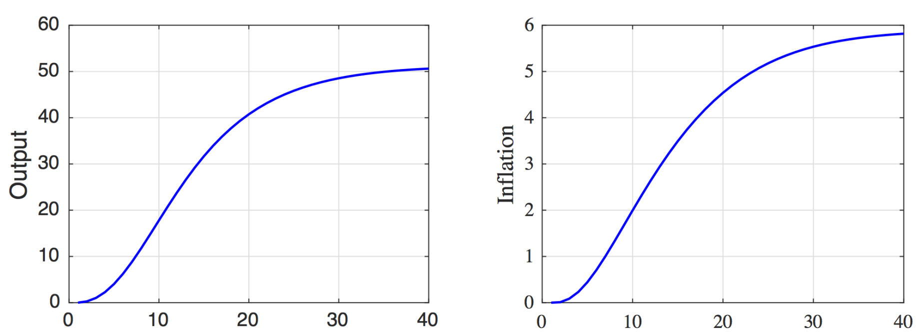

Figure 3: Forecast Error Variance Decomposition: Reserve Money

5 Model

In this section we build a money in utility model to identify and check for the impact of money on output separately from the interest rate. The model is based on Ireland (2004b, 2010). The economy consists of the following economic agents: a representative household, a representative finished goods producing firm, a continuum ($i \in [0,1]$) of intermediate goods producing firms and a central bank. Intermediate goods producing firms operate in a monopolistic output market and a competitive factor market– the labour market. The representative finished goods firm converts the goods obtained from the intermediate goods firms into final goods in a competitive market. This job can be delegated to the household which will do cost minimisation without changing the main dynamics of the model.

The representative household maximises discounted present value of life time utility and money in utility is introduced to explore the role played by money demand shocks in the business cycle. We choose partial indexation. Nominal goods prices set by intermediate goods producing firms ensures that the model's version of the NKPC is partially backward and partially forward looking. Goyal and Tripathi (2015) provide evidence on partially backward looking price setting in India. The central bank conducts monetary policy according to a modified Taylor (1993) rule for setting the nominal interest rate. Since for most of the period of analysis there was no official inflation target in India, we also allow for a time varying inflation target.

5.1 Household

The representative household enters period t holding M_{t-1} and B_{t-1} units of money and one-period bonds respectively. In addition to this endowment, the household receives a lump sum transfer T_t from the monetary authority at the end of the period. During period t the household supplies $L_t(i)$units of labour to each intermediate good producing firm indexed over $i \in [0,1]$ for a total of:

$$L_t = \int_0^1 L_t(i)di$$

The household gets paid at the nominal wage W_t. At the end of period t, the household receives nominal profits $D_t(i)$ from each intermediate goods-producing firm for a total of:

$$D_t = \int_0^1 D_t(i)di$$

The household carries the M_t amount of money and B_t amount of bonds to the next period. The budget constraint of the household for each period t is given by:

$$\frac{M_{t-1} + B_{t-1} + T_t + W_t L_t + D_t}{P_t} \geq C_t + \frac{B_t/r_t + M_t}{P_t}$$

In addition, we impose a no-Ponzi-game condition to prevent the household from excessive borrowing. Given these constraints, the household maximises the stream of their life time utility given by:

$$E_t \sum_{t=0}^{t=\infty} \beta^t a_t \left\{ u\left[C_t, (M_t/P_t)/e_t\right] - \eta L_t \right\}$$

Where $0 < \beta < 1$ is the discount factor. The utility function contains a preference shock a_t and money demand shock e_t which follow stationary autoregressive processes given respectively by:

$$log(a_t) = \rho_a log(a_{t-1}) + \epsilon_{a,t} \qquad 0 \leq \rho_a < 1 \qquad \epsilon_{a,t} \sim N(0, \sigma_a^2)$$

$$log(e_t) = (1 - \rho_e) log(e) + \rho_e log(e_{t-1}) + \epsilon_{\theta,t} \qquad 0 \leq \rho_e < 1 \qquad \epsilon_{e,t} \sim N(0, \sigma_\theta^2)$$

5.2 Final Good Producer

The final good is produced by a firm in a perfectly competitive market. It combines intermediate goods using a constant returns to scale technology given by:

$$Y_t \leq \left[\int_0^1 Y_t(i)^{(\theta_t-1)/\theta_t} di\right]^{\theta_t/(\theta_t-1)}$$

Where θ_t is the elasticity of substitution between intermediate goods $Y_t(i)$ with given price $P_t(i)$. In equilibrium, θ_t translates into a random shock to the intermediate goods-producing firms' desired markup of price over marginal cost and therefore acts like a cost-push shock in the New Keynesian traditions (Clarida, Gali, and Gertler, 1999). The final good producer firm's problem is to minimise its cost E (it can be also done using profit maximisation) by choosing $Y_t(i)$ for $t = 0, 1, 2, ...$ and $i \in [0, 1]$ subject to the constraint given by the technology above:

$$E = \int_0^1 P_t(i) Y_t(i) di$$

Solution of the above problem leads to the following demand conditions for intermediate goods by final goods producing firms for all i and t:

$$Y_t(i) = \left[\frac{P_t(i)}{P_t}\right]^{-\theta_t} Y_t$$

Where the zero profit competitive aggregate price P_t is given by:

$$P_t = \left[\int_0^1 P_t(i)^{1-\theta_t} di\right]^{1/(1-\theta_t)}$$

And θ_t follows a stationary autoregressive process as given by[5]:

$$log(\theta_t) = (1-\rho_\theta) log(\theta) + \rho_\theta log(\theta_{t-1}) + \epsilon_{\theta,t} \qquad 0 \leq \rho_\theta < 1 \qquad \epsilon_{\theta,t} \sim N(0, \sigma_\theta^2)$$

[5] In steady state θ and $log(\theta)$ are constant.

5.3 Intermediate Good Producers

Each intermediate good is produced by a monopolistically competitive firm according to a constant returns to scale technology by hiring $L_t(i)$ amount of labour from the representative household. The production technology is given by:

$$Y_t(i) \leq z_t L_t(i)$$

z_t is the technological progress with unit root and follows an random walk with drift:

$$log(z_t) = (1-\rho_z)log(z) + \rho_z log(z_{t-1}) + \epsilon_{z,t} \qquad 0 \leq \rho_z < 1 \qquad \epsilon_{z,t} \sim N(0, \sigma_z^2)$$

Although each firm i enjoys some market power on its own output, it is assumed to act as a price taker in the factor markets and gives competitive wage as explained above. Furthermore, the adjustment of its nominal price $P_t(i)$ is assumed to be costly, where the cost function is convex in the size of the price adjustment. Following Rotemberg (1982, 1987), these costs are defined as:

$$\frac{\varphi_p}{2}\left[\frac{P_t(i)}{\pi_{t-1}^{\alpha}\pi^{1-\alpha}P_{t-1}(i)} - 1\right]^2 Y_t$$

Where $\varphi_p > 0$ determines the size of the price adjustment cost and π represent the steady rate of inflation being targeted by the central bank with $0 \leq \alpha \leq 1$. Since Reserve Bank of India recently started targeting inflation, for most period of analysis there was no inflation target. Therefore we also allow inflation target to vary over time. In that case quadratic cost of adjustment is given by:

$$\frac{\varphi_p}{2}\left[\frac{P_t(i)}{\pi_{t-1}^{\alpha}(\pi_t^*)^{1-\alpha}P_{t-1}(i)} - 1\right]^2 Y_t$$

Where inflation target evolves as:

$$log\left(\pi_t^*\right) = \left(1-\rho_{\pi^*}\right) log\left(\pi^*\right) + \rho_{\pi^*} log\left(\pi_{t-1}^*\right) + \epsilon_{\pi^*,t}$$

Extent of backward and forward looking inflation depends upon α. When $\alpha = 0$, then price setting is purely-forward looking and for $\alpha = 1$ price setting is purely backward-looking. This specification leads to partial indexation for $0 < \alpha < 1$ implying that some prices are set in a backward looking manner. The firm maximises its present market value given by:

$$E \sum_{t=0}^{\infty} \beta^t \lambda_t \left[\frac{D_t(i)}{P_t} \right]$$

The market value of these firms are given by the present discounted value of utility that these firms can provide to the household through the distribution of dividend. λ_t represent the marginal utility of one unit of profit. Firm profit distributed as dividend to the household is given by:

$$\frac{D_t(i)}{P_t} = \frac{P_t(i)}{P_t} Y_t(i) - \frac{W_t L_t(i)}{P_t} - \frac{\varphi_p}{2} \left[\frac{P_t(i)}{\pi_{t-1}^{\alpha} \pi^{1-\alpha} P_{t-1}(i)} - 1 \right]^2 Y_t$$

Which in case of time varying inflation target becomes:

$$\frac{D_t(i)}{P_t} = \frac{P_t(i)}{P_t} Y_t(i) - \frac{W_t L_t(i)}{P_t} - \frac{\varphi_p}{2} \left[\frac{P_t(i)}{\pi_{t-1}^{\alpha} (\pi_t^*)^{1-\alpha} P_{t-1}(i)} - 1 \right]^2 Y_t$$

5.4 Monetary Authority

Monetary policy is represented by a generalised Taylor (1993) rule of the form:

$$\hat{r}_t = \rho_r \hat{r}_{t-1} + \rho_\pi \hat{\pi}_{t-1} + \rho_m \hat{u}_{t-1} + \rho_y \hat{Y}_{t-1} + \epsilon_{r,t}$$

Central bank responds to deviation of inflation (π_t), money growth rate and output gap (Y_t) from their respective steady state values. We also allow for interest rate smoothening by including a lagged interest rate.

In case of time varying inflation target the monetary policy rule becomes:

$$\hat{r}_t = \rho_r \hat{r}_{t-1} + \rho_\pi \hat{\pi}_{t-1} - \rho_{\pi^*} \hat{\pi}_{t-1}^* + \rho_m \hat{u}_{t-1} + \rho_y \hat{Y}_{t-1} + \epsilon_{r,t}$$

5.5 Log Linearised Model

The complete log linearised model is given below.

First order conditions are obtained and we look for the symmetric solution of the model in which all identical goods producers make identical decisions. The idea of symmetric solution implies that $P_t(i) = P_t, Y_t(i) = Y_t, L_t(i) = L_t, D_t(i) = D_t$ for $t = 0, 1, 2....$The market clearing conditions for bond market implies $B_{t-1} = B_t = 0$ and market clearing conditions for money market implies $M_t = M_{t-1} + T_t$ for all t. Define $\frac{P_t}{P_{t-1}} = \pi_t$. Lagrange multiplier for the household λ_t, L_t, $w_t = \frac{W_t}{P_g}$ and $d_t = \frac{D_t}{P_t}$ is eliminated from the system. Steady state of the model is obtained and remaining equations are log linearised around steady state.

$$\hat{a}_t = \rho_a \hat{a_{t-1}} + \epsilon_{a,t} \tag{E.1}$$

$$\hat{e}_t = \rho_e \hat{e_{t-1}} + \epsilon_{e,t} \tag{E.2}$$

$$\hat{z}_t = \rho_z \hat{z_{t-1}} + \epsilon_{z,t} \tag{E.3}$$

$$\hat{\Theta}_t = \rho_\Theta \hat{\Theta}_t + \epsilon_{\Theta,t} \tag{E.4}$$

Where $\hat{\Theta}_t = -\hat{\theta}_t / \varphi_p$

$$\hat{\pi}_t^* = \rho_{\pi^*} \hat{\pi}_{t-1}^* + \epsilon_{\pi^*,t} \tag{E.5}$$

$$\hat{Y}_t = E_t \hat{Y}_{t+1} - w_1 \left(\hat{r}_t - E_t \hat{\pi}_{t+1} \right) + w_2 (\hat{m}_t - E_t \hat{m}_{t+1}) + w_1 (1 - \rho_a) \hat{a}_t - w_2 (1 - \rho_e) \hat{e}_t \tag{E.6}$$

Where:

$$w_1 = -\frac{u_1 \left(Y, m/e \right)}{u_{11} \left(Y, m/e \right) Y}$$

$$w_2 = -\frac{u_{12}(Y, m/e)\frac{m}{e}}{u_{11}(Y, m/e)\,Y}$$

$$\hat{m}_t = \gamma_1 \hat{Y}_t - \gamma_2 \hat{r}_t + \gamma_3 \hat{e}_t \quad \text{(E.7)}$$

Where:

$$\gamma_2 = \left(\frac{r}{r-1}\right) \frac{u_2(Y, m/e)}{\frac{m}{e}\left((r-1)u_{12}(Y, m/e)\, e - r u_{22}(Y, m/e)\right)}$$

$$\gamma_1 = \left(\frac{r-1}{w_1} + \frac{w_2 Y r}{w_1 m}\right) \times \gamma_2$$

$$\gamma_3 = 1 - (r-1)\gamma_2$$

Without partial indexation, supply shock and with constant inflation target;

$$\hat{\pi}_t = \beta E_t \hat{\pi}_{t+1} + \Psi \left[\frac{1}{w_1}\hat{Y}_t - \frac{w_2}{w_1}\hat{m}_t + \frac{w_2}{w_1}\hat{e}_t - \hat{Z}_t\right] \quad \text{(E.8)}$$

Without partial indexation, supply shock and with time varying inflation target;

$$\hat{\pi}_t = \beta E_t \hat{\pi}_{t+1} + (\beta\rho_{\pi^*} - 1)\hat{\pi}^*_t + \Psi \left[\frac{1}{w_1}\hat{Y}_t - \frac{w_2}{w_1}\hat{m}_t + \frac{w_2}{w_1}\hat{e}_t - \hat{Z}_t\right] \quad \text{(E.8')}$$

With partial indexation, supply shock and with constant inflation target:

$$(1+\beta\alpha)\,\hat{\pi}_t = \alpha\hat{\pi}_{t-1} + \beta E_t \hat{\pi}_{t+1} + \Psi \left[\frac{1}{w_1}\hat{Y}_t - \frac{w_2}{w_1}\hat{m}_t + \frac{w_2}{w_1}\hat{e}_t - \hat{Z}_t\right] + \hat{\Theta}_t \quad \text{(E.8'')}$$

With Partial Indexation supply shock and time varying inflation target:

$$(1+\beta\alpha)\,\hat{\pi}_t = \alpha\hat{\pi}_{t-1} + \beta E_t \hat{\pi}_{t+1} + (\beta\rho_{\pi^*} - 1)\hat{\pi}^*_t + \Psi \left[\frac{1}{w_1}\hat{Y}_t - \frac{w_2}{w_1}\hat{m}_t + \frac{w_2}{w_1}\hat{e}_t - \hat{Z}_t\right] + \hat{\Theta}_t \quad \text{(E.8''')}$$

$$\hat{m}_{t-1} + \hat{\mu}_t = \hat{\pi}_t + \hat{m}_t \tag{E.9}$$

Where:

$$u_t = \frac{M_t}{M_{t-1}}$$

Monetary policy rule can be linearised as:

$$\hat{r}_t = \rho_r \hat{r}_{t-1} + \rho_\pi \hat{\pi}_{t-1} + \rho_m \hat{u}_{t-1} + \rho_y \hat{Y}_{t-1} + \epsilon_{r,t} \tag{E.10}$$

In case of time varying inflation target:

$$\hat{r}_t = \rho_r \hat{r}_{t-1} + \rho_\pi \hat{\pi}_{t-1} - \rho_{\pi^*} \hat{\pi}^*_{t-1} + \rho_m \hat{u}_{t-1} + \rho_y \hat{Y}_{t-1} + \epsilon_{r,t}$$

E.1 to E.10 give the log linearised version of the model. E.6 is the IS equation, E.7 is money demand and E.8 is the NKPC. It can be seen that money enters both in the IS and in the NKPC. Equations E.6 and E.7 also show that wherever the real balances variable $\hat{m}_t$ appears in the IS and Phillips curve relationships, it is followed immediately by the money demand disturbance, $\hat{e}_t$. Thus, according to the model, an empirical measure of real balances must be adjusted for shifts in money demand to obtain an unbiased estimate of the key parameter, w_2. This shift adjustment becomes particularly important under a monetary rule, in which the monetary authority accommodates shocks to money demand with offsetting movements in the money supply (Ireland 2004b).

The benchmark model is estimated without supply shock and without partial indexation in prices using E.1, E.2, E.3, E.6, E.7, E.8, E.9 and E.10 and is same as Ireland (2004b). We estimate three variants of the benchmark model, with reserve, narrow money and broad money. We add time varying inflation target and that is our model 2 and is estimated using E.1, E.2, E.3, E.5, E.6, E.7, E.8', E.9 and E.10'. In the next stage we allow the partial indexation in price and add a supply shock to our benchmark model and is estimated using E.1, E.2, E.3, E.4, E.6, E.7, E.8", E.9 and E.10. Finally we add partial indexation, supply shock and time varying inflation target (model 4) and is estimated using E.1, E.2, E.3, E.4, E.5, E.6, E.7, E.8''', E.9 and E.10'.

The log linearised version of the model is solved using the method of Blanchard and Kahn (1980) and a state space representation is obtained by matching it to data. State space representation is used to write likelihood using Kalman filter and the likelihood is maximised to obtain parameter estimates.

6 Results, Analysis and Model Validation

6.1 Estimated Parameters

The benchmark model is estimated without supply shock and without partial indexation in prices and is same as Ireland (2004b). So in the benchmark model $\theta_t = \theta$ and $\alpha = 0$. We estimate three variants of benchmark model, with reserve, narrow and broad money. Figure 4 and Figure 5 in Appendix A.1 show data used in the estimation. The benchmark model has 22 parameters: $w_1, w_2, \gamma_1, \gamma_2, \gamma_3, \beta, \Psi, \rho_r, \rho_y, \rho_\pi, \rho_m, log(Y)$, $log(m), log(\pi), log(r), \rho_a, \rho_e, \rho_z, \sigma_a, \sigma_e, \sigma_z, \sigma_r$. w_1 is the real interest rate responsiveness of IS curve. w_2 is the coefficient we are interested in. Non zero value of this implies that money affects output and inflation. γ_1 is output elasticity of money demand and γ_2 is interest semi elasticity of money demand. $\rho_r, \rho_y, \rho_\pi, \rho_m$ are coefficients associated with lagged interest rate, lagged output, lagged inflation and lagged money growth rate. ρ_a, ρ_e, ρ_z are the AR(1) coefficient of three exogenous shock process as given above. $\sigma_a, \sigma_e, \sigma_z, \sigma_r$ are variances of the shock processes.

Out of these parameters β,γ_1 and γ_3 are not independent parameters. β in the steady state is equal to $\frac{\pi}{r}$ and we substitute β with this. Similarly γ_1 and γ_3 can be calculated using other estimated parameters. We are left with 19 parameters. We fix Ψ as 0.10 as explained in Ireland (2004). This is similar to fixing the Calvo parameter so that each individual good's price remains fixed, on average, for 3.7 quarters, that is, for a bit less than one year. Goyal and Tripathi (2015) also provide evidence that an average Indian firm changes prices about once in a year. Therefore we are left with 18 parameters, which we try to estimate.

The estimated parameters $log(Y), log(m), log(\pi), log(r)$ are basically equivalent to means in the data and thus allow us to see the fit of the model to the data. Attempts to the estimate $log(Y), log(m), log(\pi), log(r)$ gave unreasonably high value of $log(\pi), log(r)$ and even the bootstrap standard error was very high, implying that these two parameters are not being estimated with precision. Therefore all these four parameters have been assigned values to match data. This left us with 14 parameters whose estimates and standard errors are given below in Table 4. They are obtained from the three models using 500 bootstrap replications. Figure 1, Figure 2 and Figure 3 in the online appendix give the distribution of parameters of benchmark models obtained from bootstrap simulations.

Now we extend the bench mark model with time varying inflation target. This adds two new parameters σ_{π^*} and ρ_{π^*}. Results from the extended model are given in Table 5 and Figure 4, Figure 5 and Figure 6 in the online appendix give the distribution of parameters of benchmark models obtained from bootstrap simulations.

We also augment the benchmark model with partial indexation (α) in price and a supply shock by making θ time varying. This adds three new parameters $\sigma_\Theta, \rho_\Theta$ and α. ρ_Θ is AR(1) coefficient of the markup shock process and σ_Θ is the variance of the same. Results from the extended model are given in Table 6 and Figure 7. Figure 8 and Figure 9 of the online appendix give the distribution of parameters obtained from bootstrap simulations.

Finally, we estimate a model with partially backward looking inflation, supply shock and time varying inflation target. This adds five parameters σ_{π^*} ρ_{π^*} $\sigma_\Theta, \rho_\Theta$ and α to the benchmark model. Results of the same is given in Table 7 and Figure 10, Figure 11 and Figure 12 of the online appendix give the distribution of parameters obtained from bootstrap simulations.

6.2 Analysis of Estimated Parameters

In terms of likelihood models with time varying inflation target gives higher likelihood. Our extended model with partial indexation, supply shock and time varying inflation target gives highest likelihood, implying that these features are important for having a better match with the data as argued. Interest rate setting is quite persistent and the coefficient of lagged interest rate varies from 0.71 to 0.95. As pointed out by Woodford (2003b), interest rate smoothing implies a past-dependent monetary policy. If agents know that central bank policy has interest rate persistence, then one move by the central bank will lead to the expectation of several such future moves and thus private agents will accordingly adjust their inflation expectation. This mechanism strengthens the demand channel.

All the exogenous shock process are highly persistent. There is evidence that the interest rate responds to inflation whereas in the benchmark model there is weak evidence of interest rate responding to output gap. There is also significant evidence that income elasticity of narrow money is more than two times the income elasticity of broad money in case of models with time varying inflation target and these model outperform other models in terms of likelihood.

Table 4: Estimated Coefficients of Benchmark Model

Model⟶	Reserve Money (M0)		Narrow Money (M1)		Broad Money (M3)	
Parameters	Values	Std. Error	Values	Std. Error	Values	Std. Error
β	0.9987	0.0000	0.9987	0.0000	0.9987	0.0000
w_1	0.4794	0.1499	0.4761	0.1987	0.4709	0.0880
w_2	0.0404	0.1523	0.0658	0.2359	0.0843	0.1374
γ_1	0.3683	0.5519	0.4703	0.4790	0.2253	0.0705
γ_2	0.9900	0.2149	0.9981	0.3002	0.9999	0.1537
γ_3	0.9821	0.0039	0.9819	0.0054	0.9819	0.0028
ρ_r	0.7096	0.0436	0.7102	0.0447	0.7164	0.0401
ρ_y	0.0045	0.0169	0.0035	0.0169	0.0034	0.0168
ρ_π	0.2639	0.0276	0.2559	0.0250	0.2835	0.0246
ρ_m	0.0266	0.0110	0.0341	0.0100	0.0004	0.0149
ρ_a	0.9855	0.0375	0.9855	0.0382	0.9855	0.0351
ρ_e	0.9845	0.0336	0.9845	0.0367	0.9846	0.0338
ρ_z	0.9798	0.0310	0.9798	0.0294	0.9798	0.0231
σ_a	0.0222	0.0061	0.0255	0.0071	0.0272	0.0059
σ_e	0.0196	0.0018	0.0263	0.0019	0.0163	0.0012
σ_z	0.0408	0.0057	0.0413	0.0051	0.0380	0.0053
σ_r	0.0048	0.0005	0.0045	0.0004	0.0064	0.0005
LL	-999.286		-987.264		-1006.54	

Notes: ρ_r, ρ_y, ρ_π and ρ_m are weights of lagged interest rate, output gap, inflation and money growth respectively in the Taylor rule. ρ_a, ρ_e and ρ_z are persistence of preference, money demand and technology shock respectively. σ_a, σ_e, σ_z and σ_r are standard deviation of preference, money demand, technology and interest rate shocks respectively. w_1 is real interest rate responsiveness of IS curve, w_2 determines effect of money on output and inflation, γ_1 is output elasticity of money demand and γ_2 is interest semi elasticity of money demand. LL gives the log likelihood of the model.

Table 5: Parameters With Time Varying Inflation Target

Model$\longrightarrow$	Reserve Money (M0)		Narrow Money (M1)		Broad Money (M3)	
Parameters	Values	Std. Error	Values	Std. Error	Values	Std. Error
β	0.9987	0.0000	0.9987	0.0000	0.9987	0.0000
w_1	0.3334	0.0437	0.3797	0.0142	0.3448	0.0032
w_2	0.0759	0.0380	0.0324	0.0162	0.0323	0.0041
γ_1	0.9369	0.1631	0.3144	0.0543	0.1502	0.0044
γ_2	0.9785	0.0567	0.9962	0.0181	0.9986	0.0018
γ_3	0.9823	0.0010	0.9819	0.0003	0.9819	0.0000
ρ_r	0.8686	0.0308	0.8323	0.0152	0.8446	0.0026
ρ_y	0.0023	0.0201	0.0028	0.0122	0.0021	0.0036
ρ_π	0.0929	0.0412	0.1583	0.0290	0.1113	0.0031
ρ_m	0.0386	0.0172	0.0094	0.0105	0.0441	0.0029
ρ_a	0.9846	0.0130	0.9846	0.0082	0.9846	0.0010
ρ_e	0.9843	0.0109	0.9844	0.0083	0.9844	0.0012
ρ_z	0.9786	0.0291	0.9789	0.0251	0.9788	0.0013
σ_a	0.0329	0.0113	0.0179	0.0074	0.0307	0.0024
σ_e	0.0184	0.0001	0.0193	0.0001	0.0149	0.0000
σ_z	0.0500	0.0292	0.0419	0.0206	0.0486	0.0062
σ_r	0.0030	0.0006	0.0035	0.0002	0.0032	0.0002
σ_{π^*}	0.0003	0.0273	0.0005	0.0228	0.0004	0.0037
ρ_{π^*}	0.9842	0.0177	0.9843	0.0005	0.9843	0.0001
LL	-1027.2		-1014.56		-1039.6	

Notes: ρ_{π^*} and σ_{π^*} represents persistence and variance of inflation target process respectively. Rest is as in Table 3. LL gives the log likelihood of the model.

Table 6: Parameters With Supply Shock and Partial Price Indexation

Model⟶	Reserve Money (M0)		Narrow Money (M1)		Broad Money (M3)	
Parameters	Values	Std. Error	Values	Std. Error	Values	Std. Error
β	0.9987	0.0000	0.9987	0.0000	0.9987	0.0000
w_1	0.4670	0.1771	0.4651	0.1405	0.4595	0.1217
w_2	0.0319	0.2112	0.0550	0.2131	0.0716	0.2744
γ_1	0.3065	0.5248	0.4093	0.2906	0.2023	0.0727
γ_2	0.9894	0.2668	0.9986	0.2434	1.0008	0.2336
γ_3	0.9821	0.0048	0.9819	0.0044	0.9819	0.0042
ρ_r	0.7315	0.0429	0.7316	0.0373	0.7279	0.0424
ρ_y	0.0035	0.0129	0.0029	0.0110	0.0031	0.0132
ρ_π	0.2498	0.0158	0.2402	0.0134	0.2331	0.0170
ρ_m	0.0188	0.0153	0.0284	0.0119	0.0392	0.0149
ρ_a	0.9854	0.0541	0.9854	0.0355	0.9854	0.0481
ρ_e	0.9845	0.0381	0.9845	0.0303	0.9845	0.0416
ρ_z	0.9800	0.0795	0.9800	0.0500	0.9800	0.0772
σ_a	0.0264	0.0110	0.0280	0.0517	0.0259	0.0106
σ_e	0.0192	0.0023	0.0229	0.0023	0.0149	0.0017
σ_z	0.0162	0.0128	0.0168	0.0116	0.0185	0.0141
σ_r	0.0058	0.0005	0.0046	0.0005	0.0046	0.0005
σ_Θ	0.0036	0.0010	0.0052	0.0013	0.0043	0.0010
ρ_Θ	0.9857	0.0051	0.9857	0.0042	0.9857	0.0059
α	0.0700	0.1079	0.1447	0.1450	0.0310	0.1015
LL	-994.468		-986.869		-1015.45	

Notes: ρ_r, ρ_y, ρ_π and ρ_m are weights of lagged interest rate, output gap, inflation and money growth respectively in the Taylor rule. ρ_a, ρ_e, ρ_Θ and ρ_z are persistence of preference, money demand, markup shock and technology respectively. σ_a, σ_e, σ_z, σ_Θ and σ_r are standard deviation of preference, money demand, technology, markup and interest rate shocks respectively. w_1 is real interest rate responsiveness of IS curve, w_2 determines effect of money on output and inflation, γ_1 is output elasticity of money demand and γ_2 is interest semi elasticity of money demand. α is extent of backward looking inflation. LL gives the log likelihood of the model.

Table 7: Parameters With Supply Shock and Partial Price Indexation and Time Varying Inflation

Model⟶	Reserve Money (M0)		Narrow Money (M1)		Broad Money (M3)	
Parameters	Values	Std. Error	Values	Std. Error	Values	Std. Error
β	0.9987	0.0000	0.9987	0.0000	0.9987	0.0000
w_1	0.3374	0.0107	0.0748	0.0257	0.3375	0.0303
w_2	0.0319	0.0085	0.0034	0.0077	0.0282	0.0141
γ_1	0.4208	0.0853	0.3886	0.0752	0.1408	0.0228
γ_2	0.9815	0.0165	1.0135	0.0202	0.9986	0.0120
γ_3	0.9822	0.0003	0.9816	0.0004	0.9819	0.0002
ρ_r	0.8684	0.0127	0.9487	0.0179	0.8673	0.0593
ρ_y	0.0143	0.0057	0.0000	0.0086	0.0095	0.0221
ρ_π	0.1036	0.0043	0.0499	0.0200	0.0768	0.0271
ρ_m	0.0284	0.0064	0.0362	0.0137	0.0561	0.0297
ρ_a	0.9847	0.0011	0.9834	0.0018	0.9847	0.0013
ρ_e	0.9843	0.0024	0.9839	0.0016	0.9844	0.0011
ρ_z	0.9796	0.0010	0.9803	0.0019	0.9796	0.0017
σ_a	0.0286	0.0067	0.2091	0.0060	0.0359	0.0104
σ_e	0.0179	0.0000	0.0195	0.0001	0.0151	0.0001
σ_z	0.0001	0.0083	0.1074	0.0090	0.0028	0.0141
σ_r	0.0031	0.0001	0.0027	0.0012	0.0031	0.0016
σ_Θ	0.0065	0.0009	0.0010	0.0034	0.0063	0.0068
ρ_Θ	0.8823	0.0090	0.8292	0.0083	0.8807	0.0137
α	0.0000	0.0838	0.0001	0.0544	0.0006	0.1034
ρ_{π^*}	0.9840	0.0007	0.9838	0.0014	0.9840	0.0012
σ_{π^*}	0.0006	0.0060	0.0000	0.0242	0.0004	0.0430
LL	-1032.38		-1041.81		-1043.34	

Notes: ρ_r, ρ_y, ρ_π and ρ_m are weights of lagged interest rate, output gap, inflation and money growth respectively in the Taylor rule. ρ_a, ρ_e, ρ_Θ and ρ_z are persistence of preference, money demand, markup shock and technology respectively. σ_a, σ_e, σ_z, σ_Θ and σ_r are standard deviation of preference, money demand, technology, markup and interest rate shocks respectively. ρ_{π^*} and σ_{π^*} represents persistence and variance of inflation target process respectively. w_1 is real interest rate responsiveness of IS curve, w_2 determines effect of money on output and inflation, γ_1 is output elasticity of money demand and γ_2 is interest semi elasticity of money demand. α is extent of backward looking inflation. LL gives the log likelihood of the model.

The income elasticity of narrow money always exceeds that of broad money. Since narrow money includes demand deposits which are used by firms while broad money adds time deposits the difference in interest elasticity of money demand between narrow and broad money, points to the dependence of firm on the banking system in India. While informal firms need more cash (explaining the large impact of reserve money) other firms are dependent on banks. This can explain the large impact of money supply on output. Brahmananda (2002) argues that in theory it is narrow money that affects nominal national income, with real income being given by real factors. He further argues that it is narrow money that tracks prices and output whereas broad money is better suited for tracking financial assets. Interest semi elasticity of money demand is close to one.

We also find a high value of w_1 and this suggest high real interest rate responsiveness of IS curve. There is evidence of strong aggregate demand channel. Ireland (2001) finds value of $w_1 = 0.2554$ for United States which is less than what we have in case of India. This suggest strong interest rate transmission in Indian economy. Past estimations of the IS curve for India also find a low value. But this may be due to omitted variable bias. Goyal and Arora (2016) get a higher interest elasticity in an IS estimation that has the interest gap rather than the rate as an explanatory variable. Here we add money stock to the estimation. A high interest elasticity is consistent with an informal sector where cash itself has a major role. In a large economy of more than one billion people in transition a large modern sector co-exists with an informal sector.

Inflation target is very persistent and the variance of the inflation target process is not significant. The coefficient of interest w_2 lies between 0.0034 and 0.0843. It is not statistically significant in case of benchmark model and model with only partial indexation and supply shock. But once we include time varying inflation target (Table 5 and 7) w_2 becomes significant and its value lies between 0.0034 and 0.0759. Models with time varying inflation target have higher likelihood and our extended model has highest likelihood and it gives significant w_2. This implies that even after correcting for money demand shock, money plays a significant role in the determination of output and inflation.

7 Conclusion

The estimated parameters suggest that income elasticity of narrow money is more than two times of income elasticity of broad money in case of India. Interest semi elasticity of money demand is close to one. There is also evidence of high real interest rate responsiveness of output. Results obtained in this paper is useful for future work in India as they suggest that after including relevant features of Indian economy, real balances do affect output and inflation, even after correcting for money demand. Estimate obtained from regression and impulse responses obtained from structural vector autoregression substantiate the evidence obtained from a New Keynesian model. Policy makers need to pay attention to money supply, different types of money and liquidity, as well as interest rates.

Apart from the EM features introduced the estimation of the IS curve with Indian data itself captures the existence of the informal sector. Goyal (2011) introduces an informal sector in an open economy DSGE model and shows formally that the structure of aggregate demand and supply curve is the same for an emerging market with an informal sector and an advanced economy. Only the coefficients are different. And these can be estimated from the data.

Future work can further explore these micro-foundations. It can also examine how shocks to different types of money supply affect the economy, and their impact on welfare.

Ireland (2004b) and Andres et al. (2006) report that for United States and Eurozone real balance do not affect output and inflation, after correcting for money demand. Therefore we conclude that money has a different role in the business cycle in India (emerging economy) in contrast to advanced economies like Eurozone and United States. The results discover a basic asymmetry.

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Appendix

A Graphs

A.1 Data used in estimation

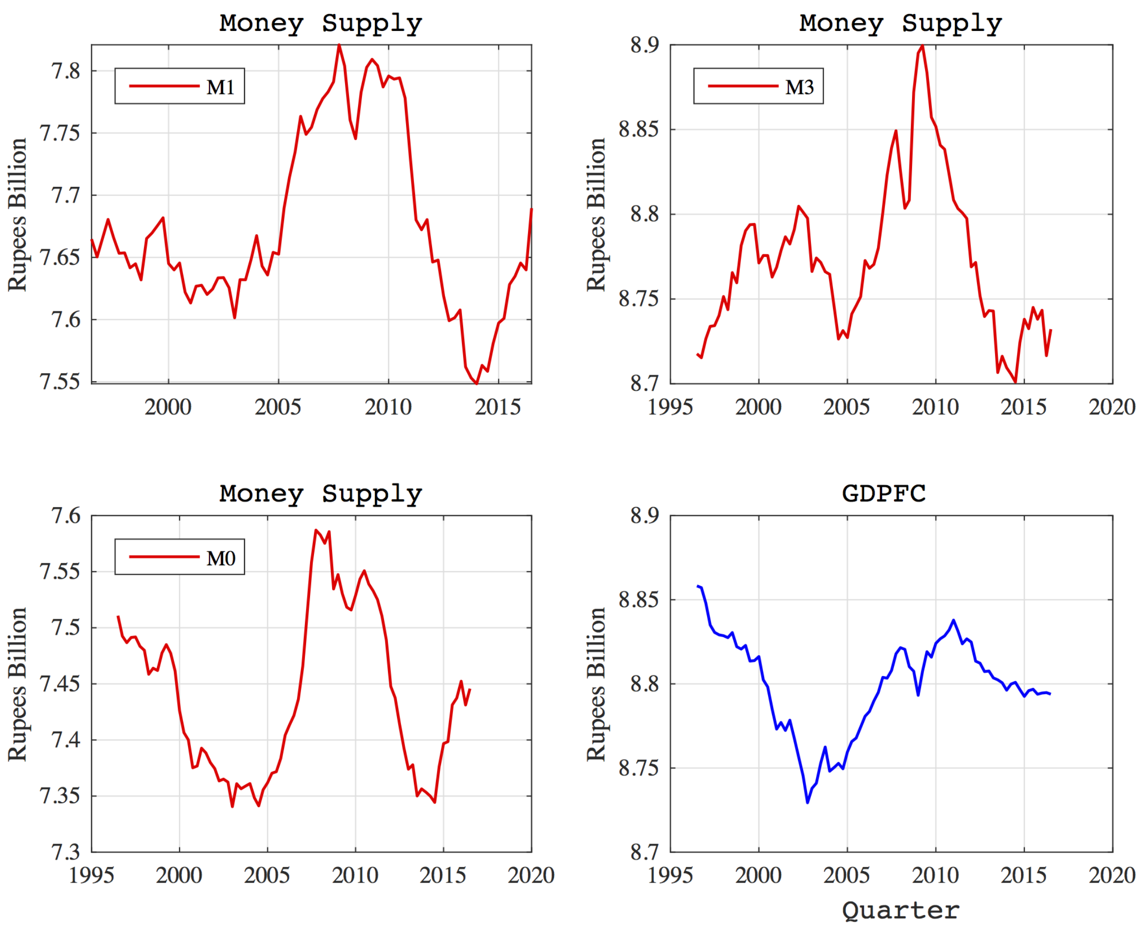

Figure 4: Data used in Estimation

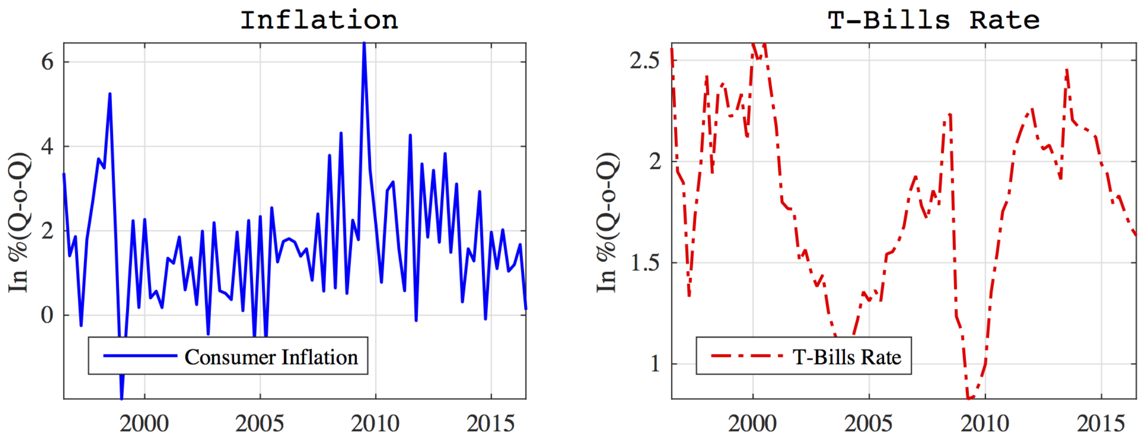

Figure 5: Data used in Estimation

A.2 Impulse Responses

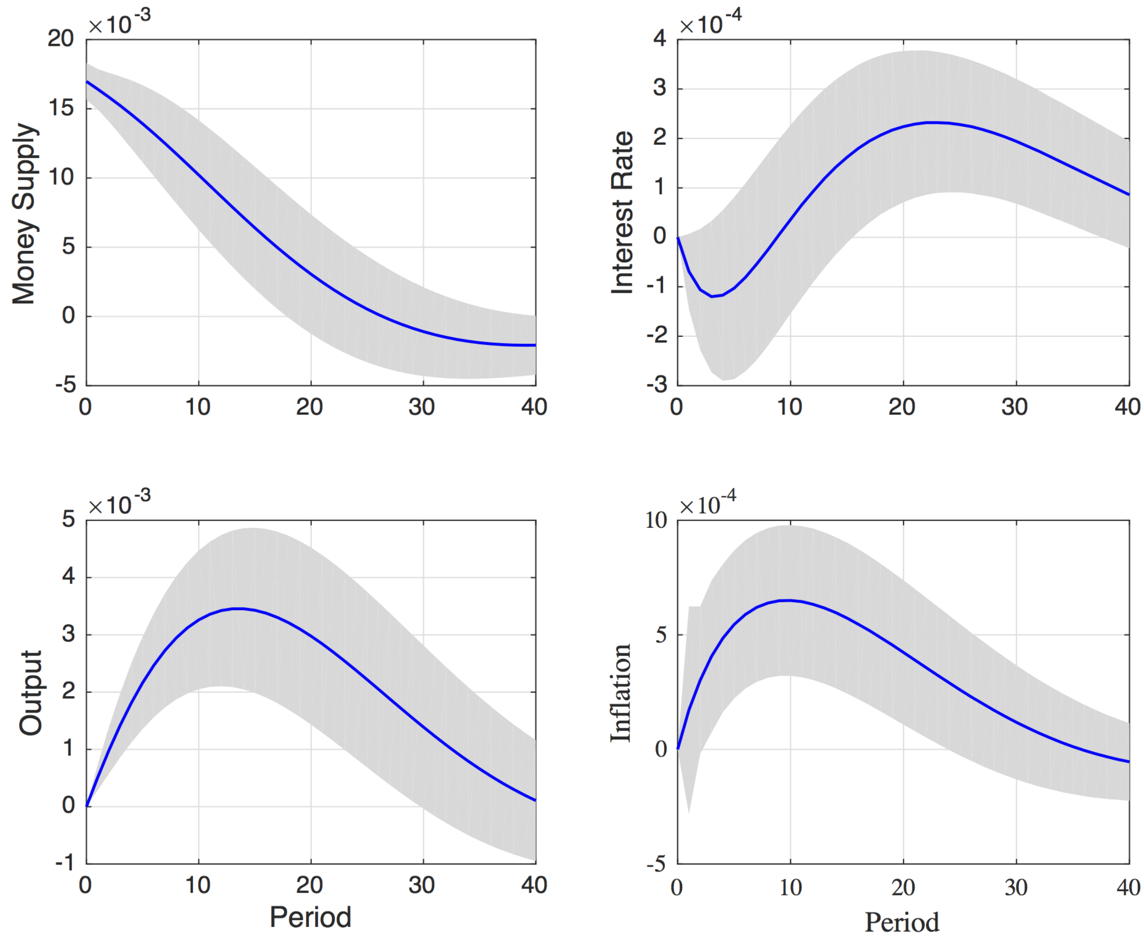

Figure 6: Impulse Response: One Standard Deviation Shock to Narrow Money

Notes: Shaded area gives 68 percent confidence band for responses..

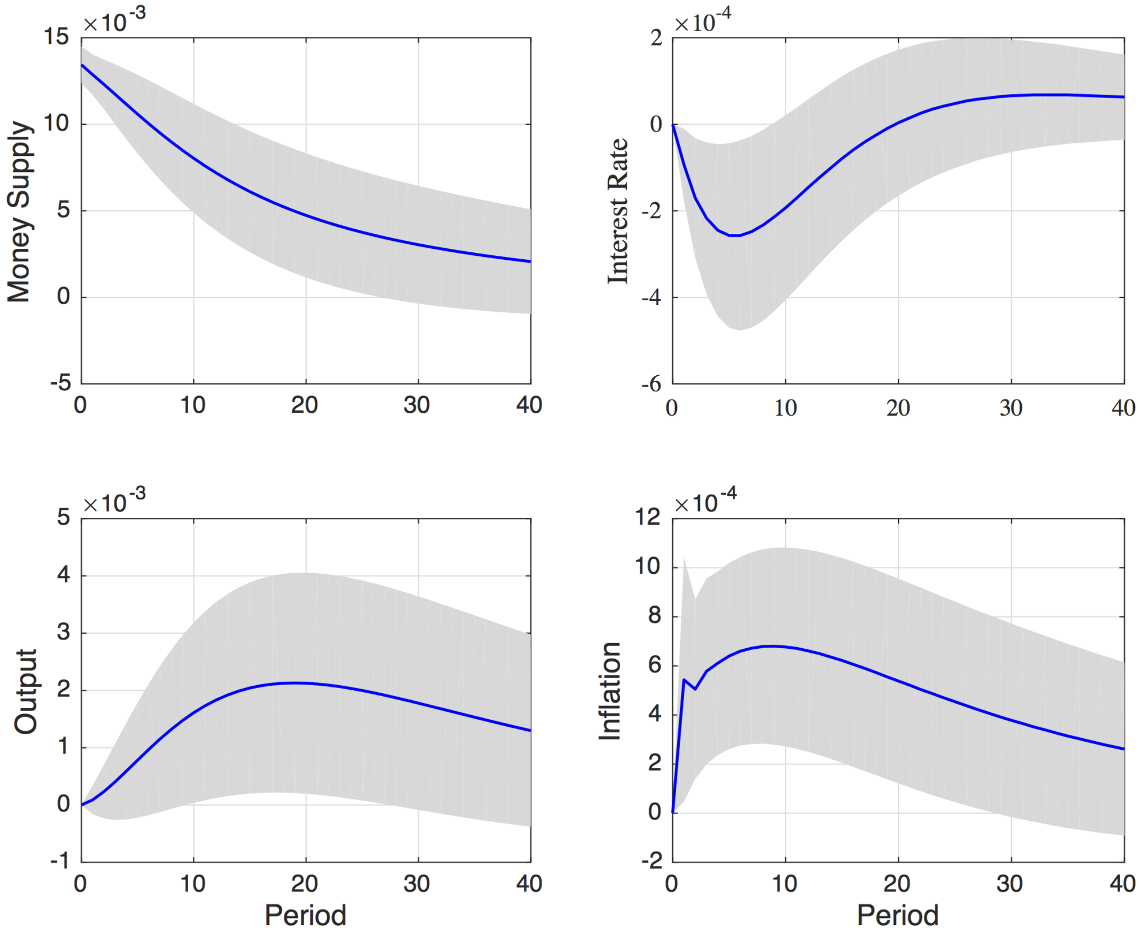

Figure 7: Impulse Response: One Standard Deviation Shock to Broad Money

Notes: Shaded area gives 68 percent confidence band for responses..

A.3 Forecast Error Variance Decomposition

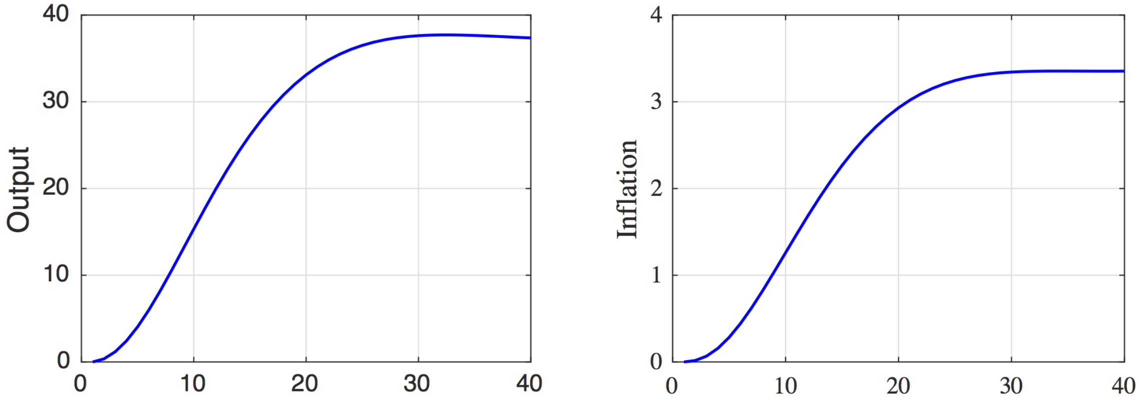

Figure 8: Forecast Error Variance Decomposition: Narrow Money

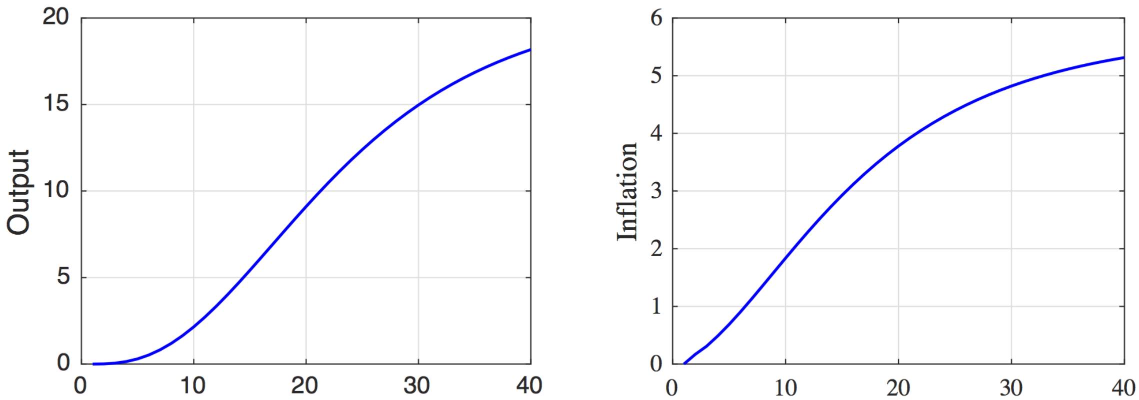

Figure 9: Forecast Error Variance Decomposition: Broad Money