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Has Money Lost Its Relevance? Resolving the Exchange Rate Disconnect Puzzle

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Abstract

The objective of this study is to identify the monetary policy shock causing exchange rate fluctuations in the economies of India, Poland and the UK. For this purpose, an open-economy structural vector auto-regression model is used, resorting to data covering the period 2000-2015. The model used in the paper is appropriate for the small, open economies being analyzed here as it facilitates estimation of theoretically correct and significant responses in terms of the price, output, and exchange rate to monetary policy tightening. The importance of monetary policy shock is established by examining the variance decomposition of forecast error, impulse response function, and out-of-sample forecast. The model also allows for the precise measurement of money through the adoption of a new monetary measure, namely, aggregation–theoretic Divisia monetary aggregate. The empirical results lead to three critical findings. Firstly, it is imperative to consider the estimated responses of output, prices, money and exchange rate to monetary policy shocks in models using monetary aggregates. Secondly, the incorporation of Divisia money in monetary policy helps in explaining fluctuations in the exchange rate. Thirdly, the inclusion of Divisia money also promotes better out-of-sample forecasting of the exchange rate.

Keywords: Monetary policy, Monetary aggregates, Divisia, Structural VAR, Exchange rate overshooting, Liquidity puzzle, Price puzzle, Exchange rate disconnect puzzle, Forward discount bias puzzle

JEL classification: C32, E41, E51, E52, F31, F41, F47

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1. Introduction

Many central banks actively resorted to an unconventional monetary policy, to deal with the impact of the recession of 2007–09. However, the adoption of this new policy has raised several questions: Do traditional structural vector autoregression (VAR) models aid in correctly appraising the level of liquidity in the small, open economies? How successful are open-economy VAR models in reflecting the new policy stance of monetary authority? Can these models successfully explain fluctuations in the exchange rate? The extant empirical literature on monetary policy models does not provide lucid answers to these questions, and instead perpetrates ambiguity on a number of key concepts in this area, including the exchange rate puzzle,[1] delayed overshooting, and the exchange rate disconnect puzzle,[2] among other things.

The traditional VAR models of open economies focus on the theoretical set-ups of a New Keynesian small open economy. These models are characterized by inflation, level of economic activity, short-term domestic rates of interest (which capture monetary policy), real exchange rate, and foreign interest rate (see Clarida et al., 2001; Svensson, 2000). One possible means of capturing the recent policy stance within the existing framework is the adoption of monetary aggregates in exchange rate models. For instance, it may not be advisable to measure the impact of monetary policy, and thereafter track policy transmission by using the interest rate alone, especially in a situation wherein the rates are stuck at near-zero.

Practical considerations suggest that money should be included in the policy rule of the central bank. One such consideration is the fact that the central bank usually does not have contemporaneous information on inflation and output,[3] but it has information about money stock. In such a case, money may help the central bank directly determine the current values of crucial variables (Goodfriend, 1999; Cochrane, 2007; Christiano et al., 2007; Nachane and Dubey, 2011).

[1] The exchange rate puzzle occurs when a contractionary monetary policy leads to an impact depreciation of domestic currency instead of domestic currency appreciation as predicted by theory. If it appreciates and does so for a prolonged period of time, the violation of the uncovered interest parity condition is known as delayed overshooting.

[2] The exchange rate disconnect puzzle refers to the weak short-run relationship between the exchange rate and its macroeconomic fundamentals. In other words, the underlying fundamentals, such as interest rates, do not explain the short-term volatility of the exchange rate.

[3] There is a time lag exists between the bank's policy move and its access to data on inflation and output (Kim and Roubini, 2000).

Therefore, the role of 'money' should be acknowledged and understood in empirical literature (Hendrickson, 2014), especially in determining the exchange rate.

The paper examines the economies of India, Poland, and the UK, which stand at various stages of the development spectrum. Cyclical fluctuations have occurred in both the advanced and emerging market economies, especially during the last decade, despite the structural differences between the two types of economies (Levine, 2012; Mallick and Sousa, 2012; Holtemöller and Mallick, 2016; Lane, 2003; and Mishkin, 2000). However, most erstwhile analyses have often focused on only similar and advanced industrial economies.[4] The probable exception here is the study by Mallick and Sousa (2012), which provides evidence of monetary policy transmission on the emerging market economies, such as Brazil, Russia, India, China, and South Africa. The period covered for the analysis in this study is 2000 to 2015. This period has been chosen to adequately gauge the effects of the new monetary policy of the central bank in the years leading up to and immediately following the financial crisis of 2007-08.

The main purpose of the paper is to investigate the role of money in the determination of exchange rate. We have used monthly data for the Bayesian structural VAR models (SVAR) of open economies to identify the monetary policy shock responsible for exchange rate fluctuations and compared how the models that include money perform vis-à-vis models with no money. The importance of monetary policy shock is determined by examining impulse response function, forecast error variance decomposition, and out-of-sample forecast. We show that our SVAR model with different measures of money (both simple sum and Divisia) estimates theoretically correct and significant responses of price, output, money and exchange rate to the tightening of monetary policy. The superiority of accurately measured monetary aggregates, such as Divisia, over simple-sum measures is also established. The estimated impulse responses of exchange rate to monetary policy shock are consistently significant with narrow error bands in models that use Divisia money. Models with Divisia money successfully address the exchange rate disconnect puzzle. The study finds that tightening of monetary policy (captured by the domestic short-term rate of interest) is an important driver of fluctuation in exchange rate. Additionally, models with Divisia money show superior out-of-sample forecasts of exchange rate compared to models that do not use money.

Section 2 further analyses existing literature and the results from this paper in details to underscore not only the importance of incorporating money as a concept in monetary policy but also the fact that tightening of monetary policy significantly influences fluctuations in the exchange rate. In addition, it highlights our enterprise in using Divisia monetary aggregates for the three selected economies. The structure of the rest of the paper is as follows. Section 3 undertakes SVAR estimation using impulse response analysis and thereafter presents the variance decomposition analysis. Section 4 contains the out-of-sample forecasting analysis. Section 5 concludes the paper.

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[4] For instance, Kim and Roubini (2000) focused on the non-US G7 industrial economies, such as Germany, Japan, the UK, France, Italy, and Canada. Bjornland (2009) tested her findings on the economies of Australia, Canada, Sweden, and New Zealand. Similarly, Cover and Mallick (2012) tried to identify the sources of macroeconomic and exchange rate variation of the UK economy.

2. Assessment of the Aggregation-theoretic Divisia Monetary Aggregates and the Role of 'Money' in the Monetary Policy Analysis.

The use of an alternative micro-foundation theoretic monetary aggregate, such as the Divisia monetary index, has been proposed for the three economies under study. Divisia provides an index of 'monetary services' that captures the traditional transactional motive for holding money, that is, the money demand behavior of the private sector. There is substantial literature studying the empirical and theoretical merits of these monetary aggregates (Belongia and Binner, 2001; Barnett and Chauvet, 2011; Barnett, 2012; Paul and Ramachandran, 2011). Belongia and Ireland (2015) have acknowledged the role of monetary aggregates, especially accurately measured aggregates such as Divisia, in explaining aggregate fluctuations in the macroeconomic variables. This finding seems relevant in the context of the substantial change in the monetary policy stance following the fiscal crisis of 2008.[5]

It is interesting to compare the behavior of the Divisia monetary aggregates with its simple sum counterparts in the years leading up to and following the 2007-08 recessions. Figures 1, 2 and 3 plot the year-on-year growth rates of narrow Divisia against simple sum M1, and simple sum M2 for UK, Divisia 3 against simple sum M3 for Poland, and, Divisia M3 against simple sum M3 for India, respectively. The most striking feature of these figures is that the growth rate of the simple sum monetary aggregates diverges markedly from the Divisia, before, during and after the recession of 2007-08. For instance, the simple sum M1 grew at a much faster rate than the narrow Divisia during the 2007-08 recessions for the UK. The difference in the growth rate between the simple sum M1 and the narrow Divisia was as high as 15 per cent in February 2008 and the simple sum M1 consistently grew at a much faster pace of more than 5 per cent than the narrow Divisia between August 2007 and December 2008. Similarly, the difference in the growth rate between simple sum M3 and Divisia 3 for Poland exceeded 5 per cent between November 2008 and July 2009.

During the recession of 2007-08, the Bank of England (BOE) laid an emphasis on the portfolio-balance effect, buying large stocks of financial assets from investors with the newly created money. BOE proceeded to rebalance their portfolio by acquiring financial assets of different risks and maturity. In doing so, the central bank attempted to raise asset prices, lower interest rates, reduce

[5] Fed's broad measure of money supply (M2) increased from 4 per cent to 6 per cent annually during the housing bubble, and then dropped to 2 per cent in 2010 in the aftermath of the burst. A measure from the New York-based Center for Financial Stability that used Divisia monetary aggregate captures several kinds of money. A technically sound computing method also found that the money supply (M2) in the U.S. increased from 6 per cent to 8 per cent during the bubble before shrinking to a negative growth number following the crisis. Similarly, the simple sum series overstated money growth during the episode of disinflation and financial deregulation of the early 1980s; such an overstatement was the result of a failure to internalise portfolio shifts out of traditional non-interest-bearing monetary assets into newly created less liquid, interest-earning accounts, such as money market mutual funds. Friedman's prediction that the economy would return to high inflation during the period 1984–85 was based on the steady growth of the simple sum monetary aggregate. Barnett (2012) argued that Friedman might have reached a different conclusion had he monitored the data on the Divisia aggregate, which provided a strong and accurate signal of monetary tightness during the early 1980s. Divisia M2 also increased at a rate that consistently exceeded the growth rate of simple sum M2, especially during the periods characterized by falling interest rates, that is, 1990–1991, 2001, and the recession of 2007–09 (Belongia and Ireland, 2015).

borrowing costs, and encourage households and businesses to increase their investments. The graphical representation indicates that during periods when the monetary policies of the central banks are accommodative or unconventional, broad monetary aggregates like simple sum M3 tend to move in the opposite direction from the Divisia counterparts. The reason for this occurrence is that the construction of quantity indices like Divisia is based on the index number theory, which can take in pure substitution effects that, by definition, occur when the levels of monetary service flows are unaltered. On the other hand, the simple sum measures fail to incorporate pure substitution effects, as a result of which interest rate movements cause shifts in a simple sum aggregate, even when there has been no change in monetary service flows.

In the case of India, going back in time between March 1996 and February 1997 would also reveal that the growth in simple sum M3 outpaced the Divisia M3 growth by more than 5 per cent. The early policy of financial liberalization in India focused on gradually freeing and raising interest rates, improving and strengthening the bank regulation, and simplifying the regulations under which Non-bank Financial Corporations (NBFCs) to operate. Therefore, such episodes highlight the failure of simple sum measures to deal with the advent of financial innovations in India that began in the 1990s.

It is important to understand the channels through which a shock to the monetary aggregates influences exchange rates. The classical flexible price monetary model provides the basic channel of transmission between the monetary aggregates and exchange rate. The bilateral exchange rate, by definition, is the price of one currency in terms of another. The relative prices in such models are determined by the supply and demand for money in the two countries. It is assumed that the money demand in the respective countries is a function of output and the opportunity cost of holding money, that is, the interest rate (user cost). Therefore, the bilateral exchange rate in the flexible price model becomes a function of the relative monetary aggregates, relative outputs, and relative interest rates (user cost) in the two countries. While the flexible price model offers the basic structure, the assumptions underlying such a model are generally strong. Dornbusch's exchange rate model, on the other hand, postulates that prices are sticky in the short run, and can explain short-run overshooting of the exchange rate. However, in the case of both the sticky price and flexible price monetary models, the money supply and variables that determine the money demand, such as output and interest rate (user cost), play an important role in explaining exchange rate movements.[6]

In view of its goal of investigating the role of money in determining the exchange rate, the study contributes to the existing literature in three ways. Firstly, monthly data for the Bayesian SVAR of open economies has been used to identify the monetary policy shock responsible for exchange rate fluctuations and to compare the performance of models incorporating money vis-à-vis models with no money. This is achieved by cross-comparing the sources of exchange rate fluctuations in three different models, that is, models with interest rate (and no monetary aggregate), models with interest rate and simple-sum monetary aggregates, and models with interest rate and Divisia money. The performances of the models have been assessed in accordance with the four puzzles

[6] Barnett and Kwag (2005) found that the introduction of Divisia aggregates into money market equilibrium helps in improving the forecasting performance of the monetary models of exchange rate.

that have plagued the empirical literature on open-economy macroeconomics, namely, the liquidity, price, exchange rate, and the forward discount bias puzzles.

Impulse response graphs have been provided for the recursive and non-recursive models without money, non-recursive models with simple-sum monetary aggregates, and non-recursive models with Divisia monetary aggregates for India, Poland, and the UK, respectively. Almost all the puzzles persist in the no-money recursive models, especially the price puzzle, exchange rate puzzle, and forward discount bias puzzle. The exchange rate puzzle is produced by the impact depreciation of currency caused by a one-percentage-point increase in the interest rate. Further, even if the currency appreciates with a contractionary monetary policy shock, it does so for a prolonged period of time, a situation characterized as the forward discount puzzle. Contractionary monetary policy shocks also lead to a persistent rise in inflation, thereby producing a price puzzle (see Barnett et al., 2016)[7].

Secondly, the study finds that tightening of monetary policy (captured by the domestic short-term rate of interest) is an important driver of fluctuation in the exchange rate. This finding is especially applicable for models that have adopted the monetary aggregates (money demand), wherein the monetary policy, along with simple-sum and Divisia aggregates, respectively, explain up to 6 per cent and 35 per cent of the exchange rate fluctuation for the UK. This monetary policy shock in the no-money model explains only 2 per cent of the variance decomposition of forecast error of the exchange rate of the British pound per US dollar (USD), a result similar to that arrived at by Cover and Mallick (2012). The monetary policy of India explains 12 per cent and 22 per cent of the fluctuation in the exchange rate in models that adopted monetary aggregates simple sum and Divisia, respectively. The monetary policy of Poland in models that adopted simple sum and Divisia can explain 14 per cent and 33 per cent of the exchange rate fluctuation, respectively. This monetary policy shock in the no-money model explains only 17 per cent of the variance decomposition of the forecast error of Indian rupees (per USD) and 2 per cent of the variance decomposition of the forecast error of Polish zloty (per USD). Additionally, models with Divisia money show superior out-of-sample forecasts of the exchange rate as compared to models that do not use money.

Thirdly, the study has further provided channels for how a shock to a monetary aggregate (money demand) can affect the other variables in the model including the exchange rate (see Appendix: Figure H, Figure I, Figure J). This is achieved by cross-comparing the impact of money demand shock in two different model set-ups , that is, models with interest rate (and simple sum monetary aggregate), and models with interest rate (and Divisia money).The contributions are similar to Barnett and Kwag (2005) and Ireland (2015). The latter found empirical evidence supporting the inclusion of money growth in the interest rate rule for policy, where in money plays an informational rather than a causal role by forecasting the future nominal interest rate. Other studies have emphasized the "information content" of monetary aggregates in predicting inflation and

[7] Holtemöller and Mallick (2016) depict the impact appreciation of the real effective exchange rate due to a tight monetary policy in India, wherein monetary policy has been captured in a standard New Keynesian framework. However, the currency kept appreciating persistently, showing the existence of a forward discount bias puzzle. The SVAR model for Poland deployed by Darvas (2013) and Kapuscinski et al. (2013) indicates the presence of price puzzles. Although Cover and Mallick (2012) have estimated puzzle-free impulse responses to a monetary policy shock for the exchange rate and price in the UK, the responses remain insignificant. This could be because their model did not include money.

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output. The following sections detail the methodology and empirical results used for arriving at these findings.

3. SVAR Estimation Model

The equation representing the dynamic structural models in vector form is

$$B_0 y_t = k + B_1 y_{t-1} + B_2 y_{t-2} + \cdots + B_p y_{t-p} + u_t \tag{3.1}$$

where y_t is an $n \times 1$ data vector, k is an $n \times 1$ data vector of constants and u_t is an $n \times 1$ structural disturbances vector. u_t is serially and mutually uncorrelated. p denotes the number of lags.

$$B_0 = \begin{bmatrix} 1 & -B_{12}^{(0)} & . & . & . & . & -B_{1n}^{(0)} \\ . & . & . & . & . & . & . \\ . & . & . & . & . & . & . \\ . & . & . & . & . & . & . \\ . & . & . & . & . & . & . \\ . & . & . & . & . & . & . \\ -B_{n1}^{(0)} & -B_{n2}^{(0)} & . & . & . & . & 1 \end{bmatrix} \tag{3.2}$$

B_s is a $(n \times n)$ matrix whose row i, column j element is given by $B_{ij}^{(s)}$ for s =1, 2... p.

If each side of [2.1] is pre-multiplied by B_0^{-1}, the result is

$$y_t = c + \emptyset_1 y_{t-1} + \emptyset_2 y_{t-2} + \cdots + \emptyset_p y_{t-p} + \epsilon_t \tag{3.3}$$

where, $c = B_0^{-1} k$ (3.4)

$$\emptyset_s = B_0^{-1} B_s \quad ; \quad for\ s = 1,2,3 \ldots \ldots, p \tag{3.5}$$

$$\epsilon_t = B_0^{-1} u_t \tag{3.6}$$

Thus, VAR can be viewed as the reduced form of a general dynamic structural model. The structural disturbance u_t and reduced form residuals ϵ_t are related by

$$u_t = B_0 \epsilon_t \tag{3.7}$$

The model should be either exactly identified or over-identified for estimating the parameters from the structural form equations. A necessary condition for exact identification is that the number of parameters in B_0 and D (covariance matrix of the structural form, $E u_t u_t' = D$) should be same as that in Ω, the covariance matrix from the reduced form, ϵ_t. This can be achieved by using the Cholesky decomposition of reduced form innovations (Sims, 1980), which imposes a recursive structure to identify the model. The non-recursive structural VAR methods can also be used with the restriction imposed on contemporaneous relations between the variables based on economic theory (Bernanke, 1986). The identification restrictions can be imposed in various ways, such as imposition of restrictions on B_0 or on B_0^{-1} or of long-run restrictions.

Letting Ω denote the variance-covariance matrix of ϵ_t, implies

$$\Omega = E(\epsilon_t \epsilon_t') = B_0^{-1} E(u_t u_t')(B_0^{-1})' = B_0^{-1} D (B_0^{-1})' \tag{3.8}$$

Since Ω is symmetric, it has $n(n+1)/2$ parameters. It is standard practice in SVAR literature to have D as the diagonal matrix, which requires n parameters. Hence, B_0 can have no more than $n(n-1)/2$ restrictions for facilitating an exact identification. B_0 is a triangular matrix for the VAR with a Cholesky decomposition of the innovations. The validity of such a recursive structure is difficult to justify theoretically.

A simple two-step maximum likelihood estimation (MLE) procedure can be employed for producing an exactly identified model, assuming that the structural errors are jointly normal. This is the full information maximum likelihood (FIML) estimator for the SVAR model. First, Ω is estimated as:

$$\hat{\Omega} = (1/T) \sum_{t=1}^{T} \hat{\epsilon_t} \ \hat{\epsilon_t}' \tag{3.9}$$

Estimates of B_0 and D are then obtained by maximizing the log likelihood for the system conditioned on $\hat{\Omega}$. However, when the model is over-identified, the two-step procedure is not the FIML estimator for the SVAR model. The estimates are consistent but not efficient as they do not take the over-identification restrictions into account while estimating the reduced form. For an over-identified system, the VAR model is estimated both without additional restrictions and with additional restrictions, to obtain 'unrestricted' and 'restricted' variance-covariance matrix, respectively, by maximizing the likelihood function. The difference in the determinants of the restricted and unrestricted variance-covariance matrix will be distributed χ^2, with the degrees of freedom being equal to the number of additional restrictions exceeding a just identified system. The χ^2 test statistic has been used to test the restricted system.

A 7-variable VAR has been used in the study, which includes the world oil price index (oil), the federal fund rate (rfed), the index of industrial production (iip), the level of inflation in the domestic small open economy (π), a domestic monetary aggregate (MD), nominal short-term domestic interest rate (rdom) producing monetary policy shocks (MP), and the nominal exchange rate in domestic currency per US dollar (ER). The identification scheme, based on Equation 3.10, is detailed below.

$$\begin{pmatrix} u_t^{oil} \\ u_t^{rfed} \\ u_t^{iip} \\ u_t^{\pi} \\ u_t^{MD} \\ u_t^{MP} \\ u_t^{ER} \end{pmatrix} = \begin{pmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ b21 & 1 & 0 & 0 & 0 & 0 & 0 \\ b31 & b32 & 1 & 0 & 0 & 0 & 0 \\ b41 & 0 & b43 & 1 & 0 & 0 & 0 \\ 0 & b52 & b53 & b54 & 1 & b56 & b57 \\ b61 & 0 & 0 & 0 & b65 & 1 & b67 \\ b71 & b72 & b73 & b74 & b75 & b76 & 1 \end{pmatrix} \begin{pmatrix} \epsilon_t^{oil} \\ \epsilon_t^{rfed} \\ \epsilon_t^{iip} \\ \epsilon_t^{\pi} \\ \epsilon_t^{MD} \\ \epsilon_t^{MP} \\ \epsilon_t^{ER} \end{pmatrix} \tag{3.10}$$

The vector of structural innovations is denoted by u, whereas ϵ is the vector of errors from the reduced form equations. The identification scheme is based on Kim and Roubini (2000) and has been slightly modified to fit the three economies. Based on the assumptions that hold for small, open economies, world shock (as captured by the world oil price index) and foreign interest rate (as captured by the federal funds rate in the USA) contemporaneously affect the domestic economy, but none of the domestic variables can affect them contemporaneously. However, the federal funds rate is only contemporaneously affected by world event shocks. Following Kim and Roubini (2000), it is imperative to include these variables to isolate and control the exogenous component of monetary policy shocks. Both industrial production and inflation in small, open economies is deeply affected by occurrences in the world and by outside shocks. However, the output and prices do not respond contemporaneously to changes in the domestic monetary policy variables and exchange rates. Real activity, such as industrial production, responds to domestic price and financial signals with a lag because of high adjustment costs to production. The money demand function usually depends on real income and the domestic interest rate, whereas in an open economy, it also depends on the foreign interest rate and the prevailing exchange rates. Allowing for contemporaneous interaction between money and the exchange rate helps in determining the performance of different monetary aggregates at play in the respective monetary policies of these economies and the manner in which they contribute in explaining the exchange rate movements. The reaction function (or monetary policy) of monetary authority helps set the interest rate in accordance with the current value of money supply, interest rate, and exchange rate.

The data have been arranged in monthly frequency with the estimation periods ranging that from January 2000 to January 2008, December 2001 to June 2015, and January 2001 to January 2013 for India, Poland, and the UK, respectively. The seasonally adjusted indices of production of the total industry for the UK, Poland, and India have been obtained from the production and sales [Monetary and Financial Statistics (MEI)] database of the Organization for Economic Co-operation and Development (OECD). The consumer price indices, wherein all items are seasonally adjusted, for all the three economies under study have been obtained from the consumer prices as given in the OECD database. The interest rate, immediate interest rate/call money/interbank rate (per cent per annum) for the UK, Poland, and India have also been obtained from MEI (in the OECD database). The simple-sum monetary aggregates M1 and M3 are the seasonally adjusted narrow and broad money indices, respectively, for the UK, Poland, and India. The values of the nominal exchange rate (the national currency per USD, monthly average) for the UK, Poland, and India have been derived from the MEI and OECD databases. The monthly crude oil price (per barrel) has been obtained from Index Mundi.

The Divisia data, which include the monthly index of monetary financial institutions and the sterling Divisia for the UK, have been taken from the database of the Bank of England. Divisia M1, M2, and M3 (which correspond to their simple-sum counterparts, M1, M2, and M3, respectively) have been abstracted from the database of the National Bank of Poland, while the Divisia monetary aggregates DM2, DM3, and DL1 for India have been derived from Ramachandran et al., 2010.The estimation period for India is constrained by the availability of a short sample of Divisia data (ibid.) The Center for Financial Stability in New York maintains the data resource, the International Advances in Monetary and Financial Measurement, which has links to the Divisia data for the UK, Poland, and India. The series has been seasonally adjusted by official sources, except for the Indian Divisia world oil prices, which have instead been seasonally adjusted by using frequency domain de-seasonalisation in RATS (see Doan, 2013). All variables except interest rates have been expressed in logarithms, except interest rates. Inflation (π) has been calculated as the annual change in log of consumer prices whereas the monthly VAR has been arrived at by using six lags for India and 13 lags for the UK and Poland, which, in turn, have been selected by using the sequential likelihood ratio test in RATS (see Doan, 2013). The result from the sequential likelihood ratio test is presented in Table A in the Appendix. The likelihood ratio test reported comparisons of VAR with p lags and VAR with (p-1) lags. The null hypothesis suggests that all coefficients on the p^{th} lags of the endogenous variables are zero. The lag has been selected in accordance with the value of the lag wherein the null hypothesis has been rejected. The absence of serial correlation has also been confirmed at the selected lags.[8]

Table B in the Appendix also reports the largest Eigen values of the estimated VARs for different lags for the three countries under study. An Eigen value of less than unity implies that the estimated VAR value satisfies the stability conditions. Appendices C and D provide the impulse response functions of monetary policy shocks for the three countries in a 6-variable model that excludes money. The 'no-money' models have been estimated by using the recursive identification assumption (Cholesky decomposition) and non-recursive assumptions. The numbers of lags used for the purpose of rendering comparisons were 6 for India and 13 for the UK and Poland each. The non-recursive 6-variable model imposes the same identification assumptions for the first four variables, that is, the world prices of oil, the fed funds rate, industrial production, and inflation. The only change observed in the 'no-money' model is that the monetary policy and exchange rate no longer depend on the monetary aggregate while the rest of the assumptions remain the same. The 'no-money' models are fraught with various puzzles, as discussed in detail in the following section.

3.1. Impulse Response Analysis

The SVAR model has been evaluated in terms of the four prevalent puzzles in empirical literature, namely, the liquidity, price, exchange rate, and the forward discount bias puzzles. Most of these puzzles have been eliminated for all the three countries. The results are robust for different samples, lags, and monetary aggregates. The model delineated correctly identifies monetary policies for India, Poland, and the UK. As shown in the authors' previous work (Barnett et al., 2016), the behavior of a private agent (money demand) should be separated from the central bank's policy (money supply) before assessing the effects of monetary policy on the economy. This approach calls for the inclusion of money in the models of exchange rates to capture money demand. Moreover, it is recommended that Divisia money should be incorporated in monetary policy because it can help weigh the different monetary components, thereby facilitating a proper summary of services rendered by money in the policy.

This section contains a detailed impulse response analysis for comparing the performance of models with Divisia money vis-à-vis that of models with simple-sum money. Appendices C and D report impulse responses for 'no money' models in a recursive (R) and non-recursive (NR) setting. The responses with regard to the exchange rate, money demand, output, and prices are free from puzzles, and in accordance with the theory, especially in the model with Divisia money. The statistical significance of the impulse responses have been examined by using the Bayesian Monte Carlo integration in RATS. The random walk Metropolis–Hastings method has been used to draw 25,000 replications for the over-identified SVAR model. The 0.16 and 0.84 fractiles correspond to the upper and lower lines of the probability bands (see Doan, 2013).

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[8] If the data is adequate, it is recommended that approximately a year's worth of lags be used, as a year's worth and one extra lag can help deal with seasonal effects. The robustness check of the results presented here was also performed on the basis of different lags and sample, and has been presented as part of the results in the Appendix. However, the main conclusion of the paper remains unchanged. For example, 6 lags were used for the UK and Poland instead of 13, and 4 were used for India instead of 6 (due to the availability of short Indian Divisia data). The absence of serial correlation has been checked at all the selected lags, and the results are available on request.

India: Figure 4 compares the impulse response graphs of the SVAR model with simple-sum M3 (left panel) and Divisia M3 (right panel) for India. The exchange rate is seen to appreciate on impact and to depreciate thereafter in both models under a contractionary monetary policy. A one-percentage-point increase in the interest rate results in an approximately 4 per cent appreciation of the rupee vis-à-vis the US dollar for models with Divisia as opposed to a 2 per cent impact appreciation of the exchange rate in models with simple-sum money, as shown in the point estimates. However, the response of the exchange rate (impact appreciation and subsequent depreciation) is significant in the left panel as compared to that in the right panel. Therefore, it is obvious that the model with Divisia money can capture a strong impact of the exchange rate that overshoots to monetary policy shock as compared with the model that adopts simple-sum M3. The recursive model with no money (Appendix C) is burdened by price and exchange rate puzzles. The non-recursive, no-money model can eliminate these two puzzles, but the point estimate of the output attributed to monetary policy shock remains positive. Holtemöller and Mallick (2016) show the impact appreciation of real effective exchange rate for India due to a tight monetary policy. However, the persistent appreciation in the currency shows the existence of a forward discount bias puzzle. The monetary policy is captured in a standard New Keynesian setting in the paper by Holtemöller and Mallick.

A one-percentage increase in the interest rate causes the money demand to fall for a few months in both models, but the impulse responses become significant only in the left panel. After the monetary policy shock, inflation falls by approximately 3 per cent in the left panel and by 1.2 per cent in the right panel. The liquidity effect, price effect, and exchange rate overshooting are more pronounced (significant) in the model with Divisia M3 than that with simple-sum M3. Additionally, the error confidence bands are generally narrow for models using Divisia aggregates. This finding points to a high degree of precision in the estimation of Divisia money models.

The United Kingdom: Figure 5 compares the impulse response graphs of the SVAR model with Divisia money (left panel), simple-sum M1 (middle panel), and simple-sum M3 (right panel). A one-percentage-point increase in the interest rate results in an approximately 1.5 per cent appreciation of the pound vis-à-vis the US dollar for the model with Divisia money. A similar result is observed for the model that uses simple-sum M3. The response of the exchange rate (impact appreciation and subsequent depreciation) to a monetary policy shock is significant in all the three cases. However, the response of the exchange rate is more pronounced in the model that contains simple-sum M1. Cover and Mallick (2012) used the SVAR model in the UK to estimate puzzle-free impulse responses for the exchange rate and prices but their responses are mainly insignificant. Their model does not include monetary aggregates to separately identify money demand shock.

The model with Divisia money shows that the money demand drops significantly by 0.06 per cent on impact and declines permanently following the policy shock. The model with simple-sum M1 exhibits a liquidity puzzle, wherein the money demand increases with an increase in the interest rates. The model with simple-sum M3 provides accurate but insignificant responses pertaining to the models using money.

The prices show a correct response, wherein the inflation rate remains below zero for the first 10 months following the tightening of monetary policy. This effect is significant for the model with Divisia money. The model with simple-sum M1 exhibits a price puzzle. A significant and permanent reduction in the output occurs due to a contractionary monetary policy shock. Industrial production shows a low positive response to the impact of a contractionary monetary policy shock and begins to drop significantly after a couple of months of the tightening of policy in the Divisia models. The same is not true for simple-sum models or no-money non-recursive (see Appendix D) models, wherein the fall in output is largely insignificant. The Cholesky decomposition in the no-money models (see Appendix C) shows both price and exchange rate puzzles.

Poland: Figure 6 compares the impulse response graphs of the SVAR model with Divisia M3 (in the left panel) and with simple-sum M3 (in the right panel) for Poland. A one-percentage-point increase in the interest rate results in an approximately 6 per cent appreciation of the Polish zloty vis-à-vis the US dollar for the Divisia model, whereas a 4.5 per cent appreciation is observed in the model with simple-sum M3. An impact appreciation of the exchange rate to a monetary policy shock is observed, followed by a mild yet significant depreciation in the left panel. The puzzle-free results for the price and exchange rate for Poland, especially in the model with Divisia money, are in sharp contrast to the results found in the existing literature. Kapuscinski et al. (2013) used four endogenous variables, namely, output, price, interest rate, and real effective exchange rate, to estimate a SVAR model for Poland. Monetary policy tightening leads to a price puzzle and insignificant fluctuations in the interest rate in the model when Cholesky and semi-Cholesky decompositions are used. Darvas (2013) used a structural time-varying coefficient VAR in a similar 4-variable framework and found a price puzzle.

A rise of one per cent in the interest rate causes the money demand to fall significantly, leading to a short-lasting impact. The prices show a correct response, wherein the inflation rate remains below zero for the first eight months after the tightening of monetary policy. Following the contractionary monetary policy shock, inflation temporarily falls by around 0.05 per cent for both cases. Finally, a restrictive monetary policy exhibits a negligible effect on the output for models with Divisia money, but the right panel records a significant rise in output from the 2 to 8 month period, showing the occurrence of an output puzzle. Therefore, the responses with regard to exchange rate, money demand, and prices to the monetary tightening are puzzle-free, precise in terms of tighter error bands, and in accordance with the theory, especially in the model with Divisia M3.

MC Convergence Test: Table C in the Appendix provides a check for Monte Carlo convergence using the Geweke test. This examines the behavior of the model over the long run rather than focusing on short-run auto-correlation analysis. It reports the mean, numerical standard error (NSE) and Geweke CD measure. Using robust estimates of the variance of the means, it tests whether the mean at the start of the keeper draws is the same as the mean at the end of keeper draws. Hence, the null hypothesis of the test is defined as a check to determine whether the two parts of the chain are asymptotically independent or not. The Geweke CD measure is normally distributed with mean one and variance zero. The critical values at the 10 per cent and 1 per cent significance levels are 1.645 and 2.575, respectively. As can be seen from the absolute value of the CD measure for the contemporaneous coefficients, they do not fall in the rejection region, that is, the null hypothesis is not rejected. Hence, this ensures good estimations provided by the model used in this study.

3.2. Variance Decomposition

The variance decomposition of the exchange rate to monetary policy shock is evaluated in Table 1. Results without money in recursive and non-recursive models and with different forms of monetary aggregates are reported. The model that contains the Divisia monetary aggregate is seen to perform relatively better than the model with simple-sum money or the model with no money.

The results in this section support the argument that the mere addition of money in the VARs is not sufficient for capturing the private sector's demand for money. The type of money added is also important.

Models with simple-sum M3, Divisia M3, Divisia M2, Divisia L1, and models with no money are reported for India. It is observed that generally, models with Divisia money perform better than models with simple-sum money (M3) or models with no money in terms of the monetary policy contributing more to the exchange rate variation at each step in the future horizon. For example, the monetary policy in the model with Divisia M3 explains 14 per cent of the exchange rate variation occurring at the first month, which increases to 16 per cent at the fourth month. The contribution of monetary policy shocks then declines gradually. In contrast, the monetary policy shock in the model with simple-sum M3 explains only 8 per cent of the exchange rate variation at the first month, which increases marginally to 10 per cent in the fourth month and to 9 per cent in the eighth month. Hence, the use of Divisia money helps in correctly capturing the money demand behavior of private agents. In fact, the performance of the monetary policy in the model with simple-sum money is worse than that of the model with no money in explaining fluctuations in exchange rates.

The results for the UK from the models with simple-sum M1, simple-sum M3 and narrow Divisia measure, along with the 'no money' models are presented in Table 2. During the initial months, no substantial difference is observed in the amount of exchange rate fluctuations explained by the monetary policy in the models with money as compared to those models with no money except in the case using M1 money. The model with M1 money exhibits good performance at the initial horizon, but its effect wanes during the later stages. The model with Divisia money allows for monetary policy to explain fluctuations in the exchange rate as we move ahead in the forecasting horizon. The interest rate can be used to explain 4 per cent of the exchange rate variation in the first month with its contribution increasing significantly to 16 per cent in the 20th month and to 18 in the 24th month in the model using Divisia money. The 'no money' model performs poorly in explaining the exchange rate fluctuations during all-time horizons of the analysis. The 'no money' SVAR models in literature indicate that monetary policy shock plays a small role in explaining the variation in the exchange rate. According to Cover and Mallick (2012), the monetary policy shock explains variations of only 1–4 per cent in the exchange rate until the 30th step in the forecast horizon. Similar results are obtained in the case of the 'no money' models with a similar band of 1–4 per cent. The addition of Divisia money facilitates an improvement in the model and helps explain up to 18 per cent of exchange rate fluctuations.

The variance decomposition analysis for the models with no money, simple-sum M2, simple-sum M3, Divisia M2, and Divisia M3 were also evaluated for Poland. Generally, monetary policy shocks in models that contain the Divisia monetary aggregate were seen to perform slightly better than their simple-sum counterparts in capturing variations in the exchange rate. However, the money demand shock (see Table 2) in the Divisia models plays a lead role and is discussed in detail later. The monetary policy shock for the model with simple-sum M3 explains 4 per cent of the variation in the exchange rate in the first month, 2 per cent in the fourth month, and 7 per cent in the 24th month. In contrast, the model with Divisia M3 explains 7 per cent of the exchange rate variation in the first month, 3 per cent in the fourth month, and 7 per cent in the 24th month. Similarly, the model with Divisia M2 performs better than the model that contains simple-sum M2.

The variance decomposition of the exchange rate to the money demand shock is evaluated in Table 2. The performances of the models with different monetary aggregates are also assessed in the table. The 'no money' VAR models failed to capture the money demand shocks separately. Hence, no values are reported. The table shows that a money demand shock in the models with simple sum and Divisia monetary aggregates in India does not result in significant differences. Similarly, no significant differences were observed in models that contain Divisia monetary aggregates at different levels of aggregation. The money demand shock by itself cannot explain most of the variations in exchange rates. However, the inclusion of the monetary aggregate may help in enabling monetary policy shocks to explain the dynamics of exchange rate dynamics observed in Table 1. Hence, monetary aggregates act as informational variables rather than causal ones, especially in explaining variations in the exchange rate.

Table 2 highlights how the model with narrow Divisia is better than the simple-sum M1 and simple-sum M3 in terms of the ability of money demand shocks to explain fluctuations in the exchange rate in the UK, especially in long horizons. Therefore, the Divisia monetary aggregate for the UK acts as both an informational and a causal variable, by itself explaining a large part of the exchange rate variations while also facilitating an explanation of fluctuations in the exchange rate through the use of monetary policy.

The money demand shock can substantially explain exchange rate variations for Poland as reported by simple-sum and Divisia models in Table 2. Models with Divisia M2 are significantly better than their simple-sum counterparts because the money demand shock explains as much as 30 per cent of the exchange rate variations in the third step. The importance of including Divisia in the exchange rate models in Poland is established in Table 2.

4. Forecast Statistics for the Exchange Rate

In this section, out-of-sample forecasts of exchange rates in different-money and no-money models have been made to evaluate: (1) changes in forecasting performance when money is added to the system; and (2) variations in the results obtained with different types of money. The forecast performance of a model has been assessed in terms of the root mean square error (RMSE) as shown in Table 3. The "out-of-sample" forecasts within the data range have been calculated by using the Kalman filter to prepare the model by using data from the starting period of each set of forecasts. The RMSE has been compiled over the sample period and expressed through the following formula:

$$e_{it} = y_t - \hat{y}_{it}, \tag{4.1}$$

where $\hat{y}_{it}$ is the forecast at step *t* from the *i*th call and y_t is the actual value of the dependent variable. Let N_t be the number of times that a forecast has been computed for horizon *t*, $i = 1,2, \dots\dots N_t$.

$$\text{RMSE}_t = \sqrt{\sum_{i=1}^{N_t} e_{it}^2 \Big/ N_t}\,. \tag{4.2}$$

Table 3 evaluates models with no money, simple sums, and Divisia in terms of the RMSE statistics. The models have been estimated and updates performed for all the three economies in 24 steps using the Kalman filter. For the UK, the model has been estimated through 2012: 12 and updates have been performed from 2013: 1 to 2014: 12; for Poland, the model has been estimated through 2013: 6 and updates have been performed from 2013: 7 to 2015: 6; and for India, the model has been estimated through 2006: 6 and updates performed from 2006: 7 to 2008: 6.

For India, the model with Divisia M3 shows a lower RMSE than the model with simple-sum M3 at every forecast horizon until 24 steps. However, when the RMSE of the model without money is compared with that of the model with Divisia money, mixed results are obtained with RMSE values that are very close to each other. For some forecast horizons, the model without money is slightly better while for others, the model with Divisia money does better. The inclusion of an extra variable implies loss of degrees of freedom in the regression. Thus, if a variable is added in the forecasting analysis, which does not have significant information content, this approach could lead to deterioration in the forecasting performance of the model. In India's case, adding money, especially Divisia money, improves the forecasting performance at some horizons (in terms of lower RMSE). The RMSE values are better and close to the no-money models for other horizons. This finding corroborates two facts: firstly, the money variable contains crucial information on exchange rates that should not be ignored, and secondly, Divisia ensures superior performance as compared to other forms of money.

No conclusive result is obtained for the UK in terms of the RMSE when models with no money are compared with models with simple-sum monetary aggregates (Table 3). In some forecasting horizon, the model with no money performs better than models with simple-sum money. However, the model that contains Divisia consistently performs better than other models at every forecast horizon. The RMSE for the model with the narrow Divisia is at the minimum level of 0.014 at a one-step ahead horizon. For Poland (Table 3), the model with Divisia M3 demonstrates the best performance when compared with other models (no-money and simple-sum models). The model with no money performs better than the model with money at few forecast horizons. The models at broad levels of aggregation perform better than their narrower counterparts. When the RMSE for the model with no money is compared with that of the model with simple-sum M1 money, the 2.45 and 2.48, are obtained, respectively, at one step ahead, and 16.92 and 17.53, respectively, at 12 steps ahead. The model with only the interest rate performs better till 12 steps ahead. The model with money then starts playing an informative role in the exchange rate forecast with RMSE values of 19.54 and 16.48 being obtained at the 16^{th} and 24^{th} steps. In contrast, the no-money model has RMSE values of 21.52 and 19.35. However, low RMSEs are obtained at every forecast horizon when the model with Divisia M3 is compared with the simple-sum M3 model or the no-money model.

The theory establishes the indispensable role of money in modelling exchange rates. Hence, the monetary aggregate variable is added in the forecasting analysis. Adding money improves the forecasting performance of some countries even though it implies losing degrees of freedom in the regression. Otherwise, the approach does not damage the forecasting performance in those countries to the extent that would be expected in terms of losing degrees of freedom. Moreover, Divisia money models are observed to persistently and unambiguously outperform models with simple-sum money.

The forecast graphs (figure 7, 8 and 9) have been obtained through Gibbs sampling on a Bayesian VAR with a "Minnesota" prior. The sequential likelihood ratio test selects 13 lags for India, the

UK, and Poland. A part of the data has been held back to evaluate the forecast performance. The graph forecasts 24 steps ahead with a ±2 standard error band using 2,500 draws. The out-of-the-sample simulations account for all uncertainty in forecasts of the uncertainty of coefficients (handled by Gibbs sampling) and shocks during the forecast period (see Doan, 2012).

Figure 7 represents the out-of-sample forecasting graph for India and compares models with simple-sum M3 and models with Divisia M3. The model forecast with Divisia M3 (represented in coral) stays close to the actual log of the exchange rate (with the LER represented in black). The model forecast with simple-sum M3 (represented in blue) diverges from the actual value over time. The forecast band for the model with Divisia M3 (represented in pink) is narrower than the forecast band for the model with simple-sum M3 (represented in green). This finding indicates higher forecasting accuracy in models with Divisia money than models with simple-sum money.

Figure 8 represents the out-of-sample forecasting graph for the UK and provides a comparison between the model with M1 money and the model with the narrow Divisia. The model forecast with Divisia (represented in coral) closely follows the actual LER value (represented in black). The model forecast with M1 money (represented in blue) does not follow the actual value over a considerable period of the forecast horizon. In the initial forecast horizon, the forecast bands for the model with Divisia (represented in pink) are relatively narrower than the forecast band for the model with M1 money (represented in green). The narrow bands imply that the model with Divisia can predict the exchange rate with greater precision.

Figure 9 represents the out-of-sample forecasting graph for Poland and provides a comparison between the model with simple-sum M1 and model with the Divisia M1. The model forecasts with Divisia M1 are represented in blue), simple-sum M1, represented in coral, and the actual LER value is represented in black. The model forecasts with the Divisia M1 perform better than the simple-sum M1. When the actual exchange rate fell over the period 2013–14, the point forecast of the exchange rate from the model with Divisia was lower than the point forecast with the model with simple sum and closer to the actual exchange rate. Similarly, when the exchange rate increased during the latter months of 2014, the point forecast of the exchange rate from Divisia models exceeded the point forecast from their simple-sum counterparts. Hence, the model with Divisia money helps in forecasting the exchange rate with high accuracy. The forecast band for the model with Divisia M1 is represented in green while the forecast band for the model with simple-sum M1 is represented in pink.

The relative forecasting performance of models has been evaluated by using the out-of-sample forecasting graphs and RMSE statistics. It may be concluded here that models with Divisia money consistently perform better than models with simple-sum money. These findings support the superiority of Divisia money models over models with no money in terms of their contribution to the forecasting of exchange rates in both the short and long runs.

5. Conclusion

This study has examined whether structural VAR models based on the traditional, new Keynesian small and open economy frameworks are able to correctly identify monetary policy shocks that cause exchange rate fluctuations. The findings of the study justify doubts about this outcome, especially during the period coinciding with the recession of 2007-09 when the central banks employed an unconventional monetary policy. The paper has also investigated the role of money in determining the exchange rate. The monetary aggregate has been incorporated in a traditional VAR (based on the New Keynesian setting) wherein the interest rate is the sole monetary policy instrument. Models with monetary aggregates, including both simple sum and Divisia aggregates, provide theoretically correct estimates, and significant responses in terms of prices, output, money and exchange rate to a monetary policy shock. This finding implies that the model presented in this paper accurately reflects the prevalent situation in small, open economies. Further, the use of the model with Divisia monetary aggregate suggests an impact appreciation of the exchange rate in monetary policy shocks, which subsequently results in impact depreciation.

An analysis of the variance decomposition of forecast error in the exchange rate to monetary policy shocks also points to moderate but consistent improvements in the explanatory power of monetary policy. This finding is particularly true for models that adopt monetary aggregates, especially with regard to the comparison between Divisia money and the no-money model. These findings have been correlated to the emerging market economies of India, Poland and the UK. It has concomitantly been observed that the monetary policy and money demand together can explain up to 22 per cent, 33 per cent, and 35 per cent of the variation in the exchange rate for India, Poland, and the UK, respectively. The results also support the superiority of Divisia money models in forecasting exchange rates as compared to models with no money. Moreover, the findings confirm the results derived by Barnett and Kwag (2005), and Barnett et al. (2016) that the introduction of Divisia aggregates can help in appraisal of the money market equilibrium as also improve the predictive power of monetary policy with regard to exchange rate volatility. Hence, these results reinforce the need to introduce monetary aggregates, especially Divisia, into the structural VAR models of open economies.

Endnote

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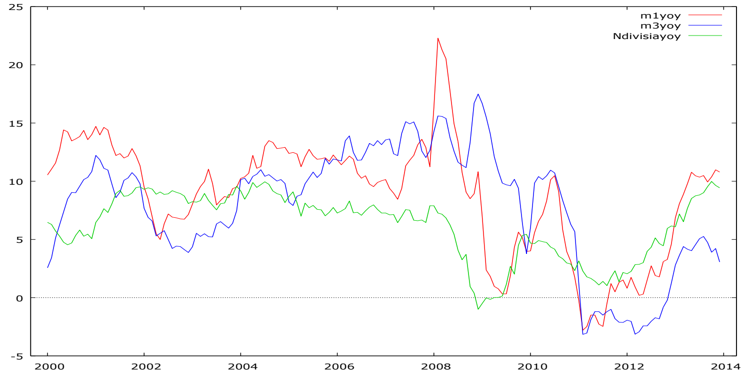
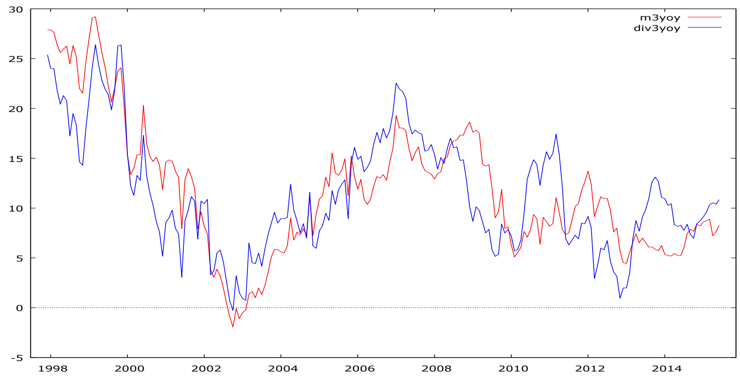
Fig 1: Growth Rates of Simple Sum M1, Simple Sum M3 and Narrow Divisia Monetary Aggregates, UK (year on year)



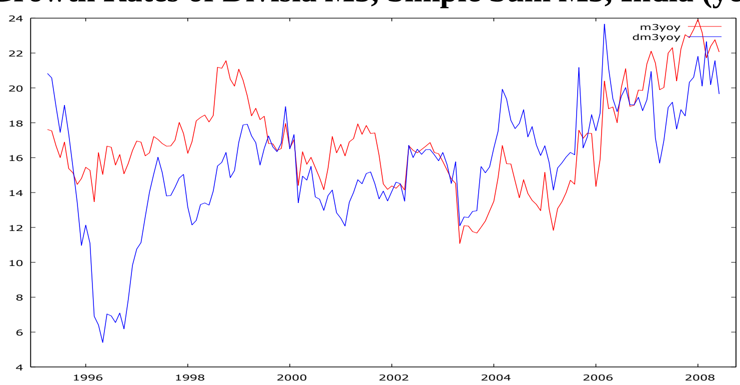
Data Source: Bank of England.

Figure 2: Growth Rates of Divisia 3, Simple sum M3, Poland (year on year)



Data Source: National Bank of Poland.

Figure 3: Growth Rates of Divisia M3, Simple Sum M3, India (year on year)



Data Source: Ramachandran, et al., 2010.

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Figure 4: INDIA

Impulse Responses for Monetary Policy Shocks

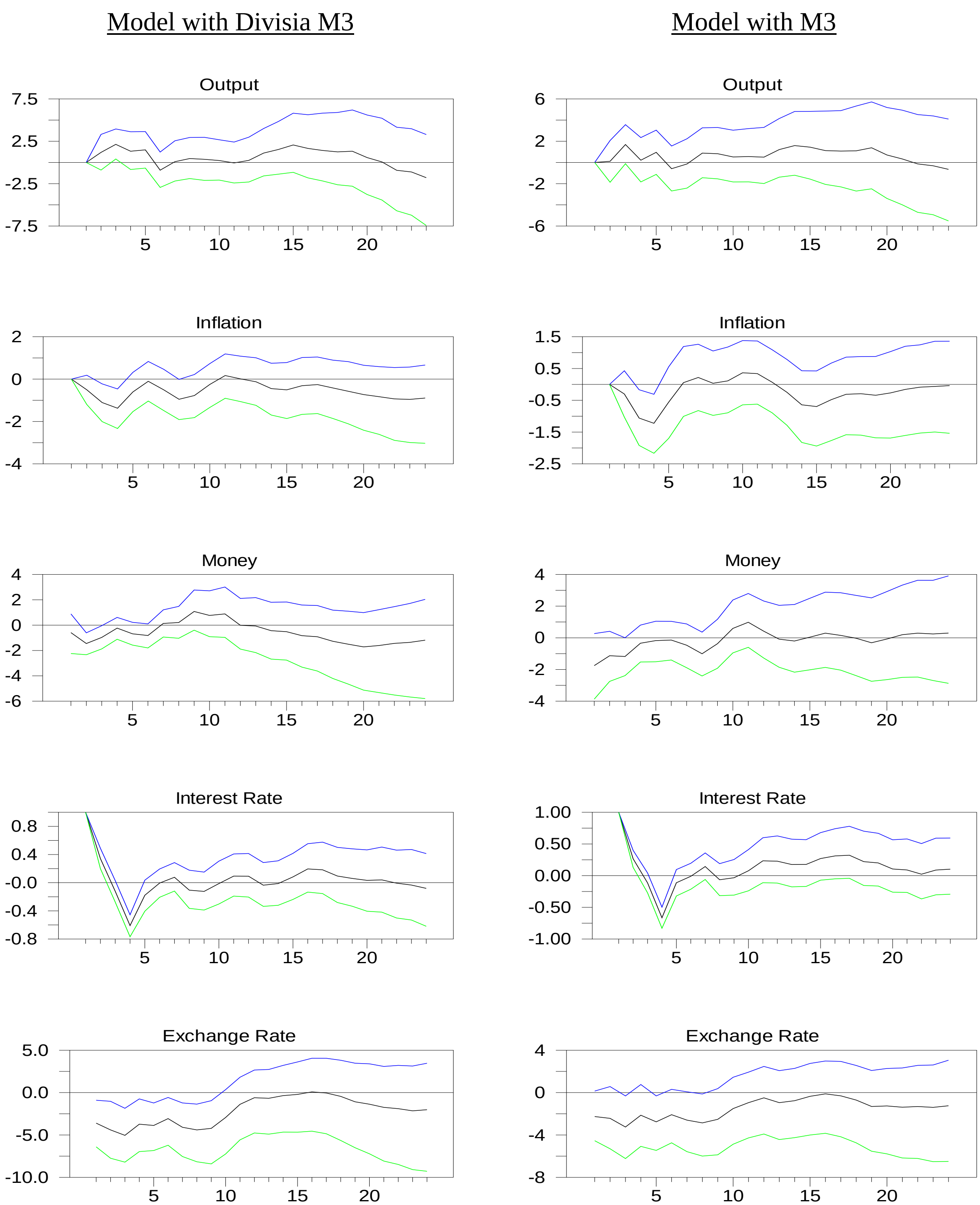

Figure 5: UK

Impulse responses for Monetary Policy Shocks

Model with Divisia Money | Model with M1 Money | Model with M3 Money

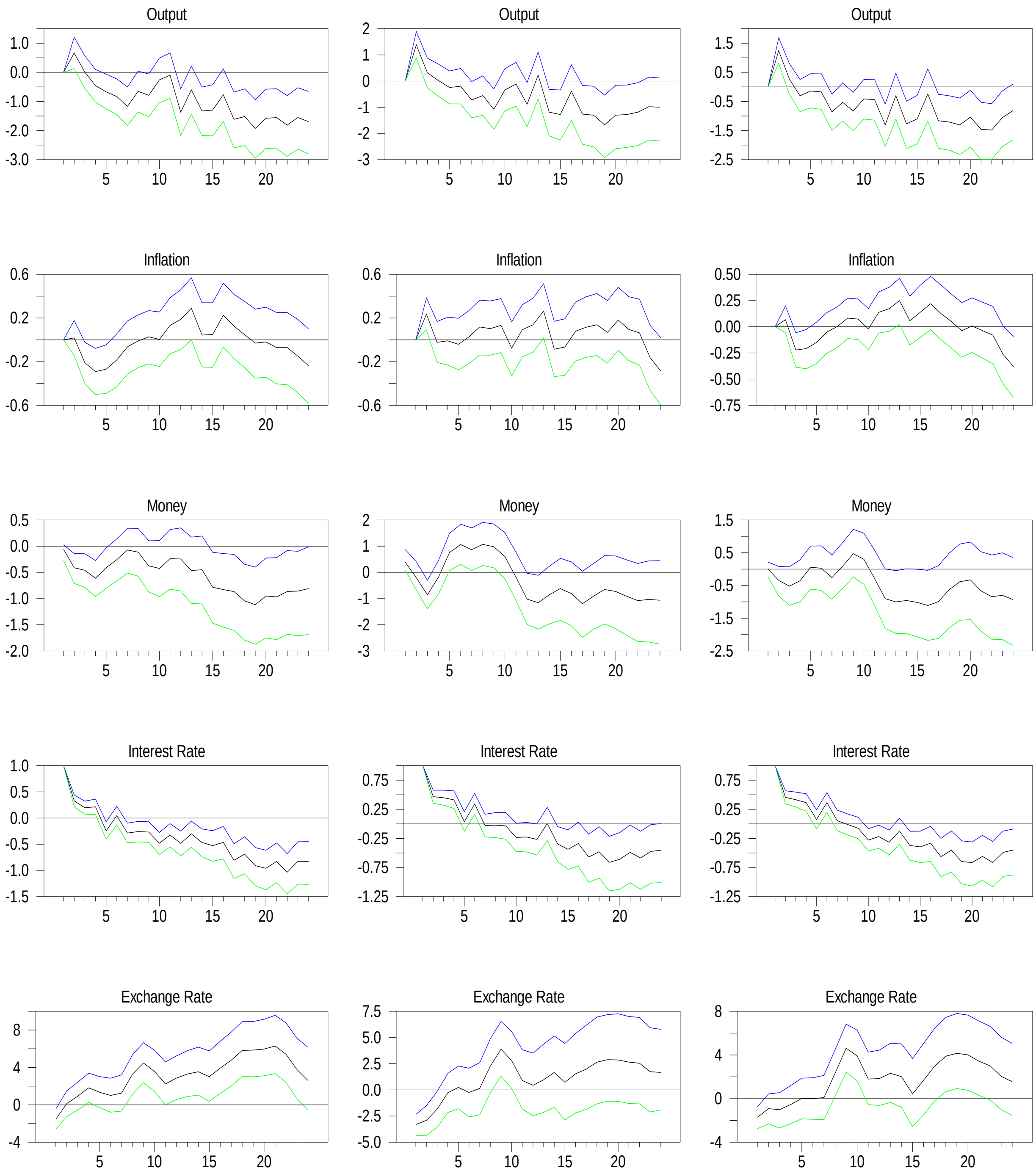

Figure 6: POLAND

Impulse Responses for Monetary Policy Shocks

Model with Divisia M3 | Model with M3

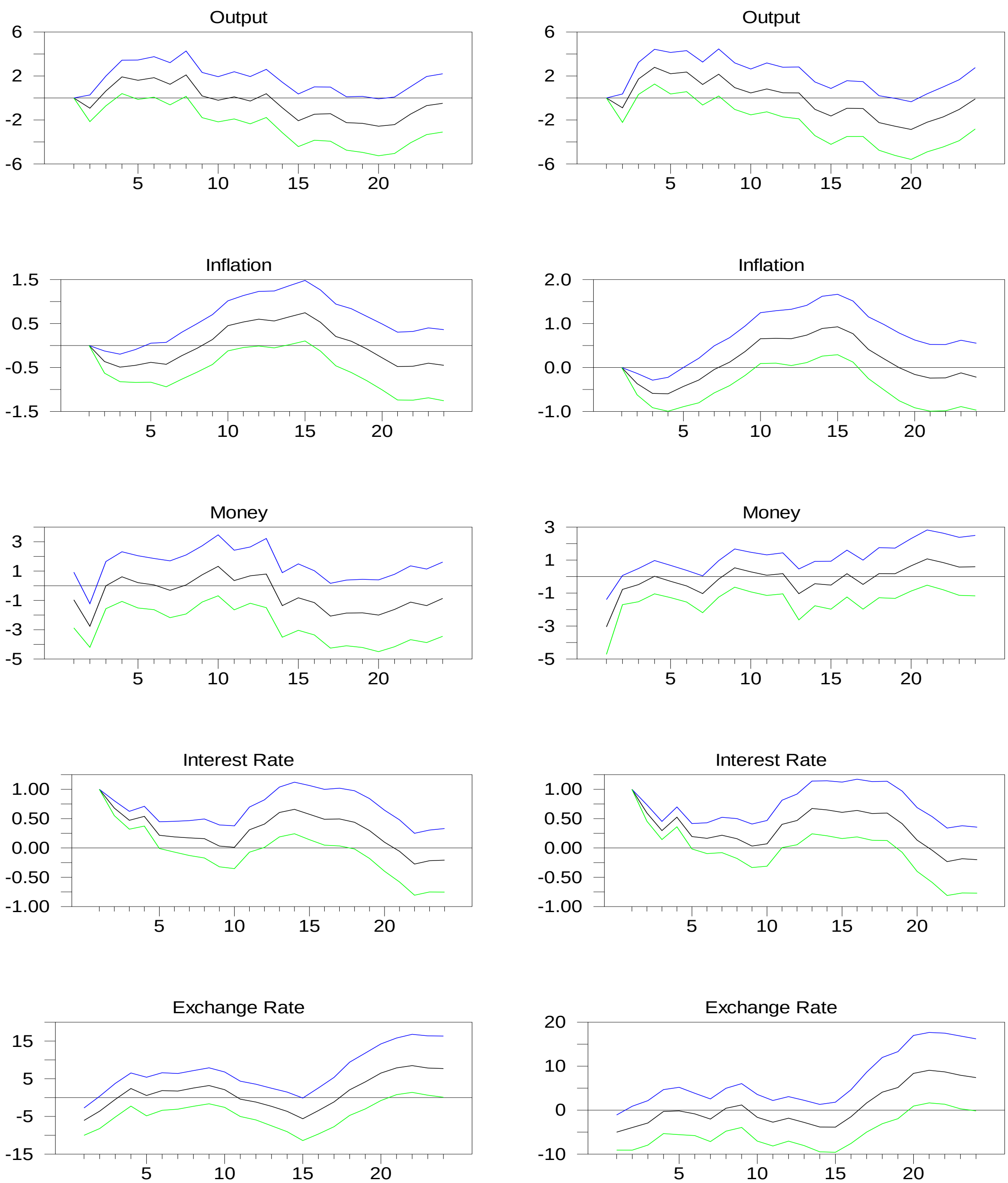

Figure 7: INDIA

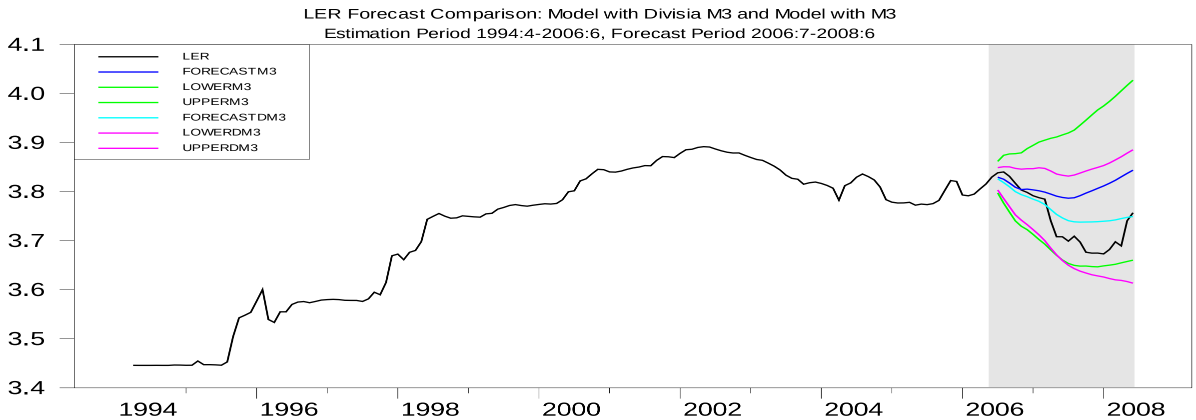

Figure 8: UK

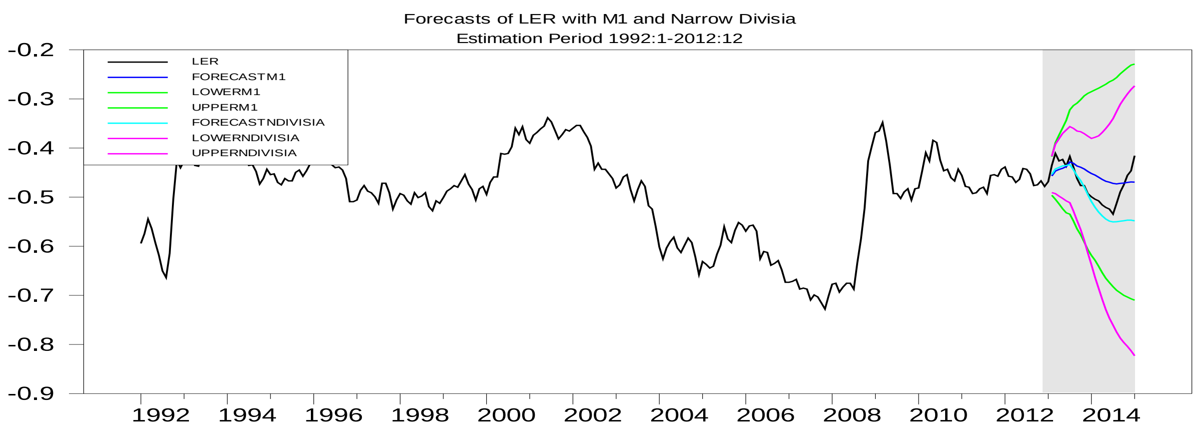

Figure 9: POLAND

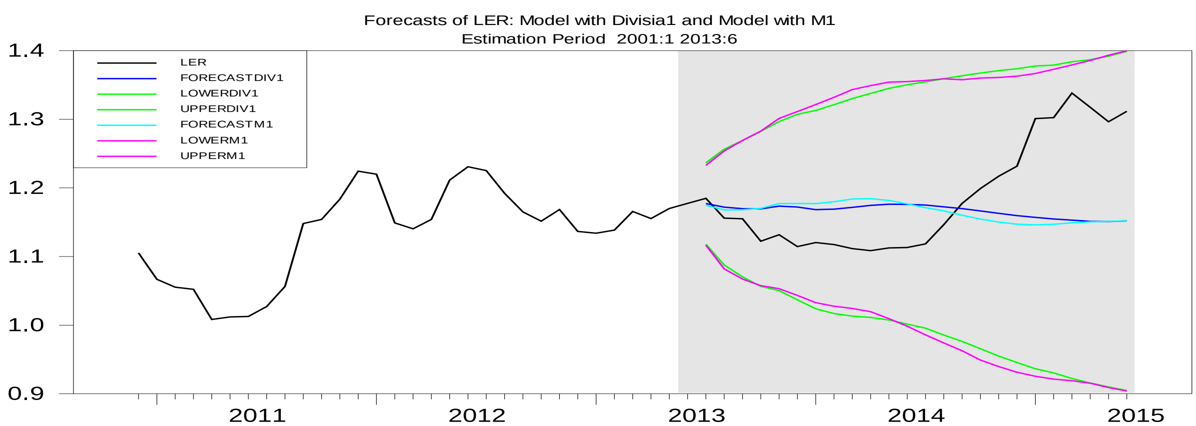

Table 1: Variance Decomposition of Exchange Rate due to Monetary Policy Shocks

Month	1	2	4	8	12	16	20	24
INDIA								
Model-R (No-Money)	10	10	12	11	9	8	7	6
Model-NR (No-Money)	14	14	17	15	12	10	10	9
Model-NR (M3)	8	8	10	9	7	6	6	5
Model-NR (DivisiaM3)	14	14	16	14	12	11	10	8
Model-NR (DivisiaM2)	17	18	21	15	13	12	11	9
Model-NR (DivisiaL1)	14	15	16	14	12	12	11	8
UK								
Model-R (No-Money)	2	3	4	2	3	2	2	2
Model-NR (No-Money)	1	2	2	2	3	2	2	2
Model-NR (M1)	11	9	5	3	4	2	3	3
Model-NR (M3)	4	2	2	2	5	3	5	5
Model-NR (Divisia)	4	2	3	4	9	10	16	18
POLAND								
Model-R (No-Money)	0	0	0	1	2	1	1	2
Model-NR (No-Money)	5	3	2	2	3	2	1	2
Model-NR (M2)	5	3	2	2	2	2	3	8
Model-NR (Divisia2)	7	4	3	3	3	4	4	7
Model-NR (M3)	4	3	2	2	2	2	3	7
Model-NR (Divisia3)	7	4	3	3	4	4	4	7

Table 2: Variance Decomposition of Exchange Rate due to Money Demand Shocks								
Month	1	2	4	8	12	16	20	24
INDIA								
Model(M3)	1	2	2	3	2	2	2	3
Model(DivisiaM3)	1	<1	1	2	2	3	4	3
Model(DivisiaM2)	<1	1	1	1	1	2	3	2
Model(DivisiaL1)	<1	<1	1	2	2	3	4	3
UK								
Model(M1)	2	1	1	2	1	1	1	1
Model(M3)	1	2	2	2	2	2	1	1
Model(Divisia)	1	1	2	10	12	13	15	17
POLAND								
Model(M2)	5	6	8	12	15	12	14	12
Model(Divisia2)	4	12	27	30	27	17	12	10
Model(M3)	4	4	7	11	15	12	12	11

Table 3: Forecast Statistic Root Mean Square Error							
Steps	1	2	4	8	12	20	24
INDIA							
Mod(No Money)	0.016815	0.027932	0.045089	0.081641	0.115957	0.130826	0.082897
Model(DivisiaM3)	0.016817	0.02794	0.045093	0.08162	0.11592	0.130837	0.082902
Model(M3)	0.016819	0.027943	0.045097	0.081626	0.115927	0.130855	0.082923
UK							
Mod(No Money)	0.016	0.026	0.037	0.039	0.043	0.128	0.394
Model(M1)	0.016	0.025	0.038	0.068	0.106	0.193	0.235
Model(M3)	0.016	0.026	0.039	0.06	0.097	0.229	0.523
Model(N-Divisia)	0.014	0.022	0.027	0.022	0.034	0.015	0.045
POLAND							
Model(No Money)	2.45	3.84	7.65	14.56	16.92	21.52	19.35
Model(M1)	2.48	3.92	8	15.82	17.53	19.54	16.48
Model(Divisia1)	2.46	3.85	7.82	15.62	17.46	19.79	17.14
Model(M3)	2.46	3.84	7.51	13.97	16.68	20.43	18.2
Model(Divisia3)	2.42	3.7	7.4	14.47	16.65	20.72	18.66

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Appendix:

Table A: Lag Selection Test

INDIA						
	(7 vs. 6 Lags)		(6 vs. 5 Lags)		(5 vs. 4 Lags)	
	χ^2	Significance Level	χ^2	Significance Level	χ^2	Significance Level
Model (DM3)	38.49	0.86	73.66	0.01	57.88	0.18
Model (M3)	38.24	0.87	54.12	0.29	69.43	0.03
Model (DL1)	39.09	0.84	74.33	0.01	58.11	0.17
Model (DM2)	49.71	0.44	80.31	0.00	70.37	0.02
UK						
	(13 vs 12 lags)		(12 vs 11 lags)		(11 vs 10 lags)	
	χ^2	Significance Level	χ^2	Significance Level	χ^2	Significance Level
Model (M1)	94.17	0.00	86.43	0.00	53.51	0.31
Model (M3)	96.44	0.00	67.77	0.04	76.33	0.01
Model(Divisia)	84.86	0.00	76.54	0.01	69.00	0.03
POLAND						
	(14 vs 13 lags)		(13 vs 12 lags)		(12 vs 11 lags)	
	χ^2	Significance Level	χ^2	Significance Level	χ^2	Significance Level
Model (M1)	73.04	0.01	101.33	0.00	59.43	0.15
Model (M3)	65.66	0.06	112.11	0.00	76.33	0.01
Model(Div1)	79.60	0.00	104.24	0.00	60.91	0.12
Model(Div3)	68.02	0.04	111.96	0.00	68.02	0.04

Table B: Largest Eigen Value		
India		
Lags	Lags 6	Lag 4
Model with M1	0.995655	0.995452
Model with M3	0.998252	0.999864
Model with DM3	0.980700	0.978289
UK		
Lags	Lags 13	Lag 6
Model with M1	0.998290	0.975593
Model with M3	0.980230	0.973018
Model with Divisia	0.999294	0.971836
Poland		
Lags	Lags 13	Lag 6
Model with M1	0.991314	0.987834
Model with M3	0.988180	0.988290
Model with Div3	0.986030	0.988290

Table C: MC Diagnostic Test									
Null Hypothesis: Both parts of the chain are asymptotically independent									
	India (Model with DM3)			**UK**(Model with Divisia)			**Poland**(Model with Divisia 3)		
	Variable Coefficient	NSE	CD	Variable Coefficient	NSE	CD	NSE	Variable Coefficient	CD
b21	0.002	0	3.22	0	0	1.258	0.001	0	0.228
b31	-0.008	0.002	-0.856	0.029	0.001	-0.511	-0.015	0.001	-0.889
b32	-0.157	0.071	-0.327	0.748	0.033	0.09	3.203	0.083	0.593

b41	0.018	0.001	0.487	-0.022	0	-0.241	-0.002	0	0.665
b43	0.086	0.002	-0.66	-0.029	0.002	-0.375	0	0.001	-0.122
b52	-0.274	0.059	-0.716	-0.539	0.023	-0.697	-3.604	0.144	0.584
b53	0.078	0.005	-2.239	-0.154	0.004	0.172	-0.282	0.009	-1.454
b54	-0.037	0.01	-1.662	0.002	0.012	2.038	-0.235	0.032	0.409
b56	-0.218	0.235	-1.849	0	0	0	0	0	0
b57	-0.178	0.018	-0.75	-0.038	0.012	-0.414	-0.143	0.015	1.18
b61	-0.003	0	2.561	0.004	0	-0.973	-0.007	0	0.966
b65	0.001	0.008	0.123	0.043	0.005	0.814	0.005	0.001	1.328
b67	-0.016	0.005	-2.21	0	0	0	0	0	0
b71	-0.074	0.003	0.008	0.057	0.005	-0.717	0.151	0.003	-0.753
b72	1.770	0.066	-0.052	0.74	0.191	1.259	6.84	0.144	0.35
b73	0.293	0.011	0.279	0.146	0.041	-0.6	-0.764	0.018	1.694
b74	-0.468	0.02	2.407	-0.413	0.071	1.055	-0.194	0.05	-0.241
b75	1.170	0.079	-0.621	0.269	0.269	-0.208	0.703	0.039	-1.538
b76	5.028	0.253	2.317	0.156	0.156	-2.358	3.092	0.114	-0.59

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Figure C: Impulse Response Functions due to Monetary Policy Shocks

Recursive Model with No-Money

India **UK** **Poland**

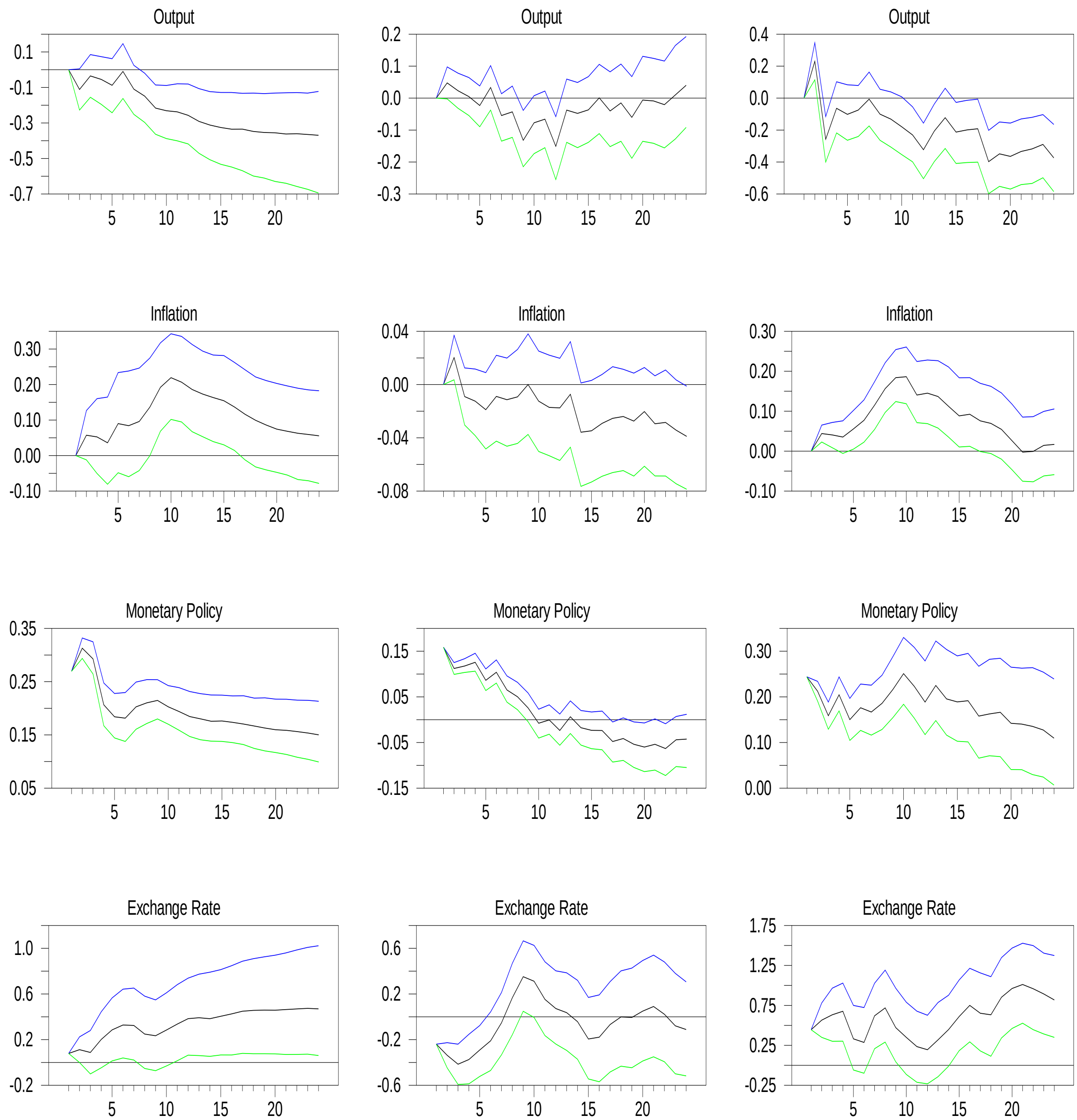

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Figure D: Impulse Response Functions due to Monetary Policy Shocks

Non-Recursive Model with No-Money

India **UK** **Poland**

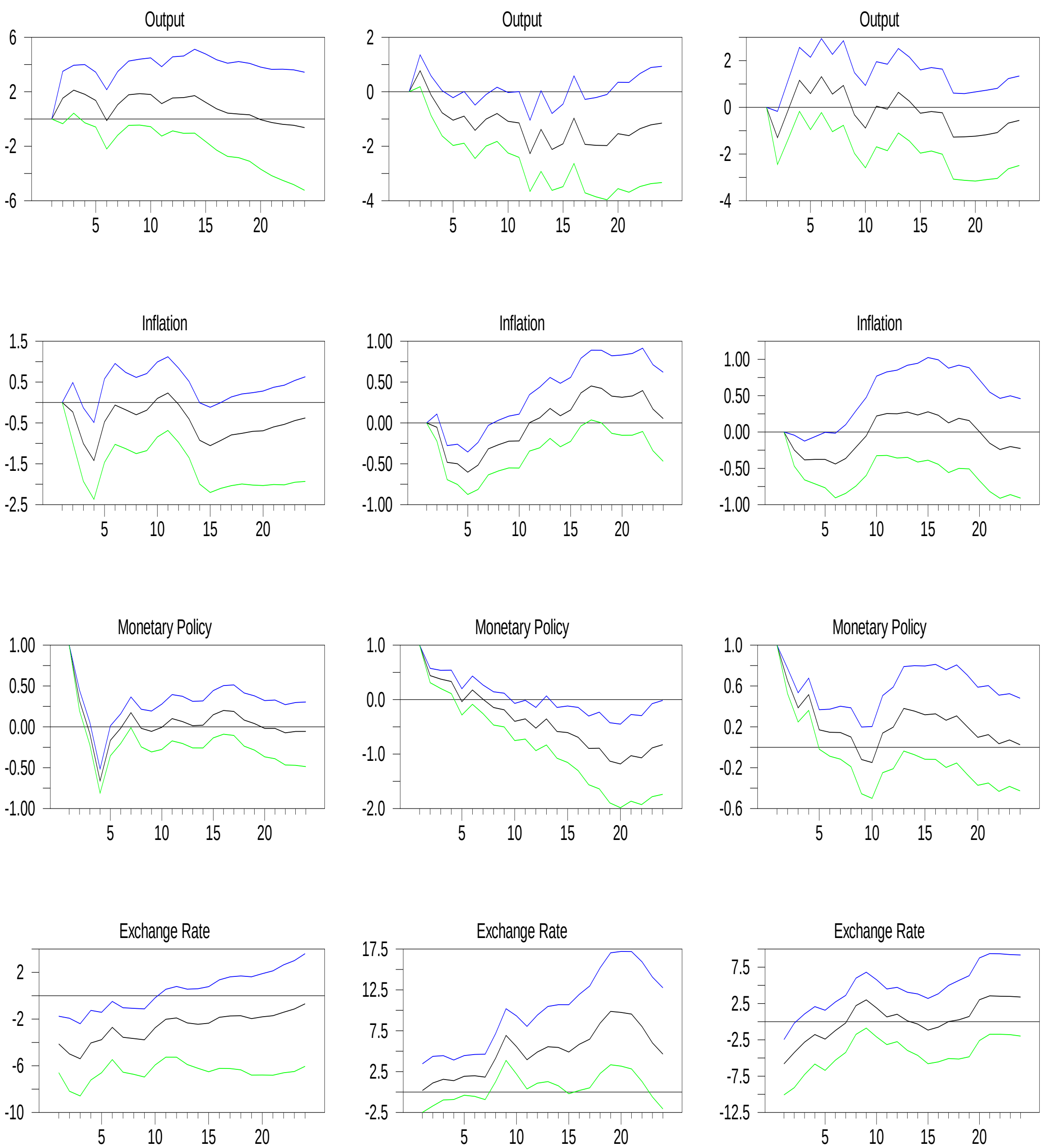

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Figure E: INDIA

Impulse Responses for Monetary Policy Shocks (Estimation period: Jan 2000- Jan 2008, Lags=4)

Model with Divisia M3 | Model with M3

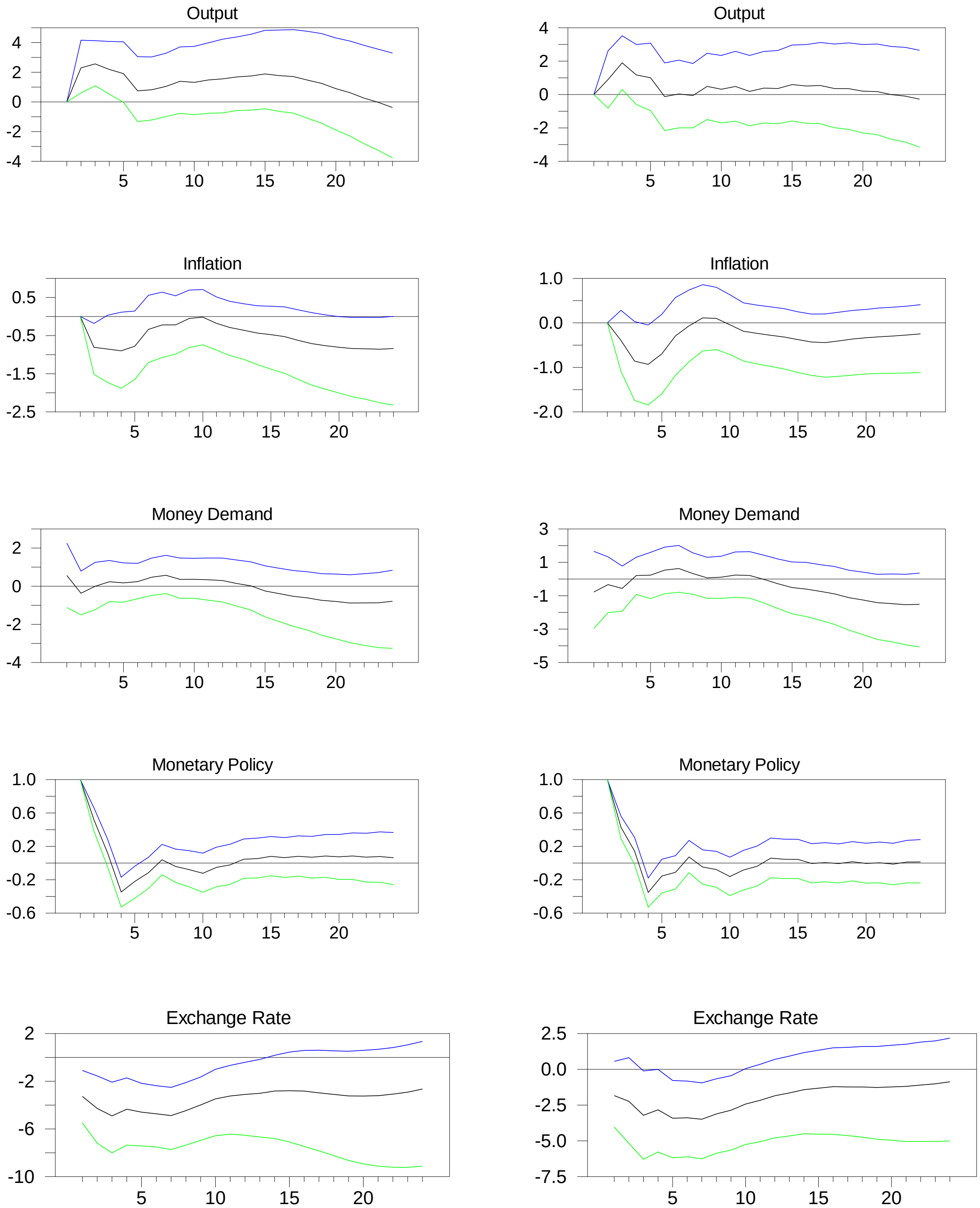

Figure F: UK

Impulse responses for Monetary Policy Shocks

(Estimation Period 1999 Jan - 2013 Dec)

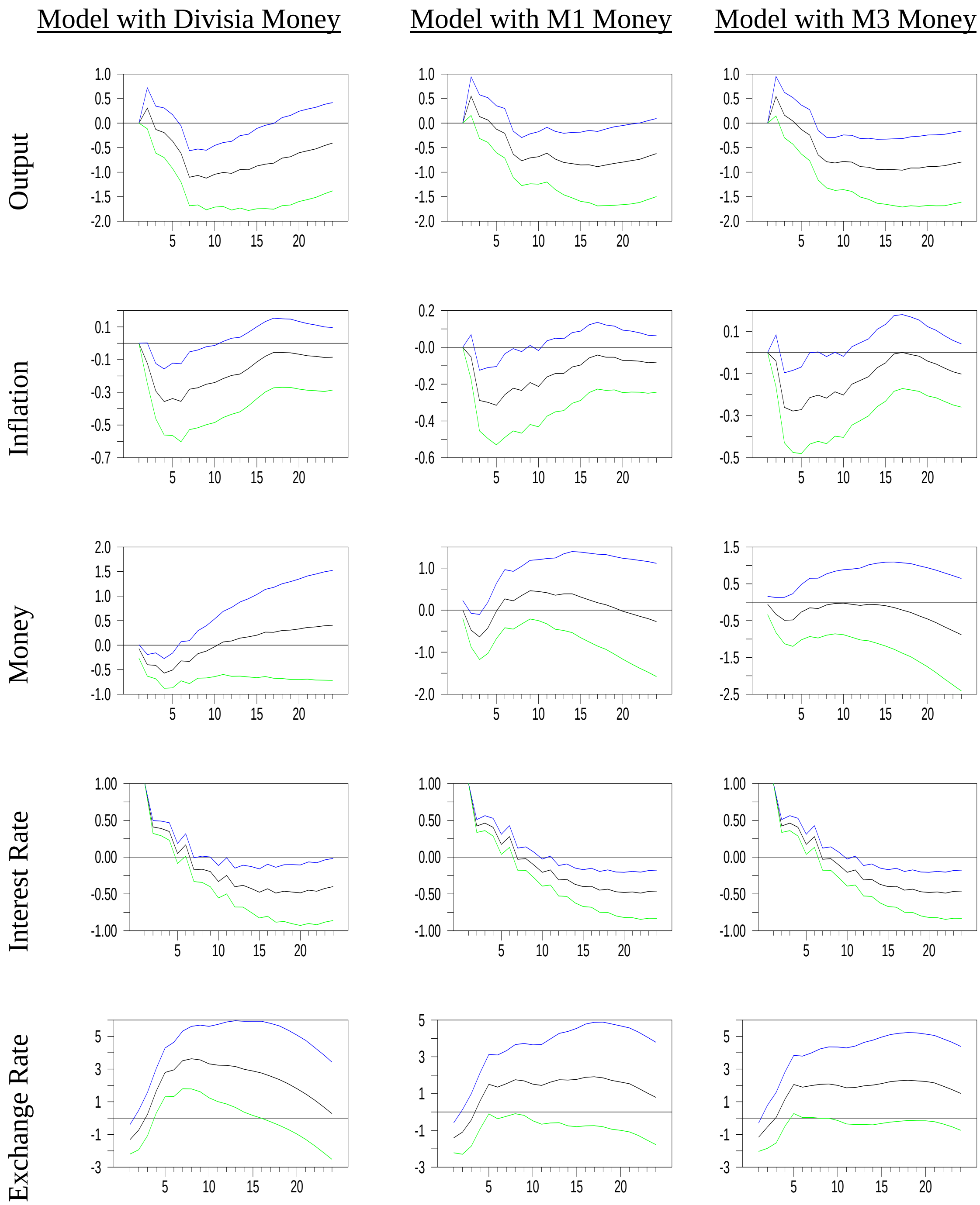

Figure G: POLAND

Impulse Responses for Monetary Policy Shocks

(Estimation Period 2005 Dec- 2015 June, Lags=6)

Model with Divisia M3 | Model with M3

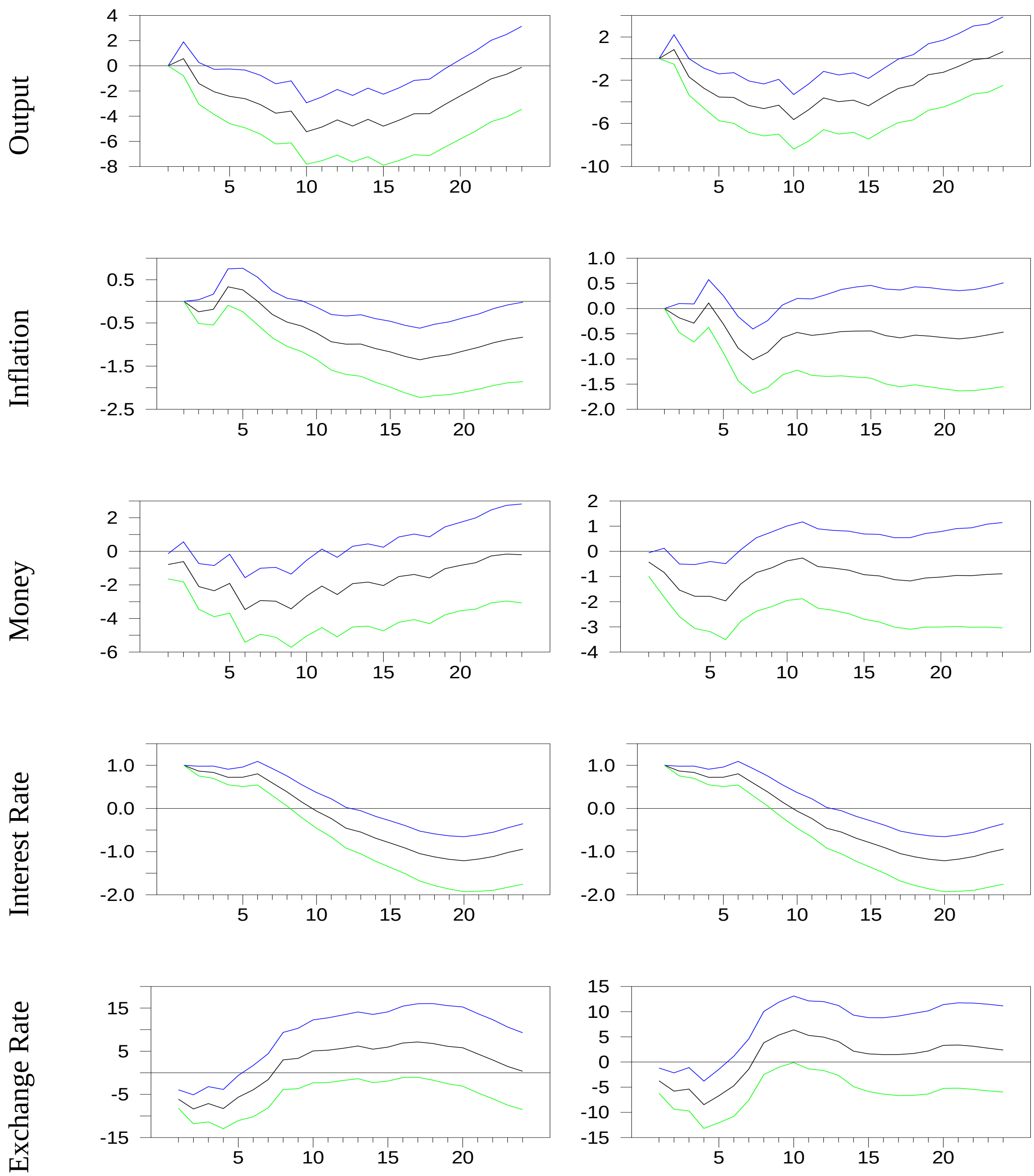

Figure H: INDIA

Impulse Responses for Money Demand Shocks

Lags = 6, Divisia DM3	Lags = 6, M3	Lags = 4, Divisia DM3	Lags = 4, M3

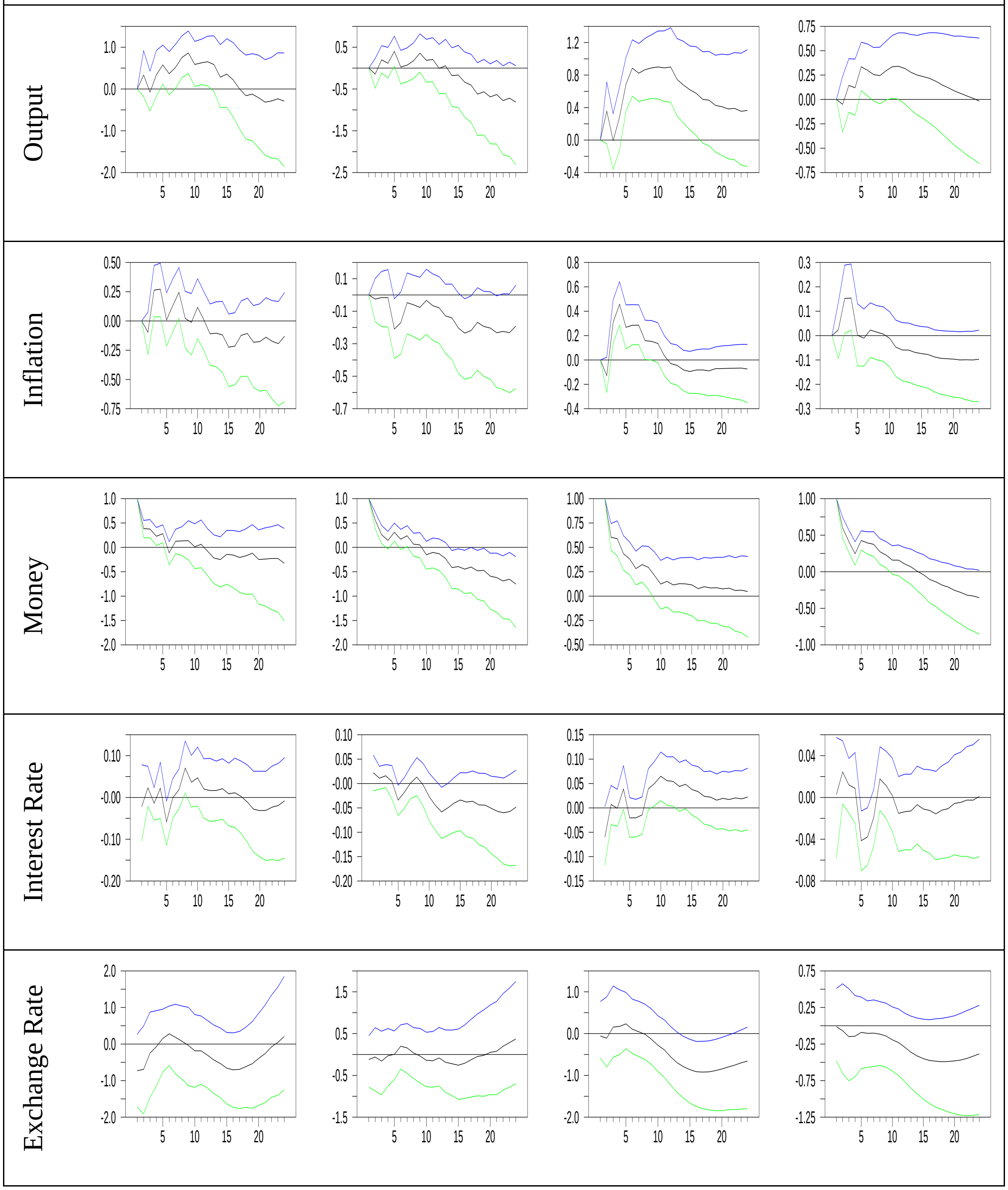

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Figure I: UK

Impulse responses for Monetary Demand Shocks

	Lags = 13, NDivisia (2001 Jan-2013 Jan)	Lags = 13, M1 (2001 Jan-2013 Jan)	Lags = 6, NDivisia (1999 Jan-2013 Dec)	Lags =6, M1 (1999 Jan-2013 Dec)

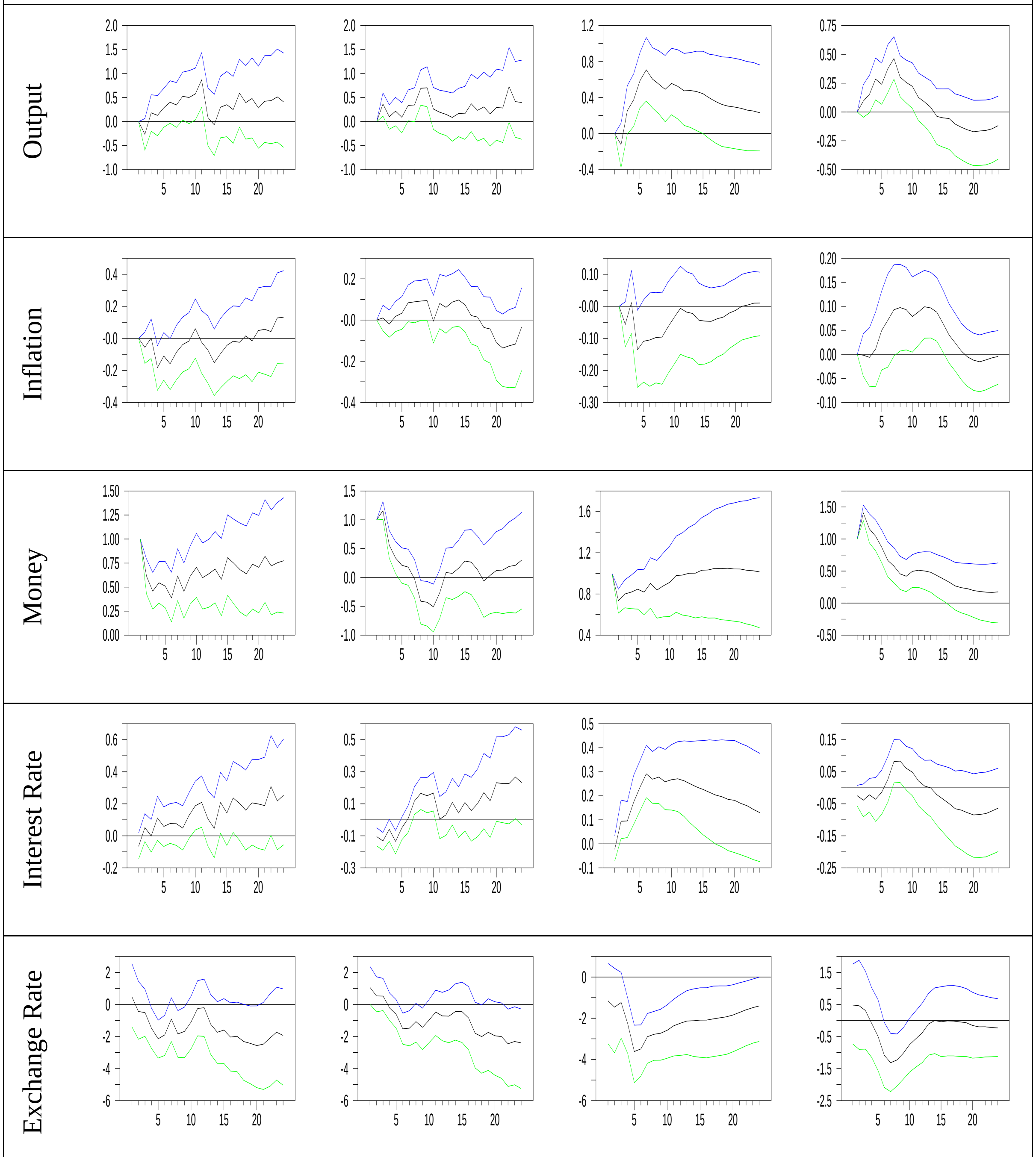

Figure J: POLAND

Impulse Responses for Monetary Demand Shocks

	Lags = 13, Divisia3 (2001 Dec-2015 June)	Lags = 13, M3 (2001 Dec-2015 June)	Lags = 6, Divisia3 (1999 Jan-2013 Dec)	Lags =6, M3 (1999 Jan-2013 Dec)