WP-2015-017

# Reassessing Exchange Rate Overshooting in a Monetary Framework

Soumya Suvra Bhadury, Taniya Ghosh

Indira Gandhi Institute of Development Research, Mumbai
June 2015
http://www.igidr.ac.in/pdf/publication/WP-2015-017.pdf

# Reassessing Exchange Rate Overshooting in a Monetary Framework

**Soumya Suvra Bhadury, Taniya Ghosh**
**Indira Gandhi Institute of Development Research (IGIDR)**
**General Arun Kumar Vaidya Marg**
**Goregaon (E), Mumbai- 400065, INDIA**
Email(corresponding author): taniya@igidr.ac.in

**Abstract**

*Money overtime has been deemphasized from most of the macroeconometric models of exchange rate making interest rate 'alone' the monetary policy instrument. One such model is Bjornland's (1999) Journal of International Economics â€œMonetary Policy and Exchange Rate Overshooting: Dornbusch was right after allâ€•. The model sets out to establish the empirical validity of Dornbusch exchange rate overshooting hypothesis for four small open economies. It does so though not with exact precision. When the same model is done using the correct econometric techniques, the impulse response functions for exchange rate due to a monetary policy shock are infact 'insignificant'. In this paper we revisit the Dornbusch exchange rate overshooting in a different model setting. A real money demand equations is added to the original model. Identification is achieved by imposing short-run and long-run restrictions while keeping the short-run interactions between the two variables monetary policy and exchange rate free. Classical neutrality of money is imposed according to which the monetary shocks are long-run neutral to certain real variables. Our paper rediscovers the validity of Dornbusch Overshooting hypothesis for Australia, Canada, Newzealand and Sweden when we compare it with Bjornland's model. More specifically, a contractionary monetary policy shock leads to exchange rate overshooting as predicted by Dornbusch. The exchange rate appreciates 'significantly' on impact to a monetary policy shock as shown by the impulse response functions and thereafter depreciates. Also the variance decomposition results justify our analysis by showing that money demand and money supply shocks explain siginificant portion of exchange rate fluctuations vis-a-vis Bjornland's original model.*

**Keywords: Monetary Policy; Money Demand; Structural VAR; Short Run; Long Run; Exchange Rate Overshooting; Liquidity Puzzle; Price Puzzle; Exchange Rate Puzzle; Forward Discount Bias Puzzle**

**JEL Code: C32, E41, E51, E52, F31, F41, F47**

**Reassessing Exchange Rate Overshooting in a Monetary Framework**

Soumya Suvra Bhadury, Taniya Ghosh[1]

March 20, 2015

## Abstract

Money overtime has been deemphasized from most of the macroeconometric models of exchange rate making interest rate 'alone' the monetary policy instrument. One such model is Bjornland's (1999) Journal of International Economics "Monetary Policy and Exchange Rate Overshooting: Dornbusch was right after all". The model sets out to establish the empirical validity of Dornbusch exchange rate overshooting hypothesis for four small open economies. It does so though not with exact precision. When the same model is done using the correct econometric techniques, the impulse response functions for exchange rate due to a monetary policy shock are infact 'insignificant'. In this paper we revisit the Dornbusch exchange rate overshooting in a different model setting. A real money demand equations is added to the original model. Identification is achieved by imposing short-run and long-run restrictions while keeping the short-run interactions between the two variables monetary policy and exchange rate free. Classical neutrality of money is imposed according to which the monetary shocks are long-run neutral to certain real variables. Our paper rediscovers the validity of Dornbusch Overshooting hypothesis for Australia, Canada, Newzealand and Sweden when we compare it with Bjornland's model. More specifically, a contractionary monetary policy shock leads to exchange rate overshooting as predicted by Dornbusch. The exchange rate appreciates 'significantly' on impact to a monetary policy shock as shown by the impulse response functions and thereafter depreciates. Also the variance decomposition results justify our analysis by showing that money demand and money supply shocks explain siginificant portion of exchange rate fluctuations vis-a-vis Bjornland's original model.

**Keywords**: Monetary Policy; Money Demand; Structural VAR; Short Run; Long Run; Exchange Rate Overshooting; Liquidity Puzzle; Price Puzzle; Exchange Rate Puzzle; Forward Discount Bias Puzzle

**JEL Classification**: C32, E41, E51, E52, F31, F41

[1] S. Bhadury
University of Kansas, Lawrence, Kansas, USA

T. Ghosh
Indira Gandhi Institute of Development Research (IGIDR), Mumbai, India

## Section 1: Introduction

The exchange rate overshooting hypothesis widely known as the Dornbusch(1976) overshooting model holds a very important position in the modern international macroeconomics literature. The theory predicts that a contractionary monetary policy shock (an increase in the domestic interest rate) should lead to on impact appreciation of the exchange rate (exchange rate overshooting) and thereafter depreciation of the currency in line with the uncovered interest parity. Bjornland's (1999) Journal of International Economics paper "Monetary Policy and Exchange Rate Overshooting: Dornbusch was right after all", establishes the empirical validity of Dornbusch exchange rate overshooting hypothesis for small open economies. A higher return on investments due to increase in interest rates in the domestic economy leads to a higher demand for domestic currency, appreciating the domestic currency vis-à-vis the foreign currency. However on careful examination of the facts using the correct econometric technique does point out some problems with the modelling procedure used in the paper. More precisely, Bjornland's model show exchange rate impulse responses which are actually 'insignificant' for some countries from a monetary policy shock. The monetary policy is not properly identified in the model. This calls for a closer look in to the possible causes of the issue and how we can fix them. We found that in the model, the domestic interest rate variable captures the policy reaction function of the Central bank without any reference to any 'money' term. And there lies the clue.

Money is relegated to an inferior position from most of the macroeconomic models over the time. In majority of exchange rate literature, interest rate alone plays the role of monetary policy instrument as Bjornland's (1999, Bjornland henceforth) model. In this paper we emphasize to bring money back into the system other than the interest rate. Bjornland in her paper examined exchange rate overshooting. But when we use the corrected error bands which is usually wider than given in her paper, we get, 'insignificant' impulse responses of exchange rates due to a monetary policy shock. The corrected error bands are computed using summing the lags of the coefficients drawn from Monte Carlo procedure which was evidently not done in the paper. Barnett et al. (working paper, 2015) have shown that the results from the exchange rate models improve greatly when money is added to the system. In comparison to model without money and the models with some contemporaneous interactions between money and funds rate, Leeper and Roush (2003) have found large and significant effects on the estimated real and nominal effects of policy. Hence money provides information important to identifying monetary policy-information that is not contained in the Federal fund rate.

Rotemberg and Woodford (1999) show that a Taylor (1993) rule is nearly optimal in the context of a standard New Keynesian model. Ireland (2001a, 2001b) finds empirical support for including money growth in the interest rule for policy. In Ireland's model, money ambiguously plays an informational rather than a causal role by helping to forecast future nominal interest rate. The realization of this neglect has revived attempts to assess the role of money in monetary policy making, by examining the "information content" of various monetary aggregates for predicting inflation (and output) over the alternate time horizons (Masuch et al.2003; Bruggean et al.2005 etc). Nelson (2003) offers an alternative role of money. He posits that money demand depends on a long-term interest rate. This is because the long rates matter for aggregate demand and the inclusion of a long rate in money demand amplifies the effects of changes in the stock of money on real aggregate demand. Nelson's specification of the Fed's interest rate rule is a dynamic generalization of the conventional Taylor rule, which exclude money. Money now has a direct effect that is independent of the short-term interest rate, an effect that Nelson argues support U.S. data. Anderson and Kavajecz (1994) noted that monetary aggregates can largely play as an indicator and/or targets of the monetary policy.

Goodfriend (1999) argues that money plays a critical role even under an interest rate policy because ``credibility for a price-path objective stems from a central bank's power to manage the stock of money, if need be, to enforce the objective.". In equilibrium money is not playing a causal role, yet it is essential for establishing the credibility that allows the Central bank to determine expected inflation at every point in time. Goodfriend calls for the exploration of models in which "monetary aggregate plays a role in transmitting monetary policy independently of interest rate policy". Similar argument have been posited by the following authors Christiano et al. (2007); Cochrane (2007) that monetary aggregates may play a nominal anchor role, whereby the announcement of a reference trajectory for future monetary growth, help agents form expectations about future prices.

In this paper we want to fix Bjornland's small open economy structural vector auto-regression (SVAR) model on exchange rates. We introduce real money demand as one of the equations in the SVAR. The inclusion of real money demand in addition to the interest rate captures the dynamics of the money market accurately. Money market has to be represented properly in a model in order to correctly identify the monetary policy. A model is able to identify the monetary policy well when a monetary policy shock gives mostly puzzle- free results.

The exchange rate puzzle occurs when a restrictive domestic monetary policy leads to on impact depreciation of domestic currency. Or, if it appreciates, it does so for a prolonged period of time violating the uncovered interest parity condition which is known as the forward discount bias puzzle or delayed overshooting. The liquidity puzzle is an empirical finding when a money market shock is associated with increases in the interest rate instead of a decrease. This is the absence of the liquidity effect (negative correlation between monetary aggregates and interest rates) in the system. Lastly, "price puzzle" is a phenomenon where a contractionary monetary policy shocks identified with an increase in interest rates, leads to a persistent rise in price level instead of a reduction of it.

By introducing real money demand to the Bjornland model and by employing appropriate SVAR model with short-run and long-run restrictions, our model is able to eliminate some of the most common anomalies, like liquidity puzzle, price puzzle, exchange rate puzzle and forward discount puzzle, which have plagued the empirical literature on exchange rates. Kim and Roubini

(2000, Kim and Roubini henceforth) have addressed the issue and eliminated some of the puzzles for G-6 countries. Although they are able to get rid of all the major puzzles and establish Dornbusch overshooting, as discussed by Bjornland, Canada and Germany still showed 'delayed overshooting' in their paper. Also Kim and Roubini 's model is overidentified with restrictions well and above an exactly identified system. The overidentified system is always more complicated to estimate. On the other hand, we have a just-identified system with very minimal short-run restrictions and the model is exactly identified by imposing additional long-run restrictions. In other words, we have an exactly identified system yet we are setting the contemporaneous interaction between monetary policy and real exchange rate free, an important assumption required to achieve exchange rate overshooting (Bjornland). Moreover, we have an additional money demand equation in the model.

Kim and Roubini have identified the monetary policy in the model by assuming that domestic interest rate does not respond contemporaneously to output and price shocks for a monthly data. This is due to a lag in availability of information on output (GDP) and prices as they are only published quarterly whereas monetary policy is set more frequently say for many countries monthly. This is the key assumption used to identify the money demand and money supply which entails the use of monthly data. The same assumption is not sensible to be used for a quarterly data analysis. In the empirical literature, it is actually an immensely challenging task to identify the money supply and money demand correctly as the data seem to confound each other. And in many cases adding the money variable and not being able to properly identify the money demand shocks from the money supply shocks makes the model very complicated. This has led to have most of the empirical analyses employing Kim and Roubini kind of identification assumptions on a monthly dataset or more conveniently, to keep the model simple by just having interest rates as the sole monetary policy instrument in the SVAR analysis. Real activity is represented by industrial production in a monthly data analysis. But any Central Bank's monetary policy is based on real GDP and not industrial production and also many countries do not publish monthly data on many macroeconomic variable. Hence, we believe that having a model with identification assumptions which can be used for a quarterly as well as for a monthly data analysis is important.

As predicted by theory we have money supply (monetary policy) and money demand both affected by real GDP and inflation contemporaneously in our model. And identification of money demand and money supply is achieved by imposing long-run neutrality assumptions while keeping the short-run interactions free between the two variables monetary policy and exchange rate free. In the long-run, neutrality of money on real exchange rate and real money demand are imposed. According to this theory, in the long-run the Central Bank does not affect the real variables of the economy through its monetary policy. The results that we obtain in this paper holds with alternative identification restrictions once we add money demand equation to the model.

To make a direct comparison of our work with Bjornland's original model, we consider the same four set of countries Australia, Canada, Newzealand and Sweden and use the same dataset as her. Our model is able to get 'significant' impulse responses for all countries depicting exchange rate overshooting as predicted by Dornbusch which the original paper could not if done the right way. Barnett et al. (2015) claim that money plays the role of the informational variable in terms of rightly capturing the flow of monetary variables and that the presence of money increases the predictive content of the policy variables. Money plays an informational role if it facilitates the domestic interest rate to explain a significant part of the exchange rate fluctuation and causal role if the monetary aggregates by itself explain a significant part of the exchange rate fluctuation. The variance decomposition table establishes the informational role of money by allowing the domestic interest rate to explain more of exchange rate variance for Australia, Newzealand and Canada and causal role for Sweden.

**Section 2: Estimation**
**Model**

The system of equation representing dynamic structural models can be collected and written in the vector form as

$$y_t = B(L)u_t \tag{3.1}$$

Where $B(L) = B_0 + B_1 L + B_2 L^2 + B_3 L^3 \dots \dots \dots$, each $B_i$ is a $n \times n$ matrix, $L$ is the lag operator, $y_t$ is an $n \times 1$ data vector and $u_t$ is an $n \times 1$ structural disturbances vector. $u_t$ is serially and mutually uncorrelated. Although for simplicity, we have ignored the deterministic terms in the structural moving average representation (3.1), but they have not been suppressed in our empirical analysis.

If $B(L)$ is invertible, premultiplying equation (3.1) by $B_0 B(L)^{-1}$ , the result is

$$\Phi(L)\, y_t = \epsilon_t \tag{3.2}$$

Where $\Phi(L) = \Phi_0 + \Phi_1 L + \Phi_2 L^2 + \Phi_3 L^3 \dots \dots \dots,$

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

$$\epsilon_t = B_0 u_t \tag{3.3}$$

And the reduced form coefficients in $\Phi(L)$ are nonlinear functions of coefficients from the structural moving average representation

$$\Phi(L) = B_0\, B(L)^{-1} \qquad (3.4)$$

It is possible to recover the structural parameters (given in equation 3.1) from the reduced form model if $B_0$ is identified as $\Phi(L)$ can be estimated by ordinary least squares on each equation in (3.2). Ideally, the restrictions imposed to identify a SVAR are broadly consistent with the economic theories and provide sensible outcomes. Generally, the metric used is whether the behavior of the dynamic responses of the model accords with the economic theories. Given a set of variables of interest and criteria for model selection, identification restrictions can be imposed in a number of different ways. Most commonly, these involve restrictions on $B_0$ (the contemporaneous relationships between the variables in the system), or the long run restrictions or a combination of short-run (actually the contemporaneous restriction on $B_0$) and long-run restrictions (restrictions on long-run matrix). The long-run restrictions on macroeconomic variables due to a structural shock is imposed using restrictions on the long-run multiplier matrix which is the sum of coefficients in $B(L)$ and is given by $B(1)$ evaluated at $L$ =1. It is related to $\Phi(1)$, a matrix representing the sum of reduced-form VAR coefficients, as given below

$$\Phi(1) = B_0\, B(1)^{-1} \qquad (3.5)$$

Letting $\Omega$ denote the variance-covariance matrix of $\epsilon_t$ and $D$ denote the covariance matrix of the structural form, implies

$$\Omega = E(\epsilon_t \epsilon_t') = B_0^{-1} E(u_t u_t')(B_0^{-1})' = B_0^{-1} D (B_0^{-1})' \qquad (3.6)$$

To estimate the parameters from the structural form equations requires that the model be atleast exactly identified. For a *n*-variable VAR, exact identification requires no more than *n.(n-1)/2* restrictions on $B_0$. The Cholesky decomposition of reduced from innovations (Sims, 1980) imposes a recursive structure to identify the model where $B_0$ is a triangular matrix. This makes the economic interpretation of the model extremely difficult. Hence, for our paper we apply a combination of short-run and long-run restrictions imposing exactly *n.(n-1)/2* restrictions on $B_0$ and long-run matrix ($B(1)$) together to identify the monetary policy.

**Identification**

We have a 6-variable VAR[2] that includes trade weighted foreign interest rate ($rfor$), the level of inflation in the domestic small open economy ($\pi$), real output ($gdp$), first difference of real money ($\Delta \frac{M}{P}$) where real money is the M1 (or M3) money balances deflated by the consumer prices, first difference of real exchange rate, domestic currency per trade weighted foreign

[2] It is shown that differencing of variables do not provide gain in asymptotic efficiency of the model and may throw away information regarding the co-movements in the data like cointegrating relationship between the variables in a VAR.

currency ($\Delta RER$) and nominal short-term domestic interest rate ($rdom$). Our identification scheme based on equation (3.7) is given below.

$$\begin{pmatrix} \epsilon_t^{rfor} \\ \epsilon_t^{\pi} \\ \epsilon_t^{gdp} \\ \epsilon_t^{rdom} \\ \epsilon_t^{\Delta M/P} \\ \epsilon_t^{\Delta RER} \end{pmatrix} = \begin{pmatrix} b_{11} & 0 & 0 & 0 & 0 & 0 \\ b_{21} & b_{22} & 0 & 0 & 0 & 0 \\ b_{31} & b_{32} & b_{33} & 0 & 0 & 0 \\ b_{41} & b_{42} & b_{43} & b_{44} & b_{45} & b_{46} \\ b_{51} & b_{52} & b_{53} & b_{54} & b_{55} & b_{56} \\ b_{61} & b_{62} & b_{54} & b_{64} & b_{65} & b_{66} \end{pmatrix} \begin{pmatrix} u_t^{rfor} \\ u_t^{\pi} \\ u_t^{gdp} \\ u_t^{rdom} \\ u_t^{\Delta M/P} \\ u_t^{\Delta RER} \end{pmatrix} \tag{3.7}$$

$u$ is the vector of structural innovations and $\epsilon$ is the vector of errors from the reduced form equations where the vector is given by (foreign interest rate shocks, inflation shocks, real output shocks, money demand shocks, monetary policy shocks, and real exchange rate shocks). Generally, restrictions on $B_0$ are motivated in the following way. Foreign interest rate in a small open economy framework appears exogenous with none of the domestic variables being able to affect it contemporaneously (but can do so overtime). We would like to study the effect of a exogenous monetary policy shock on macroeconomic variables of a domestic economy, it is necessary to include the foreign interest rate to isolate and control the exogenous component of monetary policy shocks. A further type of behavioral restriction often imposed is that certain variables respond slowly to movements in financial and policy variables due to nominal rigidities. So, for example, output and prices respond to changes in domestic monetary policy variables and exchange rates with a lag but both do respond to the foreign interest rate contemporaneously. Also output responds to domestic price instantaneously. The standard money demand function usually depends on output, prices and the domestic interest rate. People's willingness to hold cash in an open economy also depends on the foreign interest rates and the exchange rates. Monetary policy equation is assumed to be the reaction function of the monetary authority, which sets the interest rate after observing the current value of inflation, output, money supply, the interest rate and the exchange rate. We believe that the monetary authorities cannot ignore the exchange rate movements; this follows from the small open economy assumption. Also when the monetary authorities set its interest rate, we assume that it keeps an eye on the foreign interest rate which may have serious repercussion on the small open economy. The real exchange rate variable in the model is the most volatile variables and is quick to react to almost all shocks be it from inside or outside.

The ordering of first three variables (foreign interest rates, inflation and output) and domestic interest rate being the sole monetary policy instrument is a standard practice in the VAR literature for small open economies. It implies that usually equation (3.1) is a 5-variable VAR with no equation with money. Also, as noted by Bjornland to achieve identification most such VAR models impose restrictions on contemporaneous interactions between monetary policy and real exchange rates (through the recursive Cholesky decomposition). Such VAR models have shown to be plagued by various empirical puzzles and results inconsistent with Dornbusch's theory. Bjornland tried to tackle the problem of achieving the identification requirements of the model yet not constraining the contemporaneous relationship between the two variables by employing the short-run and long-run procedure. She has kept the short-run (that is the contemporaneous relation) between monetary policy and the real exchange rate free but instead has imposed an additional restriction of long-run money neutrality. By doing so she is able to achieve Dornbusch overshooting but 'insignificant' in some cases as shown by the impulse responses in section 3 when done in the correct way.

The argument is we possibly cannot identify the monetary policy perfectly in a model without actually having a 'money' term in it. In our effort to improve the model, we add a money demand equation to the model and make it a 6-variable VAR system. The advantage of the model is we keep the short-run interactions between the three variables money, domestic interest rates and the real exchange rate as free as possible. The free interaction in the short-run between monetary policy and exchange rates is a crucial assumption in order to capture accurately the exchange rate dynamics as we believe there is a two-way interaction between the variables (that is, real exchange rate affects monetary policy and monetary policy in turn, affect real exchange rates) in the short-run. We impose an additional short-run restriction of either $b_{56} = 0$ or $b_{45} = 0$ in (3.7) to identify the money supply vis-à-vis money demand. When we set $b_{56} = 0$ in the short run, we assume that the Central Banks do care about money when setting its interest rates (and money demand does depend on the domestic interest rate) while people desire to hold cash does not depend on the real exchange rate, but the real exchange rate, in turn could affect the money demand. Or, we set $b_{45} = 0$ in the short run, where we assume that the Central Banks do not care about money when setting its interest rates (but money demand does depend on the domestic interest rate) while there is a two-way interactions between real money demand and real exchange rates (that is, real exchange rate affects real money demand and real money demand in turn, affect real exchange rates)[3]. And to achieve exact identification we impose two long-run neutrality of money assumption according to which the domestic interest rate does not affect the real money demand and the real exchange rate in the long-run. This assumption allows us to estimate the structural model given in equation (3.1) with much lesser restrictions on instantaneous relationships between the financial and policy variables as is usually seen in the SVAR literature and yet correctly identify the monetary policy.

The long-run neutrality assumption where in the monetary policy does not affect the real exchange rate as well as the real money demand in the long run is implemented by setting $B_{46}(1) = B_{56}(1) = 0$, where each element of $B(1)$ matrix is the sum of structural VAR coefficients.

---

[33] The qualitative results of the model are unchanged with either of the restrictions $b_{56} = 0$ or $b_{45} = 0$ used.

$$B(1) = \begin{pmatrix} . & . & . & . & . & . \\ . & . & . & . & . & . \\ . & . & . & . & . & . \\ . & . & . & . & . & . \\ . & . & . & 0 & . & . \\ . & . & . & 0 & . & . \end{pmatrix} \tag{3.8}$$

The imposition of the long-run neutrality assumption makes the 6 variable VAR model to be exactly identified with *n.(n-1)/2 =15* restrictions.

The SVAR consists of real money demand and the real exchange rate in differenced form ($\Delta \frac{M}{P}$ and $\Delta RER$, respectively). The long-run restrictions on these two macroeconomic variables due to a monetary policy is imposed using restrictions on the long-run multiplier matrix which is the sum of coefficients in $B(1)$. When we impose the condition that monetary policy disturbance has no long run effect on first difference of real money demand and first difference of real exchange rate by restricting the sum of the coefficients of them, that is, $B_{46}(1) = B_{56}(1) = 0$, it implies that, the monetary policy shock has no permanent effect on the *level* of real money demand or the *level* of real exchange rate (Blanchard and Quah, 1989).

**Section 3: Empirical Results**

We use the same dataset as Bjornland paper and it is directly taken from author's website to render comparison with our paper. The author's choice of the sample period is based on stable macroeconomic conditions in the respective countries. All the series are from OECD database except the Federal Funds rate which is from Ecowin. The authors use real effective exchange rate measured against a basket of trading partners and trade weighted foreign interest rates obtained from various sources (see Bjornland for details). Money, output and inflation are seasonally adjusted by the official sources. M1 money is used for all the analyses except for Sweden for which M3 money is used due to unavailability of early M1 data. All variables are in logarithms except the interest rates. Inflation ($\pi$) is calculated as the annual change in log of consumer prices. The quarterly VAR is estimated using 3 lags. The lags are selected by sequential likelihood ratio test in RATS (see Doan 2013). The results from sequential likelihood ratio test is presented in table A in the appendix. Based on the results select 3 lags for all the countries and 2 lags for Canada. Bjornland uses 3 lags for all the countries in her model without money demand. Also our model is stable for all the countries given by the largest root being less than one (table B in appendix).

In this section, we have 2 subsections, Subsection 3.1 we compare SVAR results of our model vis-à-vis Bjornland model for the four countries in terms of impulse response functions, Subsection 3.2 we perform the variance decomposition analysis of our model vis-à-vis Bjornland model for the four countries. Finally we conclude in section 4.

### 3.1: Impulse Response Functions

Bjornland in her paper analysed the Dornbusch exchange rate overshooting hypothesis. Although the author has tried to establish the hypothesis by showing on impact appreciation of exchange rates after a monetary policy shock and depreciation thereafter, we are not able to replicate the results. When we use corrected error bands which is usually wider than as reported by Bjornland, we get ‘insignificant’ impulse responses for exchange rate due to a monetary policy shock. The corrected error bands are computed using the lag sums for the coefficients drawn from Monte Carlo procedure rather than the OLS estimates of the coefficients. The left panel in figures 1-4 display the impulse responses from a monetary policy shock in Bjornland’s original model for Australia, Newzealand, Sweden and Canada. The impulse response functions for exchange rate are insignificant in all the four graphs. On the other hand, the right panel in figures 1-4 displays the impulse responses for our model for the four small open economies. We discuss the results in details below. In the graphs below the effect of monetary policy shock is normalized so that interest rates increase by one percentage point in the first month and a decrease in exchange rate implies appreciation. The statistical significance of impulse responses are examined using the Bayesian Monte Carlo integration in RATS to draw 1000 replications for the just-identified SVAR model. The 0.16 and 0.84 fractiles corresponds to the upper and lower dashed lines of the probability bands (see Doan, 2013).

Figure 1 represents Australia’s impulse responses from a unit monetary policy shock for the period 1987 Q1 to 2004 Q4. The original Bjornland model for Australia exhibit ‘insignificant’ exchange rate overshooting for almost all sub-samples in the dataset as also seen in the graph (left panel). On the other hand, we see that the model with money demand (right panel), the intensity of exchange rate overshooting is more pronounced (significant) as compared to Bjornland’s original model. Similarly, the fall in prices and output due to a monetary shock is more pronounced in the model with money demand as seen in the second panel. On impact to an unit monetary policy shock real exchange rate appreciates by 5 percentage points before depreciating back to the long run equilibrium, output gradually falls by almost 0.5 percentage points and the fall is significant from 9-15 quarters. After a very small increase. prices actually starts falling significantly from 8-14 quarters and it falls by almost 0.8 percentage points due to a unit monetary policy shock. Monetary aggregate falls by 3 percentage points and significantly from 4-8 quarters.

**Figure 1**
Australia

**Model Bjornland** | **Model with Money Demand**

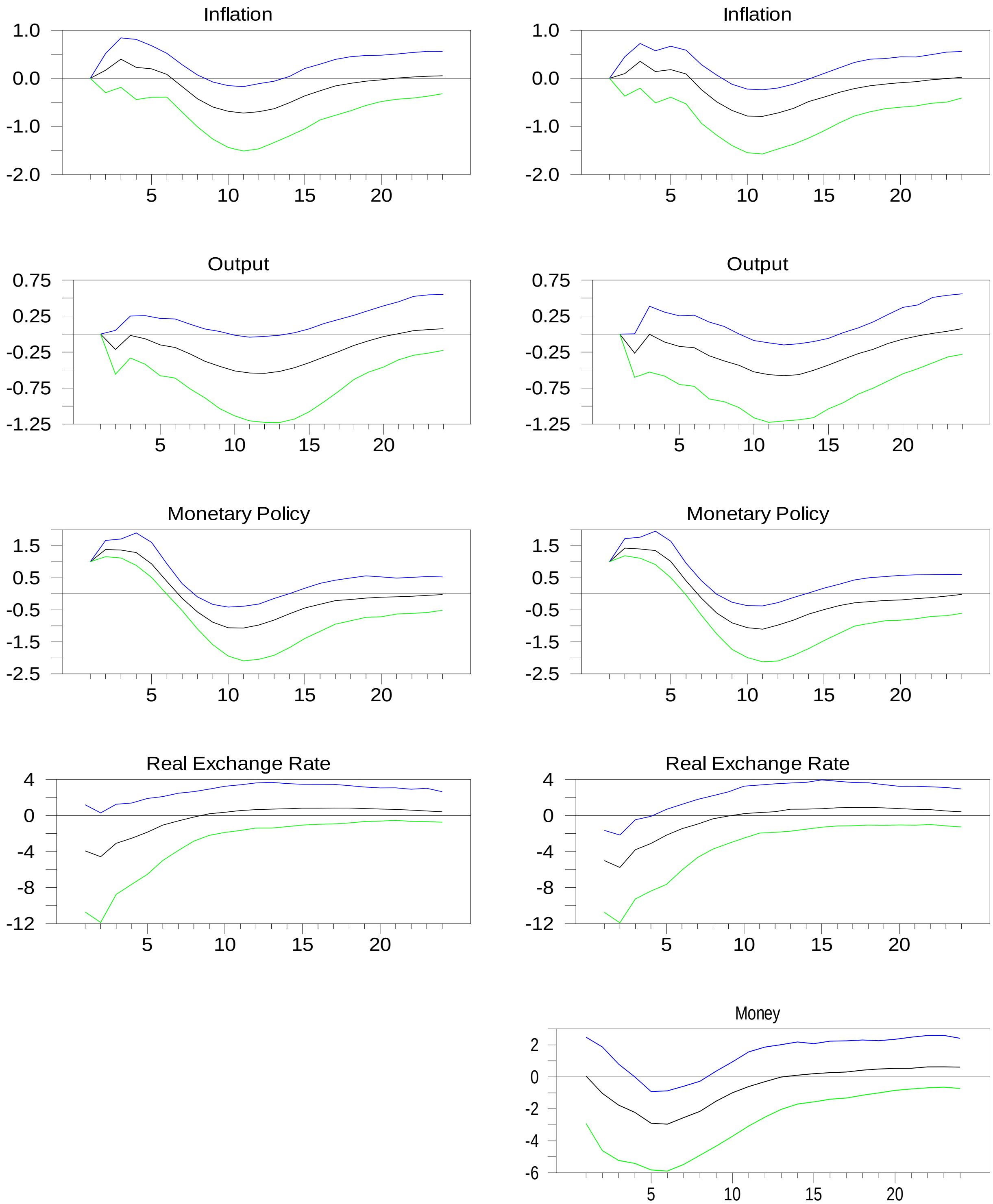
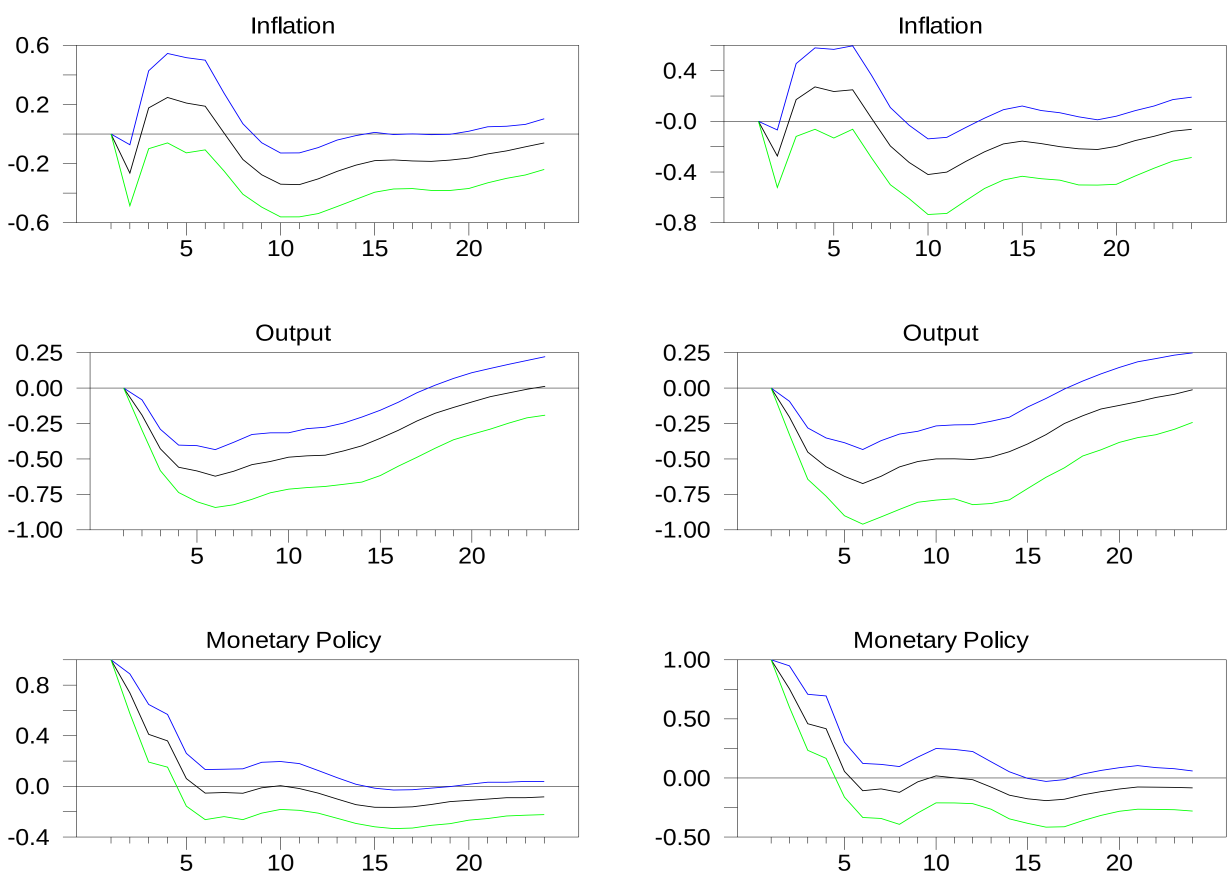


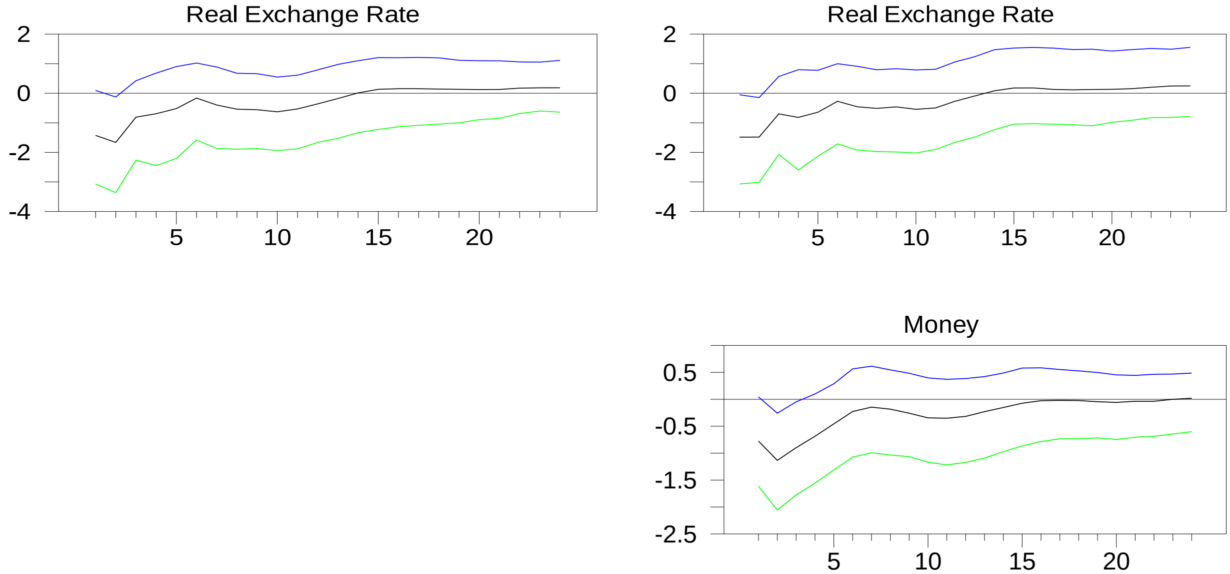
Figure 2 represents Sweden's impulse responses from a unit monetary policy shock for the period 1983 Q3 to 2004 Q4. The original Bjornland model for Sweden exhibit almost 'insignificant' exchange rate overshooting for all sub-samples in the dataset (left panel), where the upper band is slightly above the origin. On the other hand, our model (right panel), show 'significant' exchange rate overshooting in many samples where both the upper and the lower bands are below the origin on impact to a monetary policy shock. The responses of prices and output are similar in both the models. Prices, output and money demand all fall on impact to a monetary policy shock. On impact to a unit monetary policy shock real in our model exchange rate appreciates by 1.5 percentage points before depreciating back. Output gradually falls by almost 0.7 percentage points and the fall is significant throughout. Prices fall by almost 0.4 percentage points. Money falls by 3 percentage points and significantly from 4-8 quarters.

**Figure 2**

Sweden

**Model Bjornland** | **Model with Money Demand**

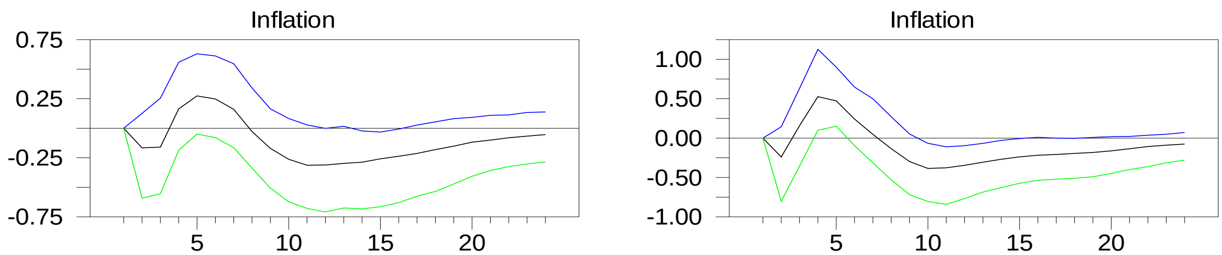





Similary for Canada we can find subsamples where we get 'significant' exchange rate overshooting for models where demand and supply aspect of money market is captures as opposed to models with interest rate being the only policy variable. Figure 3 gives impulse responses from a unit monetary policy shock for the period 1987 Q4 to 2004 Q4. Comparing the left and the right panel, we see that the original Bjornland model for Canada exhibit 'insignificant' exchange rate overshooting and the model with money demand produce 'significant' exchange rate overshooting. We get the expected behavior of prices and output in the model due to a monetary shock. On impact to an unit monetary policy shock in our model real exchange rate appreciates by 3.75 percentage points before depreciating back to the long run equilibrium, output gradually falls by almost 1.0 percentage points and the fall is significant after 4th quarter and prices fall by 0.375 percentage points significantly after 9$^{th}$ quarter. due to a unit monetary policy shock. Money demand falls by almost 2 percentage points and significantly from 3-7 quarters.

**Figure 3**
Canada

**Model Bjornland** | **Model with Money Demand**



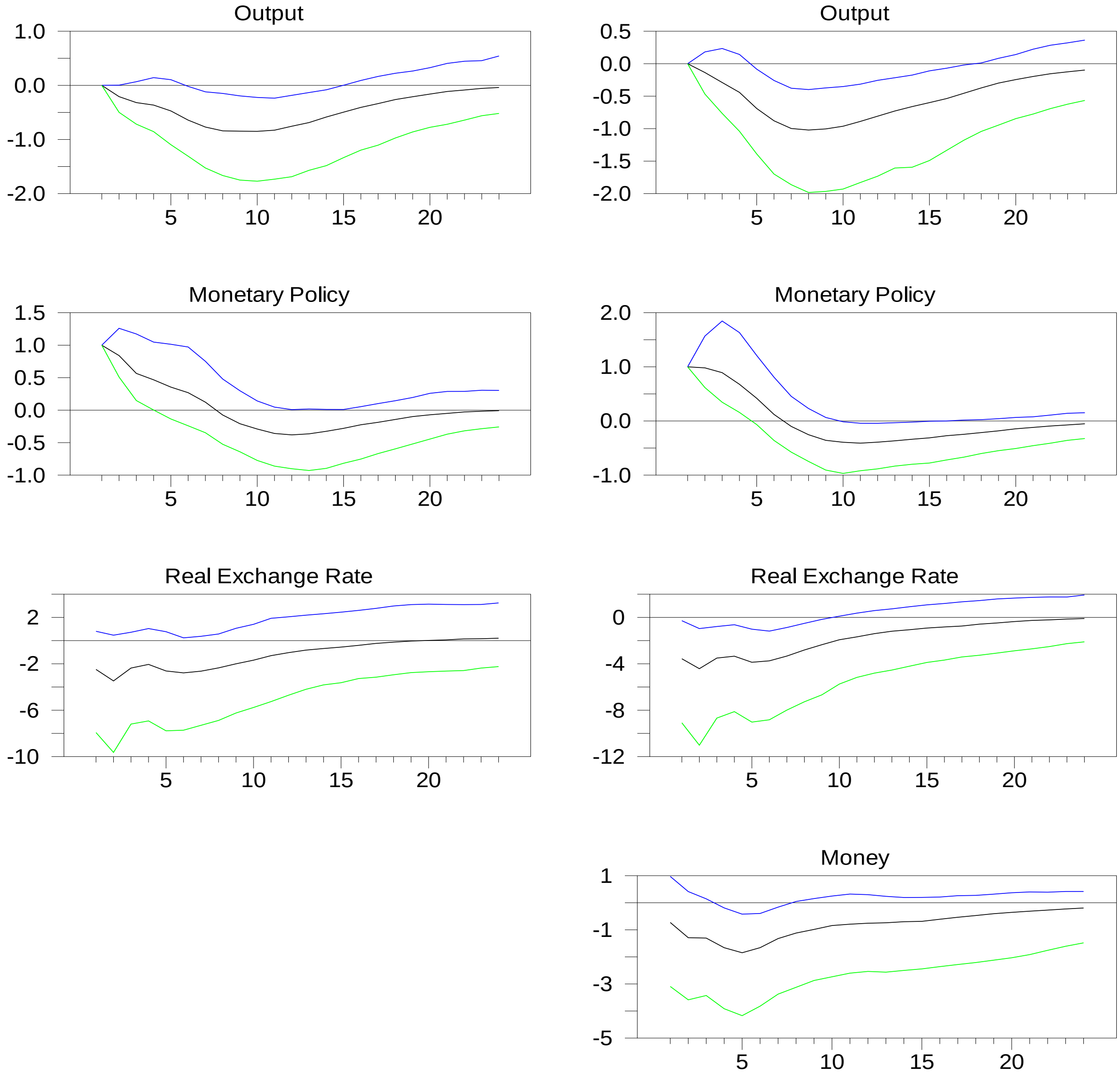
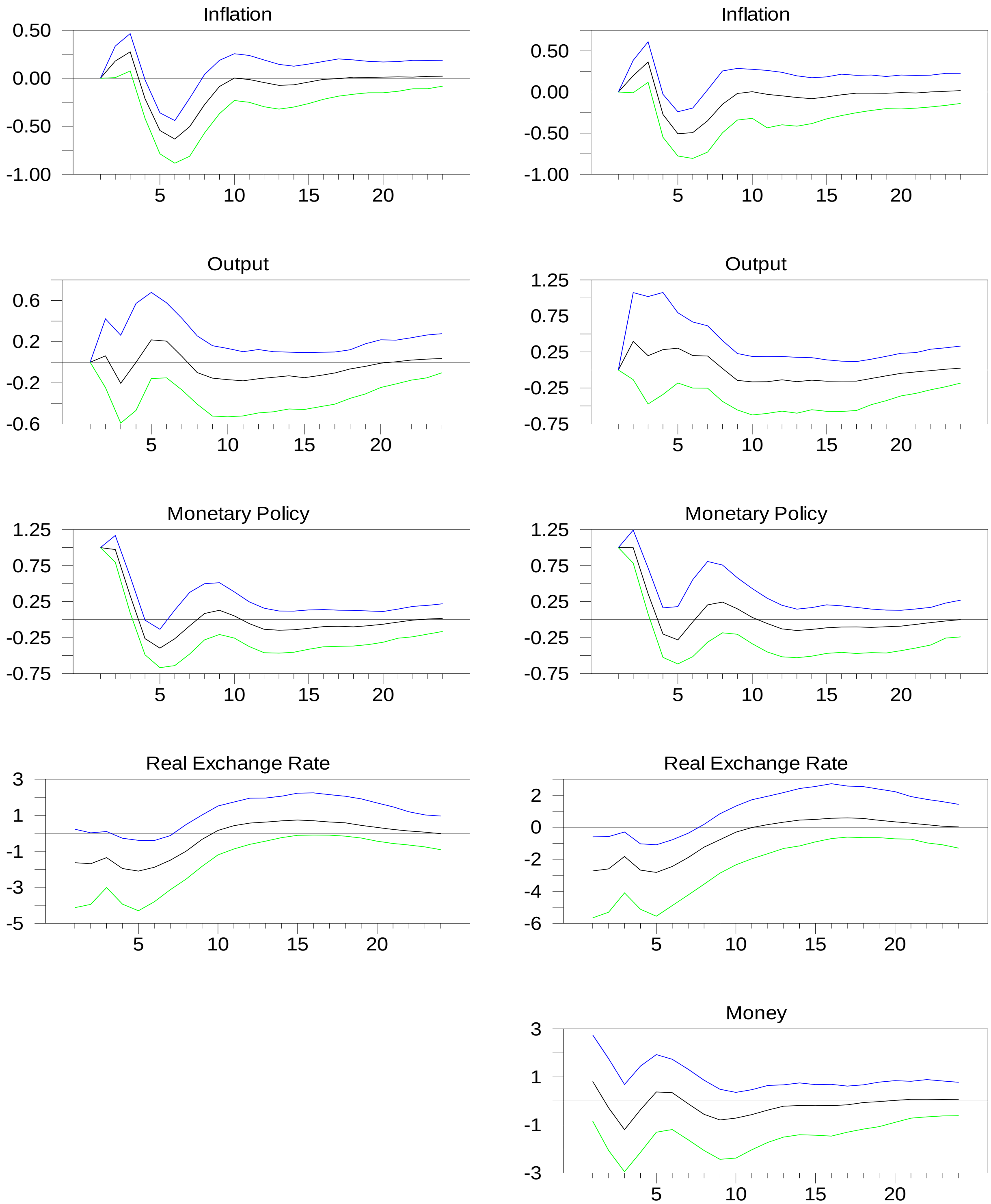



Figure 4 represents Newzealand's impulse responses from a unit monetary policy shock for the period 1990:1 Q1 to 2004 Q4. The original Bjornland model for Newzealand exhibit 'insignificant' exchange rate overshooting for almost all sub-samples in the dataset whereas our model (right panel) exhibit significant overshooting in more sub-samples than Bjornland (although not for all of them) . The exchange rate does appreciate on impact to a monetary policy shock in the original Bjornland model (left panel), but it is only significant after a couple of quarters. However, the response of output in both the model remains insignificant throughout the sample due to a monetary policy shock. The response of money demand is also insignificant. More specifically, on impact to a unit monetary policy shock in our model real exchange rate appreciates by 3 percentage points before depreciating back to the long run equilibrium. Prices fall significantly from 4-7 quarters and it falls by almost 0.5 percentage points due to a unit monetary policy shock.

**Figure 4**

Newzealand

**Model Bjornland** | **Model with Money Demand**



**Robustness Check:** The results for our model are robust to different number of lags and different variables for example different measures of output gap instead of simple output (gdp), index of industrial production for monthly data. The results also remain robust to different ordering of variables and to different samples or sub-periods and to the addition of the world price of oil variable. Different ordering of the variables can be done for example by swapping position of output and inflation or, money demand and exchange rate or, interest rate and money demand etc. The results remain consistent to different identification assumptions $b_{56} = 0$ or $b_{45} = 0$.

**Subsection 3.2: Variance Decomposition**

This section offers the variance decomposition for the five small open economies whose impulse response functions are reported in section 3.1. Table 1 reports the variance decomposition of exchange rates due to a monetary policy shock for our model and for direct comparison table 2 reports the variance decomposition for Bjornland original model.

**Table 1**

Forecast Error Decomposition: Contribution of **Money Supply (MS) Shocks** and **Money Demand (MD) Shocks** to **Exchange Rate Variation** (in percentages)

| Quarters | Australia | | Newzealand | | Sweden | | Canada | |
|---|---|---|---|---|---|---|---|---|
| | **MS** | **MD** | **MS** | **MD** | **MS** | **MD** | **MS** | **MD** |
| 1 | 45 | 0 | 21 | 12 | 17 | 67 | 36 | 0 |
| 2 | 50 | 0 | 18 | 9 | 15 | 70 | 35 | 2 |
| 4 | 40 | 5 | 15 | 9 | 8 | 55 | 26 | 7 |
| 8 | 24 | 10 | 8 | 11 | 4 | 33 | 24 | 9 |
| 16 | 12 | 13 | 3 | 16 | 2 | 26 | 10 | 7 |
| 24 | 8 | 14 | 2 | 22 | 2 | 25 | 5 | 6 |

For majority of forecast horizon, monetary policy explains more of exchange rate variance as compared to Bjornland model. Money acts as an informational variable (thereby rightly capturing the information about the flow of monetary services in the economy) in helping interest rate explain more of exchange rate variation and for Sweden's case, it has a causal role.

**Table 2**

Forecast Error Decomposition: Contribution of **Money Supply Shocks** to **Exchange Rate Variation** (in percentages)

| Quarters | **Australia** | **Newzealand** | **Sweden** | **Canada** |
|---|---|---|---|---|
| 1 | 39 | 12 | 16 | 35 |
| 2 | 44 | 11 | 17 | 36 |
| 4 | 36 | 10 | 9 | 30 |
| 8 | 24 | 6 | 4 | 31 |
| 16 | 13 | 3 | 2 | 15 |
| 24 | 8 | 2 | 2 | 7 |

In Bjornland's model (table 2) Australian monetary policy plays a much more important role in explaining the exchange rate variation as compared to other countries. The same pattern is witnessed in our model (table 1) but with a more amplified effect. For Australia the monetary policy is now explaining 45% variance in exchange rates in the 1st quarter which even increases to 50% in the next quarter. In the $4^{th}$ quarter following the monetary policy shock, the policy variable still explains 40% of the variance in exchange rates. Interestingly, 12% of the exchange rate fluctuation is still explained by the interest rate, 16 quarters after the monetary policy shock hit the system. From table 2, the monetary policy explains 39% variance in exchange rates in the first quarter, 44% in the next quarter and 35% in the $4^{th}$ quarter. Hence in our model the Australian monetary policy shock explains more of exchange rate variations in the initial quarters compared to Bjornland's model which enables the model to correctly capture the on impact responses of exchange rates to a monetary policy shock as given in figure 1. From the variance decomposition analysis we believe that the Australian monetary aggregate mostly play the role of an information variable thereby facilitating policy rate to explain higher percentage of the exchange rate fluctuation. Similarly for Newzealand, interest rate explain about 21% , 18% and 15% of the exchange rate fluctuation in the 1st, 2nd and 3rd , respectively, as compared to 12%,11% and 10% from table 2. The model with money demand enables Newzealand's monetary policy to explain remarkably more of exchange rate variations as compared to the model without it.

In addition to money supply shocks, money demand shock also plays a significant role in explaining the exchange rate variation with its role becoming more important for later quarters. Initially the money demand shock for Australia does not contribute anything but its contribution keeps increasing for future forecast horizons with contributing up to 14% in $24^{th}$ quarter. For Newzealand, money demand shock explains 12% of the exchange rate variation in the $1^{st}$ quarter before decreasing slightly in the next two quarters. Eventually it picks up and is able to explain up to 22% in the final period of the analysis.

For Canada, interest rate explain about 36% of the exchange rate fluctuation in the $1^{st}$ quarter. The monetary policy shock consistently explains a very high percentage of exchange rate variation till the $8^{th}$ quarter and is still able to explain 10% percentage of variation in the $16^{th}$ quarter. Similar trend for Canadian monetary policy is captured by the Bjornland model, however, money demand shock does not seem to play a very substantial role here.

For Sweden, we use the broader money M3 in the money demand equation whereas we use M1 money for other countries. Sweden's M1 series starts from 1998 which makes estimation of quarterly SVAR impossible due to a small sample. It is established in many empirical studies that narrower monetary aggregate works better for such analyses. We present the results with M3 money for Sweden. On impact to a monetary policy shock, there is not much difference between our model via-a-vis Bjornland model in terms of variance decompositiom. However money demand with broader monetary aggregates plays a role of causal variable explaining 67%, 70%, 55% of the exchange rate fluctuations in the $1^{st}$, $2^{nd}$ and $4^{th}$ quarters, respectively and still explaining 25% of the volatilities in the $24^{th}$ quarter.

## Section 4: Conclusion

One of the most prominent international macroeconomics theory of Dornbusch overshooting hypothesis has been empirically tested and established by Bjornland (2002) and Kim and Roubini (2005) among others. However the exact results from Bjornland (2002) cannot be replicated in terms of significant impulse responses due to use of incorrect error bands in the original model which is giving ‘insignificant’ exchange rate responses to a monetary policy shock. In this paper we reinstate the Dornbusch overshooting theory with a corrected model and error bands. Bjornland’s model has only the domestic interest rate as the monetary policy variable ignoring the demand side implications of money market behaviour. Our model has an additional money demand equation compared to Bjornland’s model and uses much less identification restrictions as compared to Kim and Roubini. The demand for money can too have direct or indirect influence on exchange rate movements which can be captured with an appropriate identification assumption. We offer a direct comparison of our model with Bjornland’s model. Our model establishes the exchange rate overshooting hypothesis with more precision for Canada, Newzealand, Australia and Sweden. The multicountry analysis corroborates our claim. For majority of subsamples our model does substantially better and for some cases our model does atleast as good as the original Bjornland model in terms of impulse response functions. This justifies our claim that SVAR models of exchange rates should have both the money demand and the money supply equations to capture the dynamics of money market properly instead of having interest rate alone as the monetary policy instrument. This is also supported by variance decomposition analysis where the monetary policy either explains more of exchange rate fluctuations in models with money demand and money supply, money thereby playing an informational role or, money, by itself, explaining a substantial amount of variations in exchange rates. We found that introduction of money adds valuable information to the model.

## Acknowledgements

Anderson,G., K.A.Kavajecz, 1994. A historical perspective on the Federal Reserve’s monetary aggregates: Definition, construction and targeting Federal Bank of St. Louis Review, 76, 1-31

Barnett,W.A., Bhadury Soumya Suvra, Ghosh Taniya, 2015. A SVAR Approach to Evaluation of Monetary Policy in India, Working Paper

Bruggeman,A., G Camba-Mendez, B.Fischer, J.Sousa, 2005. Structural filters for monetary analysis: the inflationary movements of money in the Euro are. ECB Working Paper, n 470

Bjornland,H. C., 2009. Monetary policy and Exchange rate overshooting: Dornbusch was right after all, Journal of International Economics 79 64-77

Blanchard, O. J. and Quah, D., 1989. The Dynamic Effects of Aggregate Demand and Supply Disturbances, The American Economic Review, Vol. 79, No. $, pp. 655-673

Cochrane,J. H., 2007. Inflation determination with Taylor rules: a critical review. NBER Working Paper, n 13409

Christiano,L. J., R.Motto, M.Rostagno, 2007. Two reasons why money and credit may be useful in monetary policy. NBER Working Paper, n 13502

Doan,T., 2013, RATS Manual, Version 8.3, Estima, Evanston, IL

Doan,T., 2012, RATS Handbook for Bayesian Econometrics, Estima, Evanston, IL

Dornbusch, R., 1976. Expectations and Exchange Rate Dynamics. Journal of Political Economy 84, 1161-1176

Goodfriend, M., M. J.Lacker, 1999. Limited Commitment and Central Bank Lending, Fall, 1999

Hamilton (1994), Time Series Econometrics, January 11, 1994

Ireland, P.N., 2001a. Sticky-price models of the business cycle- specification and stability, Journal of Monetary Economics, Volume 47, 2001, pp. 3-18

Ireland,P.N., 2001b. Money's role in the monetary business cycle. Working paper 8115, National Bureau of Economic Research

Kim,S., N. Roubini, 2000. Exchange rate anomalies in the industrial countries: A solution with a structural VAR approach, Journal of Monetary Economics, 2000, Vol. 45(3), pp.561-586

Kim,S., 2005, Monetary Policy, Foreign Exchange Rate Policy, Delayed Overshooting. Journal of Money, Credit and Banking, Vol.37, No.4, August, 2005

Leeper, E. M., J.E. Roush, 2003. Putting "M" Back in Monetary Policy, Journal of Money, Credit and Banking Vol.35, No.6

Masuch,K. S., S.Nicoletti-.Altimari, S, M.Rostagno, 2003. The role of money in monetary policy making. BIS Working Paper, n 19-2003

Nelson,E., 2003. The future of monetary aggregates in monetary policy analysis, Journal of Monetary Economics, Elsevier, vol. 50(5), pages 1029-1059, July

Rotemberg, J. J., M. Woodford, 1999. Interest Rate Rules in an Estimated Sticky Price Model, in Monetary Policy Rules, ed. By J. B. Taylor, pp. 57-119. University of Chicago Press, Chicago

Taylor,J.B., 1999. Monetary Policy Rules, University of Chicago Press, 0-226-79124-6, January, 1999

**Appendix:**

| Table A<br>Lag Selection Test | | | | | | |
|---|---|---|---|---|---|---|
| **Model** | **Test for 4 vs 3 Lags** | | **Test for 3 vs 2 Lags** | | **Test for 2 vs 1 Lags** | |
| | $\chi^2$ | Significance Level | $\chi^2$ | Significance Level | $\chi^2$ | Significance Level |
| Australia | 59.359463 | 0.00843706 | 62.569388 | 0.00393780 | 82.284179 | 0.00001756 |
| Newzealand | 46.908913 | 0.10534968 | 5.115376 | 0.00209364 | 80.518748 | 0.00002976 |
| Sweden | 25.022475 | 0.91531275 | 58.310605 | 0.01072710 | 58.227758 | 0.01093040 |
| Canada | 42.228934 | 0.21971191 | 36.390126 | 0.45049484 | 80.204840 | 0.00003266 |

| Table B | |
|---|---|
| **Largest Root in the SVAR model** | |
| Australia | 0.89844 |
| Newzealand | 0.88416 |
| Sweden | 0.87439 |
| Canada | 0.81911 |