Master Thesis

2014

The Overshooting Hypothesis: An Investigation for Industrialized Countries

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“If one is in a pinch and needs a quick response to a question about how monetary policy might affect the exchange rate, most of us will still want to check any answer against Dornbusch’s (1976) model.”

-Kenneth Rogoff (2002, page 5)-

INTRODUCTION

After the transition from fix to floating exchange rate regime monetary authorities are concerned for the fluctuations in exchange rates and the consequences of these to output and inflation. At post Bretton Woods period, exchange rates are far more volatile than macroeconomic fundamentals such as money supply, output and interest rates. Currency depreciation may have adverse effects in the domestic economy because higher prices of imported goods can lead to higher domestic price level and inflation. On the other hand currency depreciation makes the domestic goods cheaper for foreigners, so increases the demand for domestic goods and leading to an output expansion.

According to Dornbusch (1976) monetary policy instability constitutes the main source of exchange rate variation under sticky prices. Dornbusch's (1976) sticky price model explains how monetary policy affects exchange rates in a world with perfect capital mobility, sluggish adjustment of goods market relative to asset market and rational expectations. It is an illustration of how a monetary policy shock which is an unanticipated permanent increase or decrease in the money supply affect exchange rates by combining many dominant theories in the field of international macroeconomics like purchasing power parity (PPP) and uncovered interest parity (UIP). The core of the model is the so called overshooting hypothesis that predicts the response of the exchange rate to a monetary policy shock.

There is a number of empirical studies that consider the overshooting hypothesis, see e.g. Sims (1992), Eichenbaum and Evans (1995) and Kim and Roubini (2000) for G7 countries, Peersman and Smets (2001) for the aggregate Euro area and Mojon and Peersman (2001) for individual Euro area countries. The main result of these studies is delayed overshooting, following an interest rate increase the exchange rate appreciates for a prolonged period, violating one of the building blocks of Dornbusch (1976) model, the UIP. This exchange rate response leads to the forward discount bias. Furthermore, exchange rate puzzle and more often price puzzle arise.

In this study we investigate the overshooting hypothesis for 9 industrialized countries: U.S., Euro zone, Japan, Canada, United Kingdom, South Korea, Denmark, Sweden and Norway. In order to investigate the overshooting hypothesis we use VAR models of monetary transmission mechanism as it is the mainstream in empirical literature for monetary policy. First, we examine the theory with a structural VAR model where the identification restrictions are based on economic theory and then we compare our results with a different identification scheme based on Cholesky decomposition. Because these 9 countries are different (e.g. some are small economies and some are large), we treat each of them separately using the same set of variables, except for U.S which we treat as a separate case. In line with the recent literature delayed overshooting is present in most cases.

The rest of the thesis is organized as follows. In chapter 1 we present a brief review of Dornbusch model and the variable we use as a policy instrument. In Chapter 2 we proceed with a survey of the relevant literature and present the frequently observed puzzles. Chapter 3 describes the econometric methodology. VAR specification and empirical results for the country models under consideration are in Chapter 4 and in Chapter 5 we consider U.S. as a separate case, the final section concludes.

Chapter 1

Theoretical Background

1.1 Overshooting Hypothesis: An Overview

The overshooting hypothesis is at the core of Dornbusch's Model. We assume that we have one country which is small in the world capital market (domestic country) and the big one the foreign country. There are four core equations describing the model.

One of the building blocks of the model is that absolute PPP holds only in the long-run, because in the short run prices are sticky due to the inertia in the adjustment of good's market. PPP has the following form:

$$p = e + p^*$$

Where e denotes the logarithm of the nominal exchange rate, which is the home currency price of foreign currency, p denotes the logarithm of price level in domestic country and p* the logarithm of the price level in foreign country. It is a generalization of the law of one price, which says that the price of homogeneous goods should be equalized across countries once converted to a common currency. Rogoff (1996) states that in short-run PPP is not verified due to stickiness in nominal prices, but in the long-run we have convergence to PPP, mentioning that taking many decades of data the random walk hypothesis of real exchange rate can be rejected. As we can infer from figure 1, which presents the relative log CPI levels of U.S. and Japan with the log of exchange rate between the two countries, it is obvious that the variability of the spot rate cannot be explained by the movements of relative price indices, confirming the hypothesis of price stickiness in the short run and the failure of PPP. Moreover, comparing figures 1 and 2 the movements of real exchange rate of yen/dollar are identical with the movements of nominal exchange rate.

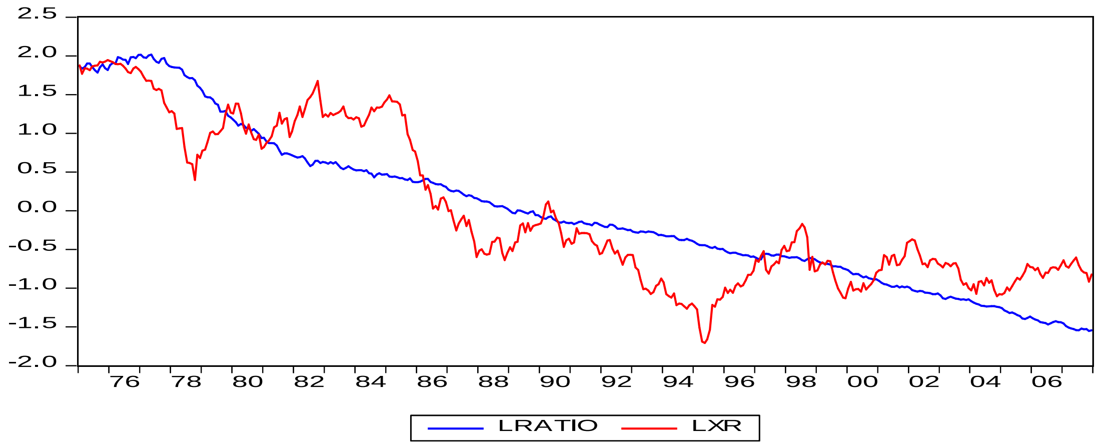


Figure 1. LRATIO is the ratio of Japan's CPI to U.S.CPI and LXR the log of nominal exchange rate of Japanese yen per U.S. dollar, January 1975 – December 2007

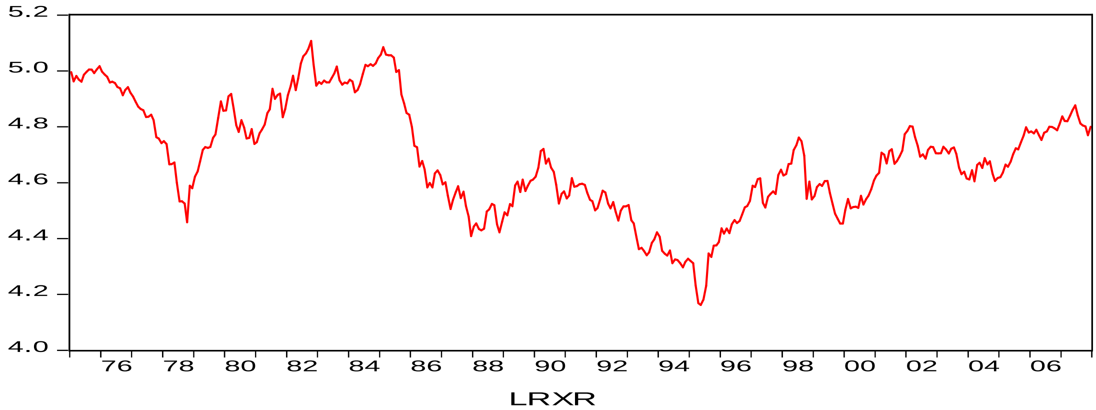


Figure 2. LRXR is the log of real exchange rate of yen per U.S. dollar

Then, the second building block of the model is the UIP, which has the following form:

$$i_t = i_t^* + [E_t e_{t+1} - e_t]$$

In this relationship i denotes nominal interest rate on domestic bonds and i* denotes nominal interest rate in foreign bonds, e has the same notion as before and E_t reflects market expectations based on time t information set. UIP says that domestic interest rate equal the foreign interest rate plus an expected rate of depreciation, therefore domestic and foreign bonds are perfect substitutes. Under the assumptions of perfect capital mobility and perfect substitution between domestic and foreign bonds if domestic interest rate is less than foreign interest rate than agents anticipate an appreciation of the domestic currency to compensate for the lower interest rate. According to Frenkel (1981*)* interest rate differentials explain a small portion of future changes in exchange rates, with the major portion explained by unexpected information or news entering in forex market about future economic developments.

The third building block of the model are the progressive expectations, the formation is the following:

$$E_t e_{t+1} - e_t = \theta * (\bar{e} - e)$$

Here $\bar{e}$ is the exchange rate in which the economy will converge in the long-run and e is the current exchange rate. The above equation says that the expected rate of depreciation depends on the difference between the long-run exchange rate and the current rate.θ represent's the speed of adjustment parameter.

The fourth core equation is the demand for money equation:

$$m_t - p_t = -a * i_t + \ddot{\ } * \mathrm{y}_\mathrm{t}$$

m is the money supply, p is the domestic price level and y the domestic output which we treat as exogenous. All the variables are in logarithms. As we can infer from the last equation, an increase in nominal interest rate decreases the demand for real money balances, the opposite outcome has an increase in output causing a rise in the demand for transactions and finally the demand for money is proportional to price level.

After taking account of the core equations specified the model, then suppose that the policymaker of the domestic country decides an unanticipated for agents permanent increase in the money supply m. Given the sluggishly adjusted goods market, the price level is temporary fixed, the supply of real balances m-p increases and nominal interest rate falls, this is the *liquidity effect*. According to Irving Fisher's quantity theory of money, agents anticipate a rise in price level. Given the long-run PPP condition where a rise in m is followed by a proportionate increase in e and p, consequently agents form expectations of a depreciating exchange rate. Consecutively, both reduced interest rate and expected depreciation of the spot rate lead short-run and long-run investors to get rid of the bond assets denominated in domestic currency so we will have an ensuing capital outflow which cause immediate exchange rate depreciation. From the uncovered interest parity condition the reduced domestic interest rate gives rise to the anticipation of an appreciation sufficient enough to compensate investors for the lower interest rate in domestic bond assets. Therefore we will have an impact depreciation causing the exchange rate to overshoot its long-run level and a subsequent gradual appreciation until it reaches its new depreciated long-run equilibrium level. This whole result is a corollary of the rigid domestic prices in combination with perfect capital mobility.

After the impact overshooting, we are in a situation with reduced interest rate and a depreciated domestic currency which decrease the relative price of domestic goods. Both factors serve to create an excess demand for domestic goods. So, we will have an increase in inflation expectations and from Fisher effect[1] an increase in nominal interest rate, leading to an appreciation of the exchange rate until it reaches its new equilibrium level. From the expectations equation we can infer that the rate at which the economy will converge to its new long run equilibrium level is the coefficient of adjustment parameter θ.

1.2 Policy Instrument

An appropriate policy instrument should be controlled by monetary authorities and be related to economic activity. There was a view that a valid indicator of monetary policy is money stock such as M1 or M2, and policymaker should aim to keep the growth rate of them at a steady rate, but M1 and M2 are largely determined by the behavior of commercial banks and depositors, so both of them are greatly reflect aggregate demand, therefore it is difficult for central bank to control them.

Most Central banks all over the world set a short term interest rate target like the overnight lending rate. Taylor (1993) states that the policy rule which may captures the short-run interest rate target is:

$$r = p + 0.5y_t + 0.5(p - \overline{p}) + \overline{r}$$

[1] The Fisher effect comes from fisher identity I = r + π^e , where I is the nominal interest rate. R is the real interest rate and π^e is the expected inflation. In the long-run, changes in expected inflation are reflected in changes to the nominal interest rate.

Where r is the federal funds rate (FFR) target, y is the percent deviation of real output from the output target, p is the rate of inflation over the previous four quarters and $\overline{p}$ is the inflation target which is 2%, also equilibrium real rate($\bar{r}$) is 2%. According to the above relationship there is a positive relation between output gap and inflation gap with the short term interest rate. A crucial point is that if the inflation rate rises by one percent, then the FFR is raised by 1.5 %, finally increasing real rate. Otherwise if it rises less than the inflation rate, real rate should fall, signaling easing of monetary policy and consequently we will have an increase in inflation expectations. Another key point in Taylor's rule is that the central bank cares not only for deviation from inflation target, but also about minimizing business cycle fluctuations.

One shortcoming of Taylor's rule is that the policymaker should react not only to the current and past values of inflation and output gap but also to the future values of them. Therefore Taylor rule should include forward looking variables[2]. Moreover as economic environment is changing, coefficients would be unlikely to stay constant.

Taylor's rule refers to the anticipated or endogenous part of monetary policy. But short term interest rates are broadly used in literature as an indicator of autonomous change in monetary policy, as Romer (2011) mentions "it cannot be passive to macroeconomic conditions". For example, an aggregate demand shock pushes output above its target and causes inflation to rise, so keeping nominal interest rate constant, the real rate falls and output expands further and inflation rate rises as well, and so on. However, it is difficult in empirical literature to control for expected inflation component of the short term interest rate. So, if innovations to interest rate represent autonomous changes in monetary policy, we can trace out the effects of a monetary policy shock on macroeconomic variables. Empirical work on the best policy instrument is presented in the following papers, where the first three refer to the U.S. economy and the fourth to Japanese economy:

Bernanke and Blinder (1992) trace out the dynamic response of macroeconomic and bank's balance-sheet variables to monetary policy using as an indicator of monetary policy stance the FFR. Their argument of using FFR as

[2] See Clarida, Gali and Gentler (2000).

a policy indicator is that using Granger causality tests and variance decomposition they proved that FFR is a better predictor of major macroeconomic variables than monetary aggregates or other interest rates for period 1961: 7 – 1989:12, also lagged values of these variables can explain movements in FFR, therefore it responds to the policymaker's perception of the economy. Moreover, they found that for the period 1959:8 – 1979:9 FFR within the month is unresponsive to nonpolicy influences, that being so it is a plausible measure of monetary policy stance.

On the other hand, Strongin (1995) examining the market for bank reserves found a new indicator of monetary policy, the ratio of non borrowed reserves (NBR) to total reserves (TR). Changes in monetary policy in his model accrue from the change in the mix of borrowed and nonborrowed reserves given total reserves. He supposes that the central bank pays no attention to the FFR within a month period.

Bernanke and Mihov (1998) developed an SVAR in order to evaluate the three broadly used measures of monetary policy (NBR, FFR and NBR/TR) and a more complex index examining the market for bank reserves. Their inference is that for the period 1965-1996 using FFR or NBR/TR as an indicator of policy gives reasonable results.

Kasa and Popper (1996) considered the most appropriate monetary policy instrument for Japan following a similar method with Bernanke and Mihov (1998). They found that the operational procedure of the Bank of Japan could be described by a combination of non borrowed reserves and money market rate targeting with the weight on the money market rate increasing over time.

Theoretically, Mishkin (2009) argues that short term interest rate is better policy instrument than monetary aggregates and narrower monetary aggregates because it satisfies three criteria: First, it is quickly observable and accurately measurable, so signaling policy stance rapidly in contrast to monetary aggregates which are reported with lag, second it is better controllable meaning that policymaker can get it back to its target level if it deviates and third it is closely related with goals such as inflation.

Chapter 2

Empirical Literature

2.1 Anomalies in Empirical Literature

There are a number of puzzles emerging from the VAR-based empirical work on the effects of monetary policy on economic activity. The puzzles are:

1) *The liquidity puzzle*: When innovations to monetary aggregates like M1 or M2 used for the identification of monetary policy shocks, these innovations lead to an increase rather than decrease in nominal interest rates. Reichenstein (1987) argues that the anticipation of financial markets that the central bank will correct any deviation from target growth rates of M1 and the rapid adjustment of inflationary expectations, prevent nominal interest rates to fall after the expansion of money growth. Additionally, Leeper and Gordon (1992) found no evidence of liquidity effect examining unrestricted VAR with nominal interest rate, money growth, output and price level. Stongin (1995) solved the liquidity puzzle using instead of M1 a narrower monetary aggregate NBR/TR.
2) *The exchange rate puzzle*: As found by Grilli and Roubini (1995) and Sims (1992) a positive innovation to nominal interest rate in some non-U.S. G7 countries is followed by a depreciation rather than appreciation of nominal exchange rate or the appreciation is not statistically significant. According to Sims (1992) this can be explained if a negative supply shock is forthcoming and the inclusion of proxy variables for expected inflation can solve the exchange rate puzzle.
3) *Forward discount bias*: If UIP holds, the interest rate differential is an estimate of the future change in exchange rate. Under the assumption of rational expectations, this estimate of future exchange rate changes using interest rate differential should be unbiased. In literature in order to

test the unbiasedness, the change in the exchange rate is regressed on the interest differential:

$$\Delta s_{t+k} = a + \beta(i_t - i_t^*) + \varepsilon_{t+k}$$

Where Δs_{t+k} is the percentage depreciation of the currency over k periods and $(i_t - i_t^*)$ is the current k period Euro interest rate less the k period foreign interest rate. In the above equation we can replace the interest differential with the forward discount, which is the difference between the current forward[3] and spot rate, implying that forward discount is an unbiased estimate of the future change in the exchange rate under risk neutrality and rational expectations. Froot and Thaler (1990) found the average coefficient β across 75 published estimates to be -0.88, therefore rejecting the null hypothesis of unbiaseness β=1. The failure to accept the null hypothesis is often referred to as *forward discount bias*.

In empirical literature examining the overshooting hypothesis, it is common that an increase in domestic interest rate relative to foreign leads to a persistent appreciation in contrast with UIP, which predicts an instantaneous appreciation and a subsequent persistent depreciation.

4) *The price puzzle*: The response of price level to a positive innovation to interest rate is increasing rather than decreasing as found by Sims (1992) and other studies.

   Sims (1992) suggested that the presence of a price puzzle is due to the lack of VAR framework in monetary policy analysis to include variables useful in forecasting inflation unlike policymaker who include such variables in his information set. A solution to the price puzzle according to Sims (1992) is the inclusion of a commodity price index[4].

   Giordani's (2004) view is that price puzzle emerges due to the omission of output gap in the inflation equation (augmented Philips curve). He argues that "when output gap is omitted from the inflation equation the interest rate spuriously appears in that equation with a positive coefficient, because the interest rate reacts positively to output gap

[3] The forward rate is today's euro price of foreign exchange to be delivered on a specific date in the future.

[4] World export commodity price index.

increases and thus acts as its proxy". However, Giordani (2004) did not address how to compute trend output (thus output gap). In his empirical study for U.S., capacity utilization rate of the manufacturing sector for U.S.[5] is a proxy of output gap, and including this in the VAR there is no evidence of a price puzzle.

2.2 Literature Review

The effect of monetary policy on exchange rates has been the subject of a large body of empirical literature since the early 1990's. The commonly used econometric method is VAR models of monetary transmission mechanism. Favero (2001) states that the aim of the VAR models of monetary transmission mechanism is to provide stylized facts for theoretical models for policy analysis or to discriminate between different theoretical models.

In empirical literature VAR models are employed in order to trace out the dynamic response of macroeconomic variables to exogenous monetary policy impulses. The main tools used for this work are impulse response functions and error variance decomposition. In respect of identification of structural shocks, earlier studies adopt standard Cholesky decomposition, but recent studies follow the identification method suggested by Bernanke (1986) and Sims (1986) imposing identification restrictions based on economic theory. Furthermore, identification through sign restrictions or conditional heteroskedasticity of structural disturbances is latest used.

Beyond literature technicalities, there are some plausible qualitative features that according to Christiano, Eichenbaum and Evans (1996) are needed to characterize VAR models of monetary transmission mechanism, these are: 1) Price level initially responds sluggishly, 2) interest rate initially rises, and 3) output initially falls, form a hump-shape response and revert to the pre-shock level. In what follows we briefly describe the modelling framework and more extensively the basic results in the different studies.

[5] Stock and Watson (1999) argue that capacity utilization rate of the manufacturing sector is better inflation forecaster than the difference between cycle unemployment and natural rate of unemployment.

The seminal paper which examined empirically the overall Dornbusch (1976) model is that of Driskill's (1981). Driskill (1981) estimated a reduced-form exchange rate equation. The main empirical findings of his paper are first that exchange rate overshoots by a factor of about 2 and then appreciates. Second, the exchange rate adjustment path to long-run equilibrium is not monotonic as Dornbusch (1976) model predicts, there are periods of appreciation and periods of depreciation. Finally, Driskill (1981) found that PPP holds in the long-run, with the long-run calculated to be 2-3 years.

Sims (1992) was the first who investigates overshooting hypothesis with VAR model. He examined the effects of a monetary contraction to major macroeconomic variables including exchange rates and a commodity price index common for all countries. He collected monthly data for Germany, France, U.S., Japan and UK. Sims (1992) used a standard Cholesky decomposition to achieve identification. In respect of exchange rate, for Germany and France he found an exchange rate puzzle, however for the rest countries there is no evidence of an exchange rate puzzle. The currency appreciation for UK, Japan and U.S. is not impact in contrast with what Dornbusch (1976) model predicts. This implies a failure of UIP because of the persistent appreciation. Price puzzle remains with the inclusion of a commodity price index, but it is much larger without it. As for output, it follows a hump-shape response decreasing first and then returns to its pre-shock level.

For the U.S. economy Eichenbaum and Evans (1995) studied the effects of a contractionary monetary policy shock comparing as policy instruments the FFR and the ratio of NBR/TR, including both of them in a recursive VAR ordering with NBR/TR before FFR. They conducted analysis with real and nominal exchange rates with identical results. First, shock to NBR/TR leads to a persistent appreciation of dollar relative to each of the other currencies, with the peak response range from one to three years discarding overshooting hypothesis. Variance decomposition analysis indicates that a low 8% to a high 14% of the forecast error variance of exchange rates is attributable to monetary policy shocks in totally 36 months period. The results with FFR are very similar with monetary policy shocks to account for more than 20% of the forecast error variance of exchange rates in some cases.

Then, Grilli and Roubini (1996) following recursive VAR ordering investigated the effects of a positive interest rate innovation to non-U.S. G7 countries. They found evidence of an exchange rate puzzle in some countries attributable to endogenous policy reaction to inflationary pressures. For five countries there is persistent appreciation with peak response in less than one year, again in contrast with Dornbusch's model and UIP condition. Furthermore, in all countries but Canada there is an evident price puzzle. To confront exchange rate puzzle they substitute the nominal short-term interest rate with real interest rate which is the difference between the short-term and a long-term interest rate, considering that the latter captures expected inflation. With the exception of Italy now the response of exchange rates to the innovation in real interest rate is impact currency depreciation.

A different approach to examine the effects of monetary policy shocks applied by Cushman and Zha (1997) for Canada, they used SVAR with non recursive identification. Moreover, they imposed block exogeneity by not allowing the domestic block of variables to affect the non-domestic block either contemporaneously or with lag. The policy instrument in their study is a money supply equation. Negative shocks lead neither to a liquidity puzzle nor to exchange rate puzzle. In contrast to previous literature deviations from UIP exists for only four months. So there is evidence of overshooting but again the appreciation is not immediate. As for output, monetary policy shocks have little effect on output with foreign sector having the major effect.

In the same spirit, Kim and Roubini (2000) followed the SVAR approach and identified monetary policy shocks with the explicit consideration of a money supply and demand equations. There is no evidence of price puzzle after positive interest rate innovations in the non-U.S. G7 countries. Furthermore, output in all countries fell immediately or with a short lag and return to steady state in a longer horizon. Exchange rate appreciates on impact in all countries and the peak response is in few months in contrast with Eichenbaum and Evans (1995) and Grilli and Roubini (1996) where the peak response is about two years. Also, there are significant UIP deviations only for Germany and Japan. These findings are in favor of overshooting model. In respect of variance decomposition analysis, monetary policy shocks explain output fluctuations at a range from about 3% to about 10%. As for exchange rate fluctuations monetary policy shocks explain a very large proportion, range from 4% to 58% at the peak. They find similar results with real exchange rate in the place of nominal exchange rate.

Jang and Ogaki (2001) investigated the dynamic response of dollar/yen exchange rate to a U.S. monetary contraction introducing SVECM[6]. Concretely, they estimated a structural VECM with short run and long run restrictions and compare them with a commonly used VAR in levels. In SVECM with long run restrictions there is no puzzle to the response of exchange rate, output and prices in a positive innovation to FFR. The peak response of exchange rate is in about four months then it depreciates. Imposing short run restrictions manifest a price puzzle and a persistent appreciation for five years, so no evidence of overshooting behavior. The results with VAR in levels are in line with Eichenbaum and Evans (1995), there is an evident price puzzle and a peak response of exchange rate after twenty months. More robust and consistent with overshooting model conclusions accrue with SVECM with long run restrictions.

Unlike previous studies Faust and Rogers (2003) based the SVAR identification on sign and shape restrictions[7]. So, having identified the SVAR, they tried different orderings and found that delayed overshooting result depends on the assumptions adopted. In contrast, substantial UIP deviations conditional on monetary policy shock is a common feature in alternative orderings. Also, it is worth noting that in a 7-variable VAR monetary policy explain about 10-50 percent of exchange rate variation, but in a 14-variable VAR less than 10 percent. So, the exchange rate variability due to monetary policy shocks depends on model size. According to Fry and pagan (2007) sign restrictions is a weak identification method due to the weakness of information they contain.

Scholl and Uhlig (2008) as previous authors imposed sign restrictions but their restrictions on impulse responses hold for a full year. Moreover, they identify monetary policy shock through the sign restrictions. Analyzing bilateral exchange rates for U.S.-German, U.S.-UK, U.S.-Japan and U.S.-G7, they

[6] Vector error correction model.
[7] They impose sign restrictions on impact only.

found the commonly observed in the literature delayed overshooting with the peak response of exchange rate around 2 years. When the delayed overshooting is excluded by construction, large deviations from UIP still remain.

Peersman and Smets (2001) considered an SVAR on synthetic euro area data to trace out the effects of a monetary policy shock. Foreign variables entered in VAR as exogenous. Monetary policy shock was first identified through a Cholesky decomposition putting macro variables before interest rate and exchange rate after it, second using a non-recursive identification scheme like Kim and Roubini (2000) and third combining short and long run restrictions. The results in the three identification methods are similar with no evidence of puzzles. The peak response of exchange rate is in about five quarters in all three cases, evidence against overshooting model. The contribution of monetary policy shock to output fluctuations ranges from 13% to 40% in different periods for the first model.

Following Peersman and Smets (2001), Mojon and Peersman (2001) investigated the effects of a contractionary monetary policy shock in ten countries of the euro area, for the pre-euro zone era. They estimated three SVAR models with different identification strategies for three groups of countries so to discriminate the difference in monetary policy implementation. The responses of output and prices are in line with theory, but exchange rate response is in most cases insignificant.

Kim (2005) attempted to explain the "delayed overshooting" puzzle with SVAR identification scheme considering the foreign exchange policy of Canada for Canadian dollar per U.S. dollar exchange rate. He interpreted the "delayed overshooting" as a result of a temporary intervention in foreign exchange market to mitigate the appreciation of Canadian dollar in conjunction with a prolonged monetary policy shock.

Bjornland (2009) used SVAR combining short and long run restrictions[8] to identify the monetary policy shock in small open economies. She allowed for a contemporaneous reaction between real exchange rate and nominal interest rate, in conjunction with no long run effect of monetary policy to the level of real exchange rate. There is evidence of overshooting in Sweden and in other

[8] See Blanchard and Quah (1989).

countries, the peak response of real exchange rate is after one quarter. The impact contribution of monetary policy shock to variation in exchange rate range from 9% for New Zealand to 41% for Canada. Price puzzle appears only for Australia and Canada in the beginning, attributed to the cost channel of interest rate[9] (see Ravenna and Walsh 2006). Output declines for a prolonged period and return to the steady state level. In contrast to Eichenbaum and Evans (1995) there are no significant deviations from UIP except Canada for one quarter.

Heinlein and Krolzig (2010) considered a just identified recursive structural VAR and a structural VECM model to examine the commonly noticed in empirical literature “delayed overshooting puzzle” for dollar per pound nominal exchange rate. In line with previous findings in both VAR specifications there is delayed overshooting and substantial UIP deviations. Furthermore, there is a price puzzle.

In contrast with existing literature Bouakez and Normandin (2010) identified a structural VAR by exploiting the conditional heteroskedasticity of structural disturbances. In line with previous literature findings, they obtained a delay overshooting of about 10 months for the US-G7 bilateral exchange rates. Moreover, like Eichenbaum and Evans (1995) monetary policy shocks explain a large proportion of exchange rate fluctuations from 40% in short horizon to more than 30% in long horizon. There are also significant deviations from conditional UIP except Canada. The remaining macroeconomic variables display plausible dynamic responses.

[9] When interest rate increases the borrowing cost for firms rise as well and passed to prices.

Table 1

Summary of the literature

Author	**Year**	**Sample period**	**Countries**	**Methodology**	**Policy instrument**	**Results**
Sims	1992	Began between 1957:1 and 1964:1 and ended in 1991	France, Germany, Japan, U.K., U.S.	Cholesky decomposition	Short-term interest rate	Exchange rate puzzle in some countries, delayed overshooting, price puzzle
Eichenbaum and Evans	1995	1974:1-1990:5	U.S.	Cholesky decomposition	Short-term interest rate, nonborrowed to total reserves	Delayed overshooting
Grilli and Roubini	1996	1974-1991	Non-U.S. G7	Cholesky decomposition	Short-term interest rate	Exchange rate puzzle for some countries, delayed overshooting, price puzzle
Cushman and Zha	1997	1974-1993	Canada	SVAR with non recursive identification	Money supply equation	Delayed overshooting

Kim and Roubini	2000	1974:7-1992:12	Non-U.S. G7	Bayesian SVAR with non-recursive identification	Short-term interest rate	Delayed overshooting
Jang and Ogaki	2001	1974:1-1990:5	U.S.	SVECM with short and long run restrictions for identification	Short-term interest rate, nonborrowed to total reserves	Delayed overshooting
Peersman and Smets	2001	1980-1998	Euro Area	SVAR and Cholesky decomposition	Short-term interest rate	Delayed overshooting
Mojon and Peersman	2001	1980-1998	Austria, Belgium, Finland, France, Spain, Germany, Greece, Ireland, Italy, Netherlands	SVAR and Cholesky decomposition	Short-term interest rate	Delayed overshooting
Faust and Rogers	2003	1974:1-1997:12	U.S.	SVAR with sign and shape restrictions	The ratio of nonborrowed to total reserves	Price puzzle, delayed overshooting
Kim	2005	1975:1-2002:2	Canada	SVAR with non-recursive identification	Short-term interest rate	Delayed overshooting
Scholl and Uhlig	2008	1975:7-2002:7	U.S.	SVAR identified through sign restrictions	Identify monetary policy per sign	Delayed overshooting

					restrictions	
Bjornland	2009	Q1 1983 – Q4 2004	Australia, Canada, Sweden, New Zealand	SVAR identified through short and long run restrictions	Short-term interest rate	Price puzzle, delayed overshooting
Heinlein and Krolzig	2010	Q1 1972- Q2 2009	U.K.	SVECM	Short-term interest rate	Price puzzle, Delayed overshooting
Bouake and Normandin	2010	1982-2004	U.S.	SVAR identified through conditional Heteroskedasticity of structural disturbances	A combination of reserve market variables	Delayed overshooting

In summary, empirical results in favor of Dornbusch (1976) model are limited. In all cases there is no immediate overshooting but there is a delayed overshooting spanning from a few months to two or three years, implying excess returns in foreign exchange market and in turn violation of UIP.

Chapter 3

Empirical Investigation

3.1 Methodology

The VAR approach was introduced initially by the seminal work of Sims (1980) in order to avoid the large scale simultaneous equations systems. The motivation for VAR modeling is its better forecasting performance than structural models and the treatment of variables as endogenous. However, the standard VAR is a reduced form model with no economic interpretation of the results, unless it is related to an economic model. SVAR model use economic theory to connect forecast errors with structural shocks.

An argument that arises due to handling nonstationary variables is whether we should estimate an unrestricted VAR in levels or in first differences. In literature dealing with the transmission mechanism of monetary policy, VAR in levels is the mainstream. Enders (2004)[10] mentions that “there is substantial penalty to pay if you estimate a VAR in first differences, when the data are actually cointegrated differencing throws away information contained in the cointegrating relationship”.

Another argument in the VAR models of monetary transmission mechanism is whether we should estimate a VAR in levels or a co integrated VAR. The majority of literature in this field use VAR in levels to investigate the relationships among variables. According to Favero (2001) the reason for using unrestricted VARs is that monetary transmission mechanism is a short-run phenomenon, also according to Ramaswamy and Sloek (1997), if there is no economic theory to guide for the number of long-run relationships and how to interpret them, it is appropriate not to impose the restriction of co integration on the VAR model.

[10] Page (301)

Furthermore, Naka and Tufte (1997) study the performance of VECM and unrestricted VARs for impulse response analysis over the short run and found that the performance of the two methods is similar, inferring that the loss of efficiency from unrestricted VARs is not crucial in the short term. In terms of forecast variance decomposition Clements and Hendry (1995) and Hoffman and Rasche (1996) have shown that VAR in levels is superior to a restricted VECM at short horizons when the restriction is true and to a VAR in first differences as well. Another advantage of VAR in levels model relative to a co integrated VAR is its low computational burden. In this study we use unrestricted VARs in levels because of the short run nature of the variance decomposition and impulse response analysis.

The ensuing description of VAR identification, estimation and innovation accounting follows Favero (2001).

3.2 VAR identification and estimation

A typical form of a structural VAR model is:

$$A\begin{pmatrix} Y_t \\ X_t \end{pmatrix} = C(L)\begin{pmatrix} Y_{t-1} \\ X_{t-1} \end{pmatrix} + B\begin{pmatrix} v_t^Y \\ v_t^X \end{pmatrix} \qquad (1)$$

Where, Y_t is a vector of macroeconomic variables (such as IP, CPI and XR) and X_t is a vector of policy variables (such as r, NBR and NBR/TR) controlled by the monetary authorities. Matrix A is the 'feedback coefficients' matrix and C(L) is the 'autoregressive coefficients' matrix. $v = \begin{pmatrix} v_t^Y \\ v_t^X \end{pmatrix}$ Is a vector of structural disturbances (or primitive shocks) to macroeconomic and policy variables, where v_t^x reflects the unanticipated part of the overall stance of monetary policy. We can let some shocks to affect contemporaneously more than one of the endogenous variables in the system by allowing non-zero off-diagonal elements of matrix B.

We assume that both v_t^Y and v_t^X are white noise disturbances with standard deviations $\pm_{v_t^Y}$ and $\pm_{v_t^X}$ respectively and moreover $\{v_t^Y\}$ and $\{v_t^X\}$ are uncorrelated white noise disturbances.

The problem with model (1) is that it is unviable for econometric estimation by standard estimation techniques since the orthogonality assumption for structural disturbances is violated. So, we proceed to transform the above model in a form that will allow us to estimate it with ordinary least squares.

$$\begin{pmatrix} Y_t \\ X_t \end{pmatrix} = A^{-1}C(\mathrm{L})\begin{pmatrix} Y_{t-1} \\ X_{t-1} \end{pmatrix} + \begin{pmatrix} u_t^Y \\ u_t^X \end{pmatrix} \quad (2)$$

Model (2) is a VAR in standard form. The lag-length is determined using an information criterion. Here each equation can be estimated with OLS, because OLS estimates are consistent and efficient if each equation has the same set of explanatory variables[11]. Furthermore, it can be augmented to include a vector of exogenous variables W_t as follows:

$$\begin{pmatrix} Y_t \\ X_t \end{pmatrix} = A^{-1}C(\mathrm{L})\begin{pmatrix} Y_{t-1} \\ X_{t-1} \end{pmatrix} + \begin{pmatrix} u_t^Y \\ u_t^X \end{pmatrix} + \Psi_t W_t$$

By treating some variables as exogenous means that these variables can influence the other variables in the VAR, but can be affected neither contemporaneously nor with lag. In this study exogenous variables can have a contemporaneous influence on endogenous variables and the number of lags will be the same as the number of lags of endogenous variables.

In standard VAR u denotes the residual vector, which is normally independently distributed, because it is a function of structural disturbances, with variance covariance matrix Σ **.** The relation between the residuals in u and structural disturbances is therefore:

[11]See Keating (1992).

$$A\begin{pmatrix} u_t^Y \\ u_t^X \end{pmatrix} = B\begin{pmatrix} v_t^Y \\ v_t^X \end{pmatrix}$$

Undoing the partitioning we have,

$$u_t = A^{-1}Bv_t \,,$$

Then, we can derive the relation between the variance-covariance matrices of u_t and v_t as follows:

$$E(\mathrm{u_t}\, u_t^{'}) = A^{-1}BE(\mathrm{v_t}\, v_t^{'})\,\mathrm{B}^{'}\, A^{-1} \,,$$

Where E is the unconditional expectations operator. Finally, substituting the population moments with sample moments and normalizing the unconditional variances of the structural innovations to one, i.e., assuming $v_t \sim (0, \mathrm{I_K})$[12] we have:

$$\hat{\Sigma} = \hat{A}^{-1}\mathrm{B}\,\mathrm{I}\hat{\mathrm{B}}^{'}\hat{\mathrm{A}}^{-1}$$

$\hat{\Sigma}$ is estimated from the OLS estimation of equation (2). Coefficients in equations A and B are unknowns. To achieve identification of structural parameters we need to impose theoretical restrictions in order to reduce the number of unknown structural parameters to be equal or less than the number of estimated parameters of the variance covariance matrix of the residuals[13].

Typically, the main diagonal elements of A are set to unity because each structural equation is normalized to a particular endogenous variable and B is a diagonal matrix (each equation has a structural shock) with off - diagonal elements set to zero. So, matrix $\hat{\Sigma}$ has n*(n+1)/2 estimated parameters, matrix A has n^2-n parameters and matrix B has n parameters to estimate, therefore identification requires at least n*(n-1)/2 restrictions. Finally, after imposing the proper restrictions A and B can be estimated with maximum likelihood using a scoring algorithm[14]. If an over identified model is estimated, the value of a

[12] See Lutkepohl (2007).
[13] See Keating (1992).
[14] See Amisano and Giannini (1997)

likelihood ratio statistic is calculated in order to check for the plausibility of the restrictions:

$$LR = T(\log\det(\Sigma_u^r) - \log\det(\Sigma_u))$$

Here Σ_u is the ML estimator of the reduced form model and Σ_u^r is the corresponding estimator obtained from the restricted form estimation.

In the above identification strategy and in this study we use short run restrictions in contemporaneous parameters without imposing restrictions in lag structural parameters. The other identification methods are identification through long run restrictions, identification through sign restrictions and through the conditional heteroskedasticity of structural disturbances.

Sims (1980) proposes the following identification method based on Cholesky decomposition of matrices. Suppose we have 4 variables:

$$A=\begin{pmatrix} 1 & 0 & 0 & 0 \\ \sim_{21} & 1 & 0 & 0 \\ \sim_{31} & \sim_{32} & 1 & 0 \\ \sim_{41} & \sim_{42} & \sim_{43} & 1 \end{pmatrix},\ B=\begin{pmatrix} b_{21} & 0 & 0 & 0 \\ 0 & b_{22} & 0 & 0 \\ 0 & 0 & b_{33} & 0 \\ 0 & 0 & 0 & b_{44} \end{pmatrix}$$

Cholesky lower triangular matrix decomposition (recursive structure) is a popular way to identify structural shocks. The identification depends on the ordering of variables. The importance of the ordering depends on the magnitude of correlation of the residuals in standard VAR. Enders (1995) suggest that a value greater than 0.2 constitutes significant cross-correlation rendering the impulse response function sensitive to variable ordering.

3.3 Innovation Accounting

In the next step the identified $\{v_t^Y\}$ and $\{v_t^X\}$ can be used to describe the properties of VAR models through *impulse response functions* and *variance decompositions.*

3.3.1 *Impulse Response Function*

Consider a structural VAR model without exogenous variables for a vector y_t, containing m variables:

$$A_0 y_t = \sum_{i=1}^{p} A_i y_{t-i} + B v_t$$

Which we can rewrite as:

$$[A_0 - A(L)]\, y_t = B v_t$$

$$A(L) = \sum_{i=1}^{p} A_i L^i$$

By inverting $[A_0 - A(L)]$ (under the assumption of invertibility of this polynomial) we have the moving average representation of our VAR process:

$$y_t = C(L) v_t \,, \quad (3)$$

$$y_t = C_0 v_t + C_1 v_{t-1} + \ldots + C_s v_{t-s} \,,$$

$$C(L) = [A_0 - A(L)]^{-1}$$

$$C_0 = A_0^{-1} B$$

The generic matrix C_S has the following representation: $C_S = \frac{\partial y_{t+s}}{\partial v_t}$, which called *impact multiplier*. Concretely, the element $\{i, j\}$ of matrix C_S represents the impact of a shock to the j-th variable of the system at time t on the i-th variable of the system at time t+s. *Impulse response function* (IRF) is constructing from the response of variable i to an impulse in variable j as s varies. It is imperative to mention that when a shock to variable j occurs all other shocks are set to zero. That is the result of the imposition of orthogonality among structural shocks. So, impulse response analysis is not applicable in reduce form residuals as they are correlated to each other.

3.3.2 *Variance Decomposition*

Forecast error variance decomposition refers to the proportion of the movements in a variable that is due to its own shocks and the proportion of the movements in the same variable that is due to shocks to other variables. From equation (3), the s-step ahead forecast error of y_t is:

$$(y_{t+s} - E_t y_{t+s}) = C_0 v_t + C_1 v_{t-1} + \ldots + C_s v_{t-s}$$

The variance of the s-step ahead forecast error is:

$$\mathrm{Var}(y_{t+s} - E_t y_{t+s}) = C_0 I C_0^{'} + C_1 I C_1^{'} + \ldots + C_s I C_S^{'}$$

The above equation shows the share of total variance attributable to the variance of each structural shock.

Chapter 4

VAR SPECIFICATION AND EMPIRICAL RESULTS

We are going to investigate the overshooting hypothesis and the overall effects of a contractionary monetary policy shock in the economy for 8 major industrialized countries. The monetary policy shock can be attributed to three causes according to Christiano, Eichenbaum and Evans (1998). First, exogenous shocks to the central bank authority's preferences like a shift in the relative weight given to unemployment and inflation. Second, exogenous shocks induced by the change in private agent's inflation expectations, which may be not closely related to economic fundamentals. The third cause is related to technical factors, such as measurement error in the data available to monetary authority.

Due to the large difference in the size of these countries and the extent they affect the U.S. economy, VAR specification will be different for each country in respect of the number of exogenous variables including in the model. All VARs contain a constant and a trend.

The benchmark identification consists of short run restrictions based on economic theory, but we will compare the results with an alternative identification scheme based on Cholesky decomposition. The monetary policy shock is contractionary in each case.

4.1 Data Description

In this chapter we investigate Dornbusch's (1976) overshooting hypothesis for 8 industrialized countries: Euro zone, Japan, United Kingdom, Canada, South Korea, Denmark, Sweden and Norway. The vector of variables used in our model is {CPI Advance, CPI U.S., FFR, IP, CPI, M1, R, XR}[15], CPI Advance is a consumer price index for industrialized countries, CPI U.S. is the United States consumer price index, FFR is the Federal Funds Rate, IP is the industrial production index, CPI is the consumer price index, M1 is a monetary aggregate, R is the money market rate[16] and XR is the end of period nominal exchange rate expressed as a units of domestic currency for one unit of U.S. dollars. All variables are monthly time series and are transformed into logarithm form except interest rates. Also, aggregates are seasonally adjusted. The data source is International Financial Statistics except IP and CPI for Sweden and M1 for Denmark which are taken from Federal Reserve Economic Data (FRED). The end date of the sample for each country is 2007, the year before the financial crises, except for Euro zone which is 2013 due to data limitation. Concerning the estimation period, it is:

Country	Estimation period
Japan	1975M1 - 2007M12
United kingdom (U.K.)	1988M1- 2007M12
Denmark	1975M1- 2007M12
Euro zone	1999M1 - 2013M7
Korea	1987M1 - 2007M12
Canada	1986M1 - 2007M12
Sweden	1985M1 - 2007M12
Norway	1993M1 - 2007M12

[15] We use M1 only for countries that were available in the estimation period.
[16] The last four variables are essential in identifying monetary policy in empirical literature.

4.2 Euro zone

Following Kim and Roubini (2000) we identify monetary policy shocks by explicitly modeling policy reaction function and the structure of the economy[17]:

$$\begin{bmatrix} v_{MS} \\ v_{MD} \\ v_{IP} \\ v_{CPI} \\ v_{FFR} \\ v_{\mathrm{CPI}\_advance} \\ v_{XR} \end{bmatrix} = \begin{bmatrix} 1 & g_{12} & 0 & 0 & g_{15} & 0 & 0 \\ g_{21} & 1 & g_{23} & g_{24} & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & g_{43} & 1 & 0 & g_{46} & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & g_{64} & 0 & 1 & 0 \\ g_{71} & g_{72} & g_{73} & g_{74} & g_{75} & g_{76} & 1 \end{bmatrix} \begin{bmatrix} u_{R} \\ u_{M1} \\ u_{IP} \\ u_{CPI} \\ u_{FFR} \\ u_{CPI\_advance} \\ u_{XR} \end{bmatrix}$$

where $v_{MS}, v_{MD}, v_{IP}, v_{CPI}, v_{FFR}, v_{\mathrm{CPI}\_advance}, v_{XR}$ are the primitive shocks, that is money supply shocks, money demand shocks, IP shocks, CPI shocks, FFR shocks, CPI advance shocks and XR shocks, respectively, and $u_R, u_{M1}, u_{IP}, u_{CPI}$, $u_{FFR}, u_{CPI\_advance}, u_{XR}$ are the reduced form residuals, representing unexpected changes of each variable.

We proceed specifying each of the seven equations. The first is the *money supply equation* representing the monetary authority's reaction function. The monetary authority before setting the nominal interest rate takes account of a monetary aggregate and the FFR. XR is excluded from the policy reaction function following Peersman and Smets (2001) and Eichenbaum and Evans (1995), because the Euro zone is more like the U.S., i.e. a large and relatively closed economy[18]. Unlike Kim and Roubini (2000) monetary authority contemporaneously reacts to federal funds rate because according to Faust and Rogers (2003) foreign interest rates move rapidly in response to Federal Reserve's announcements. Concerning IP and CPI, following Kim and Roubini (2000), Kim (2003) and Leeper, Sims and Zha (1996), the policy authority does not respond contemporaneously to output and price level due to information delays, i.e. IP and CPI data are not available within a month.

[17] The system is overidentified. LR: Chi^2 (6.000): 9.9771, Prob: 0.1256. Hence we accept the null hypothesis that the restrictions cannot be rejected.
[18] See Peersman and Smets (2001)

The second equation of the system is a usual *money demand function*. Demand for nominal money balances depend on real income, prices and the nominal interest rate. For the third and fourth equations, the general idea is that real activity and CPI respond to monetary and financial sector variables with a one period lag due to planning delays, as there is a planning process in changing output and prices. We let CPI advance to have a contemporaneous effect to domestic CPI due to the high cross-correlation between them.

Proceeding to the fifth and sixth equations, we have the foreign sector variables, which are not contemporaneously affected by domestic variables (with the exception of CPI), but can be affected with a one-period lag. The last equation is the exchange rate equation representing the foreign exchange market equilibrium. As the exchange rate is a forward-looking asset price, we allow all the variables of the system to affect the exchange rate instantaneously. Finally, CPI U.S. is included as an exogenous variable since it is unlikely to be influenced from a monetary contraction in Euro zone. So, we assume that it has a contemporaneous effect to all other variables but there is no feedback from the other variables to CPI U.S.

The purpose of the inclusion of CPI advance, FFR and CPI U.S. is to control for systematic responses of monetary policy to inflationary and foreign monetary policy shocks, otherwise the increase in short term interest rate may be the reaction of the monetary authority to a negative supply shock causing a subsequent inflation and recession. Thus, the inclusion of the two CPIs helps to solve the price puzzle. CPI_ advance is included as endogenous because of the large weight the Euro zone is expected to have in this index due to its size.

To sum up, the first and second equations are the money supply and the money demand equations respectively, which describe money market equilibrium. The next two equations describe the domestic goods market equilibrium. The other two equations represent exogenous shocks deriving from the world economy and the last equation describes the financial market equilibrium.

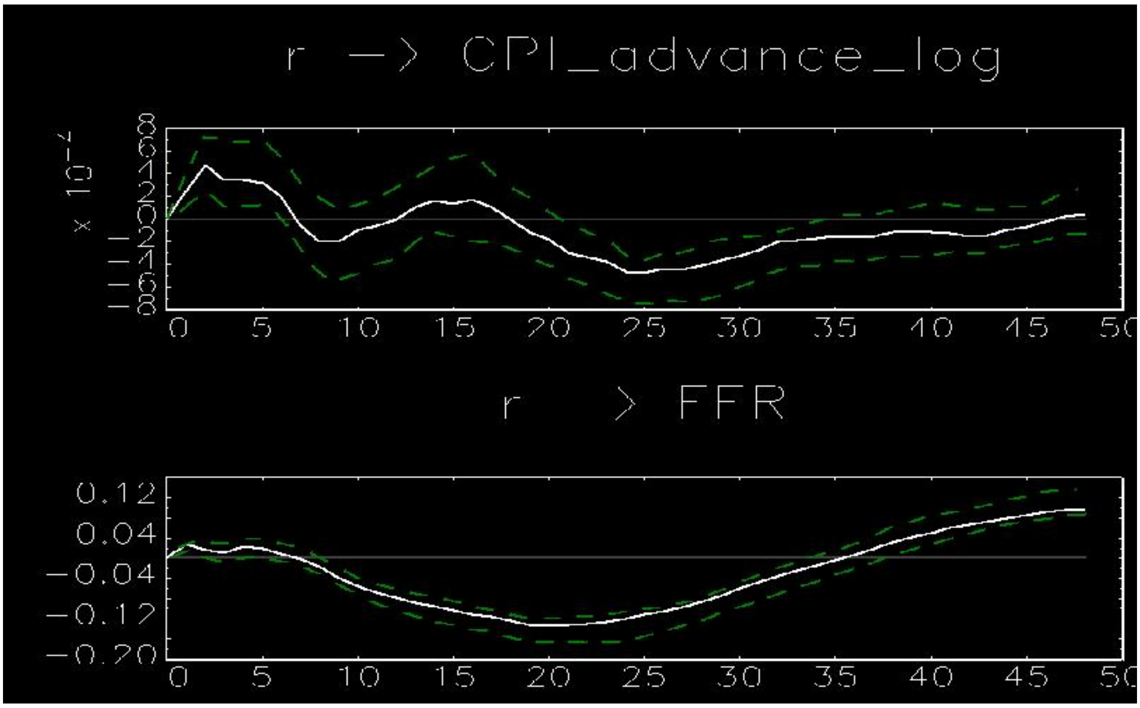
Impulse Responses

Impulse response analysis is used to analyze the dynamic interactions between the endogenous variables. In this study the exogenous variables are treated as fixed and may thereby be dropped from the system. All the results are generated using monthly data for the sample period 1999M1 – 2013M7. The number of lags is 10, following the Akaike information criterion. Four dummy variables were included: two impulse dummies[19] included for IP at 2008M4 and 2009M4 and one at 2008M9 for r, these dummies are included due to the global financial crises and a shift dummy 2002M1-2013M7, reflecting the period in which Euro currency is in circulation.

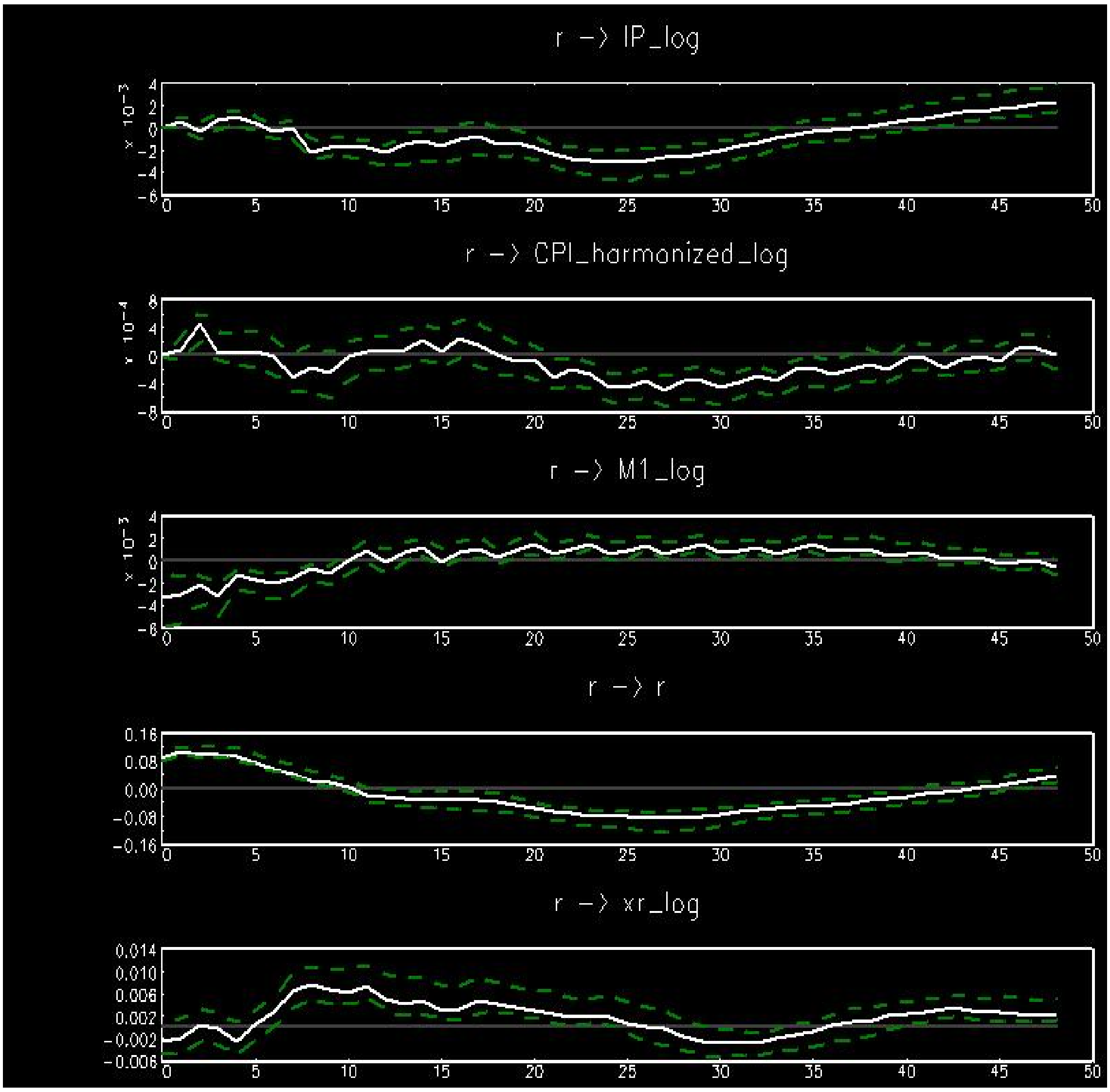
In Figure 1 we display the estimated impulse responses (over 48 months) for the Euro zone to a domestic monetary policy shock. The dashed lines represent the confidence intervals which are constructed with the Hall's percentile bootstrap method.

Figure 1

Euro Zone: Response to a monetary policy shock, using the structural VAR



[19] An impulse dummy takes the value one in one month and zero otherwise. Accordingly a shift dummy take the value one for a number of months and zero otherwise.



Note: 90% confidence intervals

In response to a monetary contraction interest rate rises and M1 falls on impact and the effects are statistically significant. The rise of the interest rate is temporary. Due to the deflation in the price level and the decline in output it returns to its steady state value after approximately 10 months. M1 increases statistically significantly for 10 months after the impact fall following the decrease in interest rate and return to its steady state value.

In respect of industrial production, it responds sluggishly for the first 6-7 months. Then it declines due to the high interest rate and the initial appreciation and remains below zero until approximately the 34th month and afterwards start to rise significantly due to the negative interest rates in the previous months. CPI Harmonized also responds sluggishly but it remains statistically significantly below zero between the 25th and the 35th months due to the recession and the high interest rate.

The impact of the monetary contraction on CPI advance has the same pattern as in domestic price level with the exception of an increase in the initial months. FFR on the other hand rises marginally statistically significant for the first 6-7 months. This result is in accordance with the 2-country Mundell-Fleming model for a large country. Then FFR starts to decline for 2 years significantly, displaying a puzzling behavior.

The effect of the monetary contraction on exchange rate is a statistically significant impact appreciation and afterward depreciation, so there is evidence of overshooting behavior. Peersman and Smets (2001) found a significant appreciation of the nominal exchange rate after the increase in interest rate which lasted for a few periods.

Variance Decomposition

Next we examine the sources of output fluctuations and exchange rate fluctuations with variance decomposition analysis. In table 1, we report the forecast error variance decomposition of industrial production, prices, M1, interest rate and exchange rate due to monetary policy shocks. At the top, we present the horizons at which forecast errors are calculated.

Table 1

Contribution of monetary policy shocks to the forecast error variance

Horizon				
	1 year	2 year	3 year	4 year
IP	0.04	0.08	0.13	0.12
CPI	0.02	0.02	0.07	0.06
M1	0.14	0.14	0.16	0.15
R	0.39	0.32	0.38	0.32
XR	0.06	0.07	0.07	0.08

The contribution of monetary policy shock to output and price variation is much more limited than in Peersman and Smets (2001). The same holds for exchange rate, only around 7 percent of the exchange rate variation is explained by monetary policy shocks in all horizons. To the contrary, Peersman and Smets (2001) found that interest rate shocks explain a substantial proportion of exchange rate variation ranging from 17 percent in one year to 27 percent in three years.

4.3 Japan

We will treat Japan in the same way as Euro zone[20], a large relatively closed economy[21]:

$$\begin{bmatrix} v_{MS} \\ v_{MD} \\ v_{IP} \\ v_{CPI} \\ v_{FFR} \\ v_{\mathrm{CPI}\_advance} \\ v_{XR} \end{bmatrix} = \begin{bmatrix} 1 & g_{12} & 0 & 0 & g_{15} & 0 & 0 \\ g_{21} & 1 & g_{23} & g_{24} & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & g_{43} & 1 & 0 & g_{46} & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & g_{64} & 0 & 1 & 0 \\ g_{71} & g_{72} & g_{73} & g_{74} & g_{75} & g_{76} & 1 \end{bmatrix} \begin{bmatrix} u_{R} \\ u_{M1} \\ u_{IP} \\ u_{CPI} \\ u_{FFR} \\ u_{CPI\_advance} \\ u_{XR} \end{bmatrix}$$

Impulse Responses

We proceed with impulse response analysis. Data are monthly for the sample period 1975M1-2007M12. The number of lags is 4 following the Akaike information criterion. A shift dummy for the period 1985M9-1985M12 is included for exchange rate. This dummy reflects the Plaza Accord[22]. In 1985M9 to 1985M12 Japanese Yen strengthen from 236.91 yen per dollar to 202.75 yen per Dollar.

In Figure 2 we display the estimated impulse responses (over 48 months) for the Japan to a domestic monetary policy shock. The dashed lines represent the

[20] The system is overidentified. LR: Chi^2 (6.000): 4.3825, Prob: 0.6251. Hence we accept the null hypothesis that the restrictions cannot be rejected.

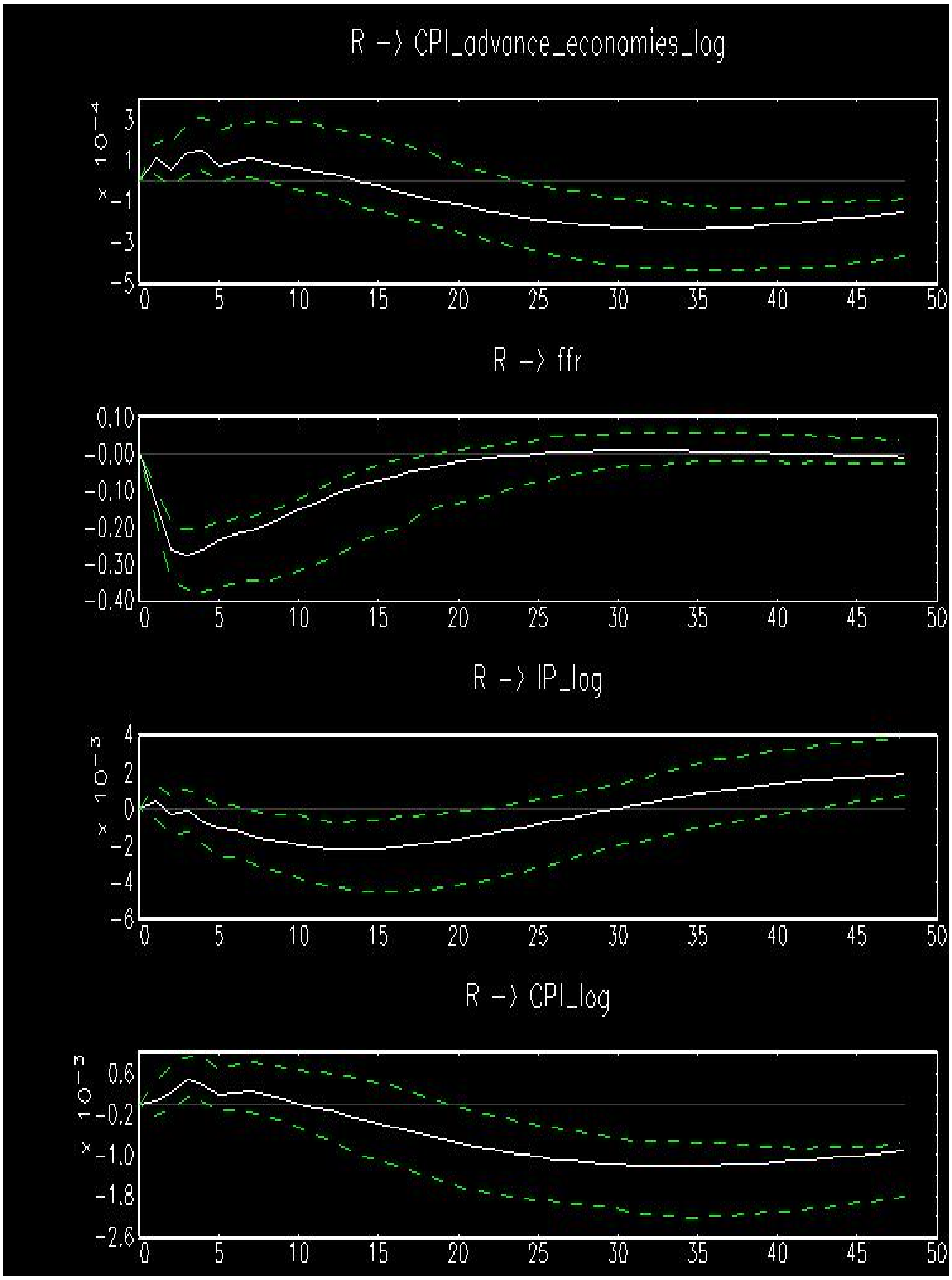
[21] See Pablo Guerron-Quintana (2011). He calculates the trade openness as the ratio of exports plus imports to GDP for some countries. For Japan he found a ratio equal to 0.31 and for U.S. 0.30, for the rest countries the ratio is over 0.5. So, we treat Japan as a large relatively closed economy.

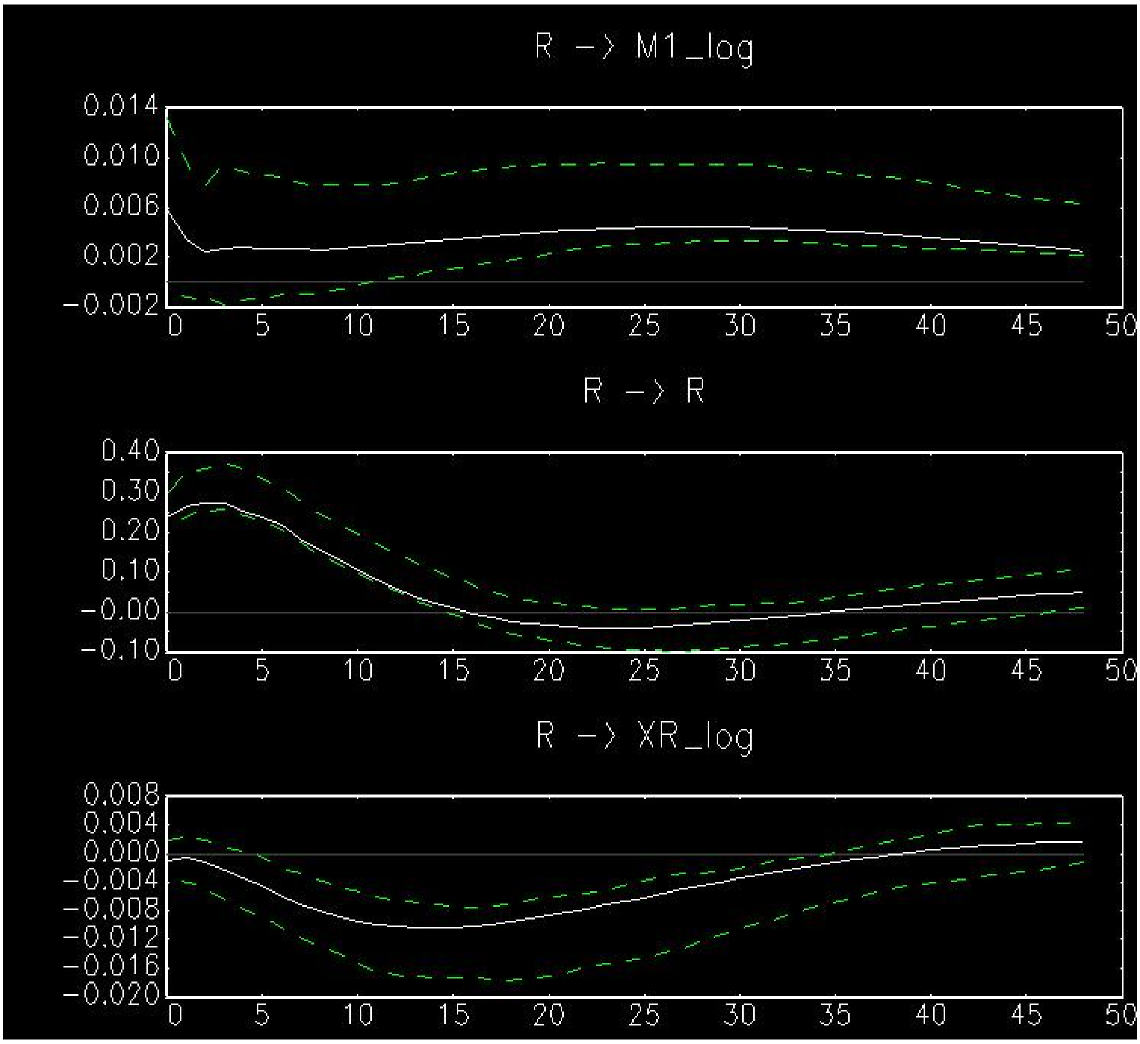
[22] The agreement between the G5 nations to intervene in currency markets to depreciate the dollar, correcting thereby the trade imbalances between U.S. and Germany and the U.S. and Japan.

confidence intervals which are constructed with the Hall's percentile bootstrap method.

Figure 2

Japan: Response to a monetary policy shock, using the structural VAR





Note: 90% confidence intervals

The response of interest rate to the monetary contraction is similar to that of Euro zone. M1 on the other hand displays a puzzling behavior, increasing immediately and then decreasing slightly and remain in this level for the whole 48 months horizon. The effect of the monetary contraction on M1 becomes statistically significant from the 10th month. In Kim and Roubini (2000) study M1 decreases significantly after the monetary policy shock.

In the third diagram, industrial production's response is similar the Euro zone's, differencing in that it responds sluggishly at the initial months. Concerning the price level the results are in line with theory, with the exception of the first few months where there is a small increase attributed to the cost channel of interest rate. However, after a year the price level falls significantly in agreement with Christiano, Eichenbaum and Evans (1998). Kim and Roubini (2000) found a similar pattern for Japanese price level without the small increase in the initial months, as for industrial production, it displays a hump-shape statistically significant response. Again our results are consistent with the qualitative features mentioned by Christiano, Eichenbaum and Evans (1996).

For the foreign sector, CPI advance follow the same course as the domestic price level. FFR displays the same puzzling result as that of Euro zone. There is a significant decrease lasting for about 1 year without a significant effect thereafter. The response of FFR to a domestic positive interest rate innovation is not in accord with Mundell-Fleming model predictions for a large country. Kim and Roubini (2000) found a statistically significant increase in FFR after the increase in Japanese nominal interest rate.

With respect to exchange rate, it appreciates for less than 1 year with the impact effect not being statistically significant, afterwards it depreciates for a prolonged period. So, there is a delayed overshooting. This result is consistent with Eichenbaum and Evans (1995) for yen/dollar exchange rate. In Kim and Roubini (2000) study the exchange rate displays a similar pattern as in this study. Scholl and Uhlig (2000) found similar qualitative results, with the peak appreciation in 1 year. The delayed overshooting implies a failure of UIP conditional on monetary policy shocks.

Variance Decomposition

We continue with variance decomposition analysis. In table 2 we present the contribution of the interest rate innovations to the forecast variance of the domestic variables.

Table 2

Contribution of the monetary policy shocks to the forecast error variance

Horizon				
	1 year	2 year	3 year	4 year
IP	0.02	0.04	0.04	0.04
CPI	0.01	0.03	0.10	0.13
M1	0.05	0.07	0.09	0.10
R	0.73	0.57	0.47	0.51
XR	0.05	0.11	0.12	0.11

The contribution of monetary policy shocks to output fluctuations is less than in Kim and Roubini (2000), who found a contribution from 6.4 percent in one year to 10 percent in two and three years. As for price level, for the first two years monetary policy shock contribution to price level variation is almost the same as for Euro zone. Concerning the proportion of exchange rate fluctuations explained by monetary policy shocks there is a sharp contrast with Kim and Roubini (2000) study who found a proportion of around 20 percent in all horizons.

4.4 United Kingdom

In contrast with Japan and Euro Area we consider U.K. as a large open economy[23], so we add in the policy authority's reaction function the nominal exchange rate as in Kim and Roubini (2000)[24]:

$$\begin{bmatrix} v_{MS} \\ v_{MD} \\ v_{IP} \\ v_{CPI} \\ v_{FFR} \\ v_{\mathrm{CPI}\_advance} \\ v_{XR} \end{bmatrix} = \begin{bmatrix} 1 & g_{12} & 0 & 0 & g_{15} & 0 & g_{17} \\ g_{21} & 1 & g_{23} & g_{24} & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & g_{43} & 1 & 0 & g_{46} & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & g_{64} & 0 & 1 & 0 \\ g_{71} & g_{72} & g_{73} & g_{74} & g_{75} & g_{76} & 1 \end{bmatrix} \begin{bmatrix} u_{R} \\ u_{M1} \\ u_{IP} \\ u_{CPI} \\ u_{FFR} \\ u_{CPI\_advance} \\ u_{XR} \end{bmatrix}$$

Impulse Responses

We continue with impulse response analysis. The sample period is 1988M1-2007M12[25]. The number of lags is 5 according to the Akaike information criterion. One shift dummy variable is included for the exchange rate for the

[23] According to BIS performance indicators the trade openness (ratio of exports plus imports to GDP) for U.K. was 65.3 in 2012, the second larger behind Germany, and 54.5 in 2002.

[24] The system is overidentified. LR: Chi^2 (6.000): 6.0519, Prob: 0.3012. Hence we accept the null hypothesis that the restrictions cannot be rejected.

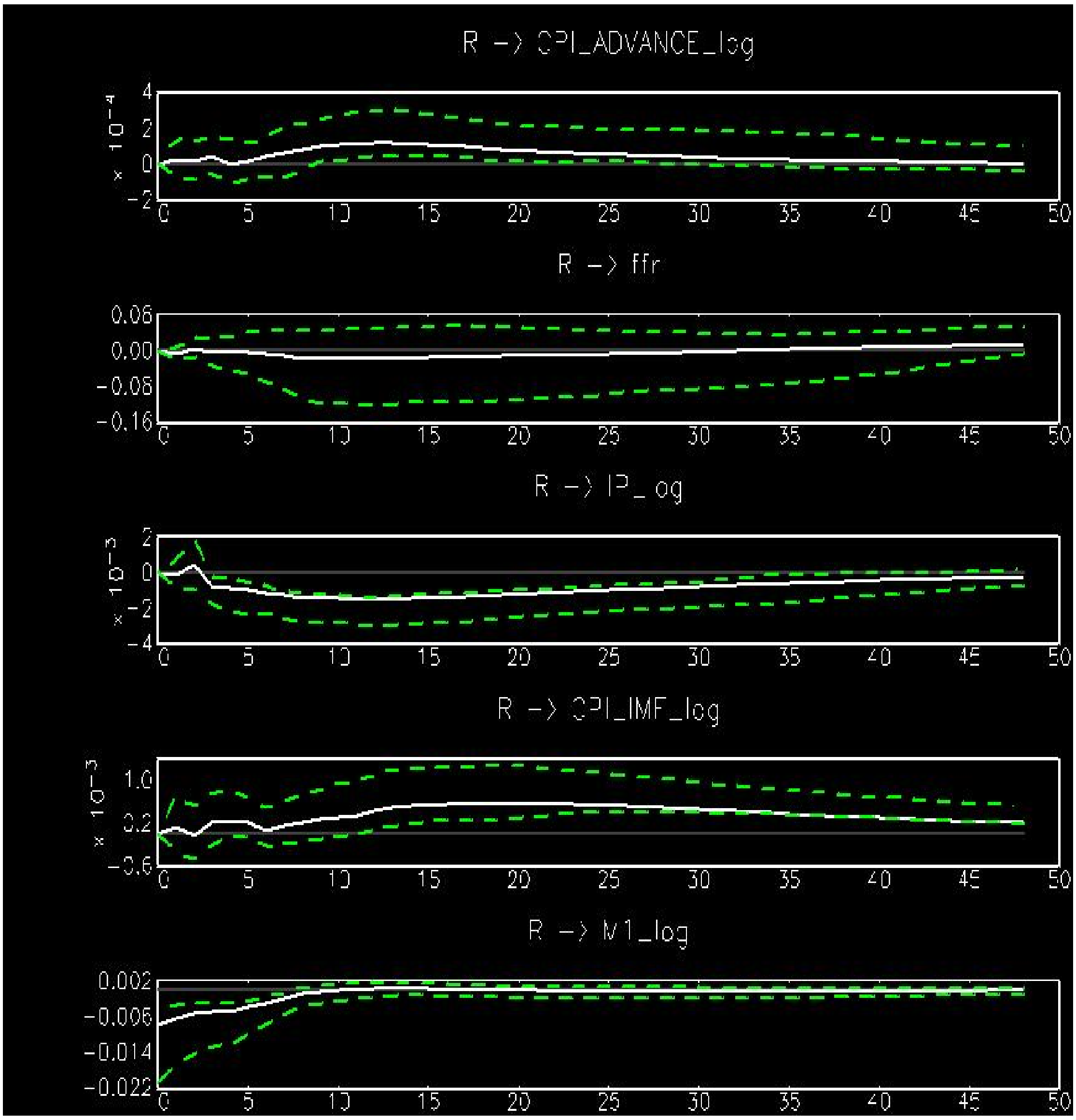
[25] The choice of 1988M1 as a starting period is due to the preceding reformations in the economy launched from Margaret Thatcher's election in 1979.

periods 1992M8-1992M11. This dummy variable reflects the Black Wednesday[26].

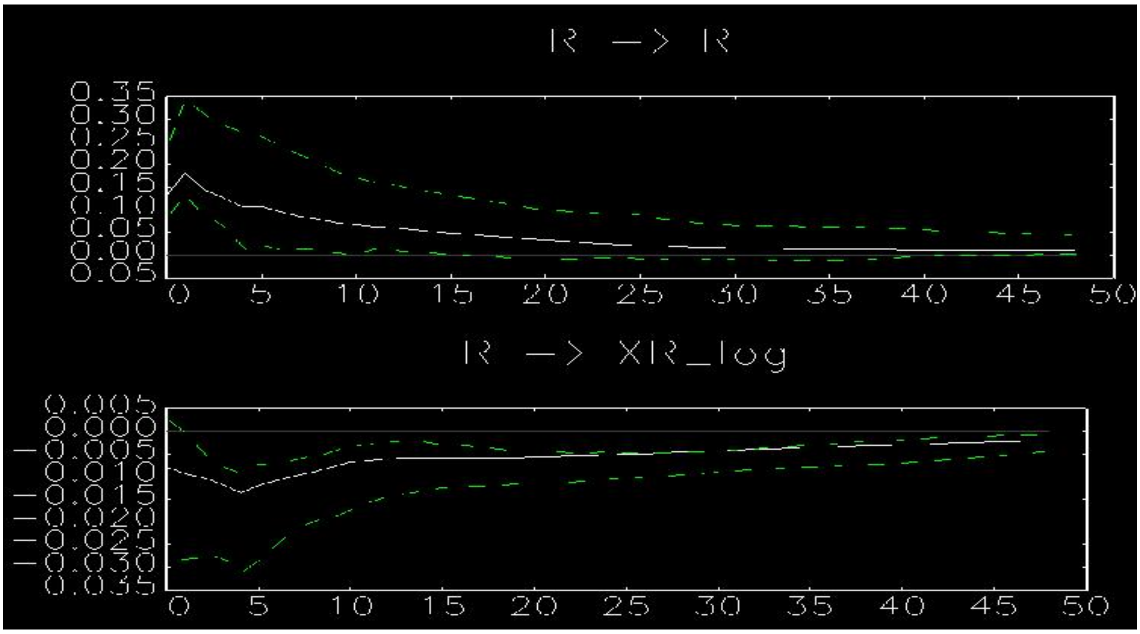
In Figure 3 we display the estimated impulse responses (over 48 months) for the U.K. to a domestic monetary policy shock. The dashed lines represent the confidence intervals which are constructed with the Hall's percentile bootstrap method.

Figure 3

U.K.: Response to a monetary policy shock, using the structural VAR



[26]In economics and politics, it refers to the September 1992, when the British government was forced to withdraw the pound sterling from the European exchange rate Mechanism.



Note: 90% confidence intervals

Monetary policy shock increases interest rate temporarily as we find in the other countries. M1 displays a similar pattern with that of Euro zone, declining immediately and increasing thereafter for 10 months reaching its steady state value. This effect is statistically significant. Kim and Roubini (2000) found similar results. Also, Heinlein and Krolzig (2010) using SVECM found a similar response of interest rate but in their study it returns to its steady state much earlier (less than 10 months).

Industrial production initially responds sluggishly to the monetary policy shock and then follows a hump-shape response, something that we observe in Japan. Industrial production's response is statistically significant over the 48 months horizon. On the contrary, price level exhibits a price puzzle. At the first 5 months it responds sluggishly but then it starts to rise. According to Sims (1992) 'interest rate rises precede output declines only because monetary authorities anticipate negative supply shocks'. Therefore, the interest rate increase is the endogenous reaction of policymaker to a forthcoming negative supply shock as we expect from Taylor's rule. Consequently, the interest rate increase does not represent an autonomous monetary policy shock. Similar results were found by Heinlein and Krolzig (2010) where the price puzzle holds for approximately a year. In Kim and Roubini (2000) the duration of output decline holds less periods and the price level's fall is statistically significant for a prolonged period.

The impact of the domestic interest rate innovation to the foreign sector variables is insignificant in all horizons. But in CPI advance we observe a significant increase from the 10th month to around 30th month reflecting the exogenous supply shock.

Concerning the exchange rate the impact effect of the monetary contraction is an immediate appreciation not statistically significant and an ensuing statistically significant appreciation for approximately 5 months, then it starts to depreciate. This depreciation coincides with the increase in price level, enhancing the view that we have a negative supply shock. So, in U.K.'s case it is inaccurate to interpret the interest rate innovation as a monetary policy shock. In Heinlein and Krolzig (2010) study, exchange rate displays delayed overshooting with the peak response in about a year.

Variance Decomposition

In table 3 we present the proportion of the domestic variables variation that is explained by the interest rate shocks.

Table 3

Contribution of the monetary policy shocks to the forecast error variance

Horizon				
	1 year	2 year	3 year	4 year
IP	0.08	0.12	0.13	0.13
CPI	0.01	0.07	0.10	0.11
M1	0.28	0.23	0.19	0.18
R	0.23	0.17	0.16	0.15
XR	0.25	0.25	0.26	0.26

The proportion of output fluctuations which are explained by interest innovation is similar to that of Euro zone and to Kim and Roubini (2000). Price level's proportions are similar to that of Japan. Unlike Japan and Euro zone, in U.K. interest rate shocks account for 25 percent of the exchange rate variation for the first two years and 26 percent thereafter in line with Kim and Roubini (2000) results.

4.5 Canada

We now turn to small open economies[27]. Concerning the VAR specification for Canada, we consider the CPI U.S. and the CPI advance as exogenous. FFR is endogenous like in other studies such as Bjornland (2009) and Kim and Roubini (2000). Following these studies, monetary policy can contemporaneously react to exchange rate shocks because small open economies are very concerned about the impact of the depreciation on their inflation rate and generally the exchange rate is an important transmission channel for foreign shocks that the central bank may respond to immediately. Furthermore, as an asset price, exchange rate reflects investor's expectations about economic variables, thereby it provides the policy maker with additional information to take into account. So, our identification scheme is now different[28][29]:

$$\begin{bmatrix} v_{MS} \\ v_{MD} \\ v_{IP} \\ v_{CPI} \\ v_{FFR} \\ v_{XR} \end{bmatrix} = \begin{bmatrix} 1 & g_{12} & 0 & 0 & g_{15} & g_{16} \\ g_{21} & 1 & g_{23} & g_{24} & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & g_{43} & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 \\ g_{61} & g_{62} & g_{63} & g_{64} & g_{65} & 1 \end{bmatrix} \begin{bmatrix} u_{R} \\ u_{M1} \\ u_{IP} \\ u_{CPI} \\ u_{FFR} \\ u_{XR} \end{bmatrix}$$

Impulse Responses

The sample period is 1986M1-2007M12[30]. The number of lags is 2 following the Akaike information criterion.

In Figure 4 we display the estimated impulse responses (over 48 months) for Canada to a domestic monetary policy shock. The dashed lines represent the confidence intervals which are constructed with the Hall's percentile bootstrap method.

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[27] Pablo Guerron-Quintana (2013) characterizes Canada as a small open economy.

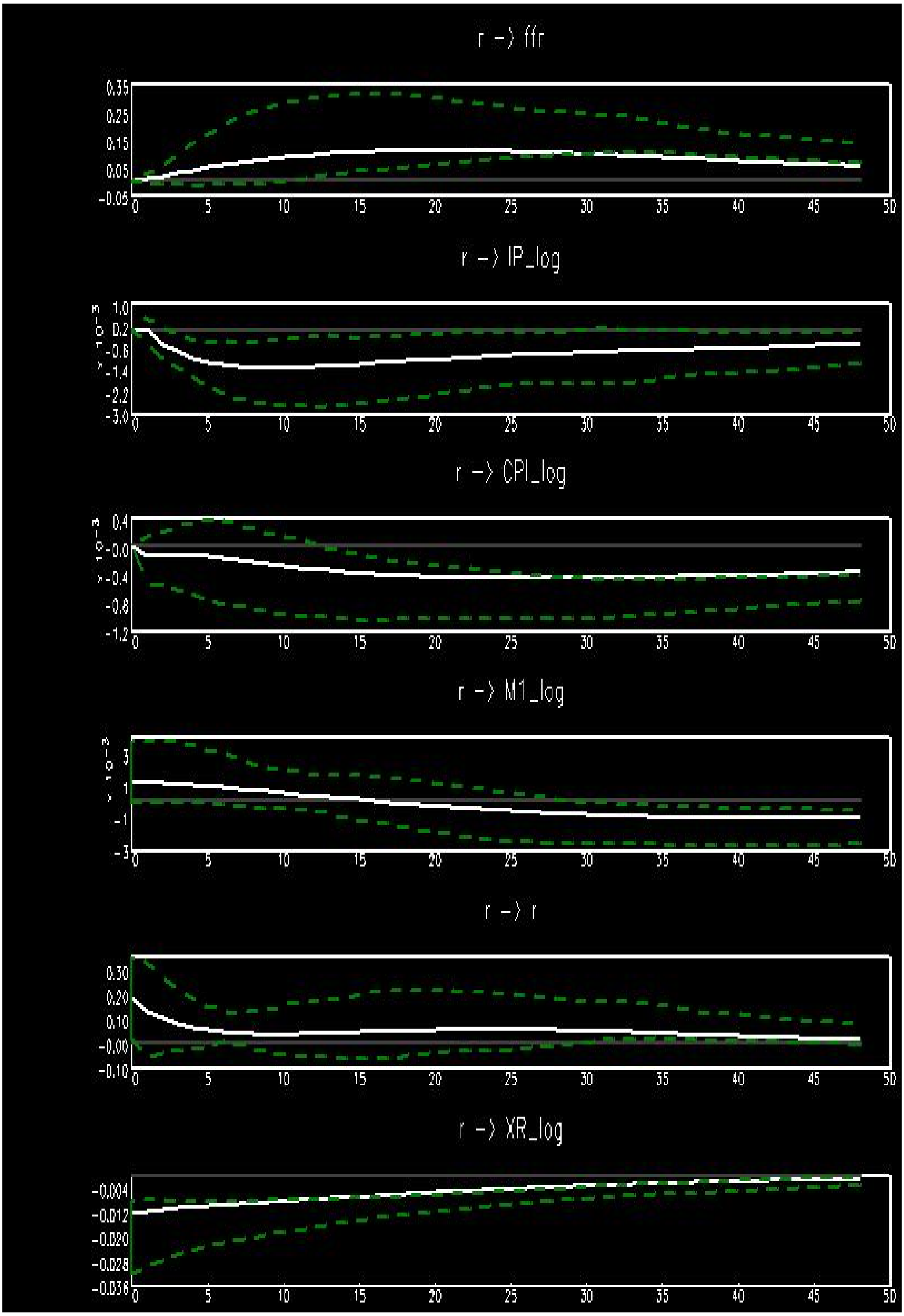
[28] In contrast with the other small open economies we include FFR as an endogenous variable because Canada is one of the G7 nations and probably its interest rate fluctuation can affect the FFR

[29] The system is overidentified. LR: Chi^2 (6.000): 7.1966, Prob: 0.0659. Hence we accept the null hypothesis that the restrictions cannot be rejected.

[30] We start from 1986M1 to avoid the early 1980s recession.

Figure 4

Canada: Response to a monetary policy shock, using the structural VAR



Note: 90% confidence intervals

Monetary policy shock leads to an impact increase in interest rate and then it falls gradually as in the other cases. The impact increase is marginally significant, but the overall movement of the interest rate is statistically insignificant. M1 initially rises and then falls, but the effect on M1 becomes statistically significant in about 30 months where it starts to decrease. Kim and Roubini (2000) found a significant increase in interest rate and a decrease in M1.

In respect of output and price level, their response to a monetary policy shock follows Christiano, Eichenbaum and Evans (1996) features. Output falls initially forming a hump-shape response and reaches its minimum after approximately 7 months, the effect on output is significant for many months. Price level on the other hand, initially responds sluggishly and from the 15^{th} month starts to decrease significantly. The same qualitative pattern follows Canada in Bjornland (2009) and Kim and Roubini (2000). The FFR increases statistically significantly for many periods as the 2-country Mundell-Fleming model for a large country predicts. The last result contradicts with the perception of Canada as a small open economy.

Finally, the exchange rate appreciates on impact and afterwards depreciates over the full 48 months horizon with the overall result be marginally statistically significant. This result confirms the UIP condition. The impact effect on exchange rate is consistent with Zettelmeyer (2004) who measured the immediate response of the exchange rate to a contractionary shock using daily data and found that a one percent increases in interest rate will appreciate the exchange rate by 2 to 3 percent on impact. Therefore, there is evidence of overshooting. In other studies such as in Bjornland (2009), Kim and Roubini (2000) and Cushman and Zha (1997) exchange rate displays delayed overshooting (the appreciation lasts few months in these studies).

Variance Decomposition

In table 4 we present the variance decomposition analysis of the domestic variables due to monetary policy shock.

Table 3

Contribution of the monetary policy shocks to the forecast error variance

Horizon				
	1 year	2 year	3 year	4 year
IP	0.05	0.07	0.08	0.09
CPI	0.01	0.04	0.07	0.08
M1	0.03	0.02	0.03	0.04
R	0.07	0.05	0.05	0.05
XR	0.57	0.60	0.61	0.61

Monetary policy shock explains a small share of output and price level variations as in the other cases. Kim and Roubini (2000) found similar results for output. On the other hand, monetary policy shocks explain a very large proportion of the exchange rate fluctuations. This remarkable result is in line with Kim and Roubini (2000) who found 60 percent for the first year about 50 percent in the second and the same for the third year. Also, Bjornland (2009) found that 41 percent of the exchange rate fluctuations are explained from monetary policy shocks in the first quarter.

4.6 South Korea

Next we examine the South Korean economy. We assume that FFR, CPI U.S. and CPI advance are exogenous variables; therefore we consider the following identification scheme:

$$\begin{bmatrix} v_{MS} \\ v_{MD} \\ v_{IP} \\ v_{CPI} \\ v_{XR} \end{bmatrix} = \begin{bmatrix} 1 & g_{12} & 0 & 0 & g_{15} \\ g_{21} & 1 & g_{23} & g_{24} & 0 \\ 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & g_{43} & 1 & 0 \\ g_{51} & g_{52} & g_{53} & g_{54} & 1 \end{bmatrix} \begin{bmatrix} u_{R} \\ u_{M1} \\ u_{IP} \\ u_{CPI} \\ u_{XR} \end{bmatrix}$$

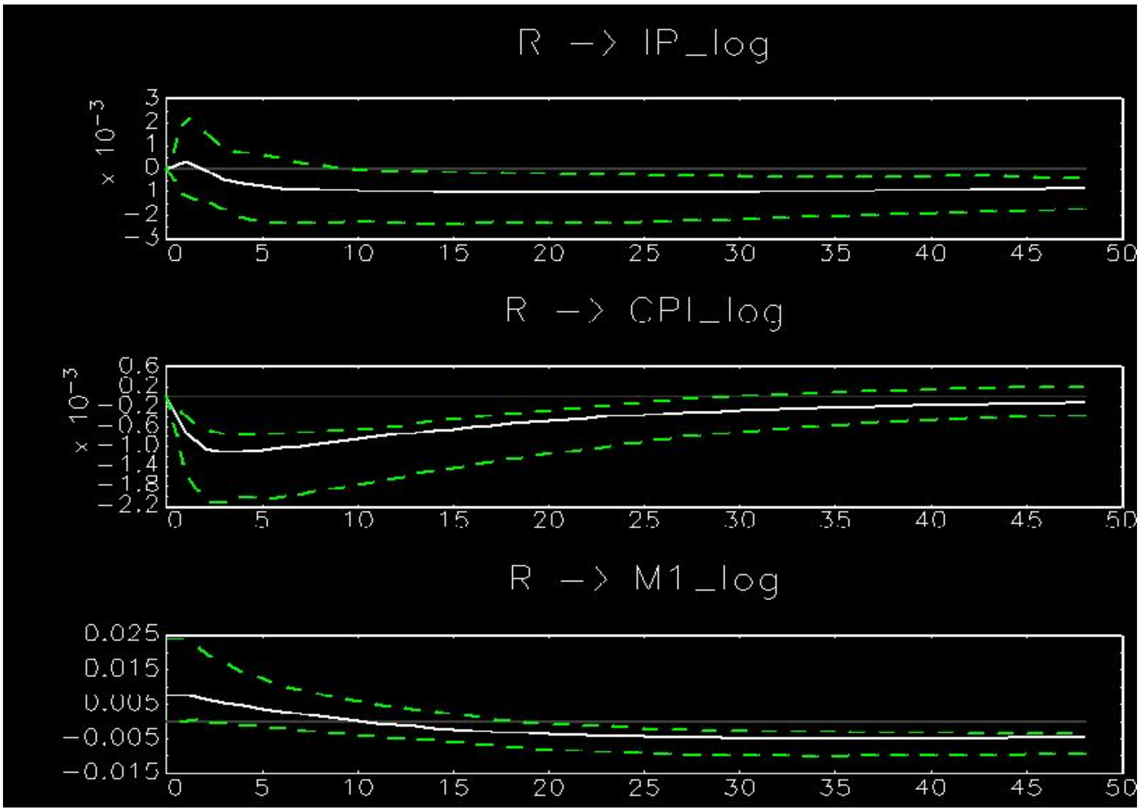
Impulse Responses

The sample period used to estimate the Structural VAR is 1987M1-2007M12[31]. The number of lags is 2 according to the Akaike information criterion. A number of dummy variables were included to take account of the 1997-98 Asian financial crises: For exchange rate an impulse dummy in 1998M2 and a shift dummy 1997M7-1997M12, for interest rate a shift dummy 1998M1-1998M10 and for industrial production an impulse dummy 1998M7.

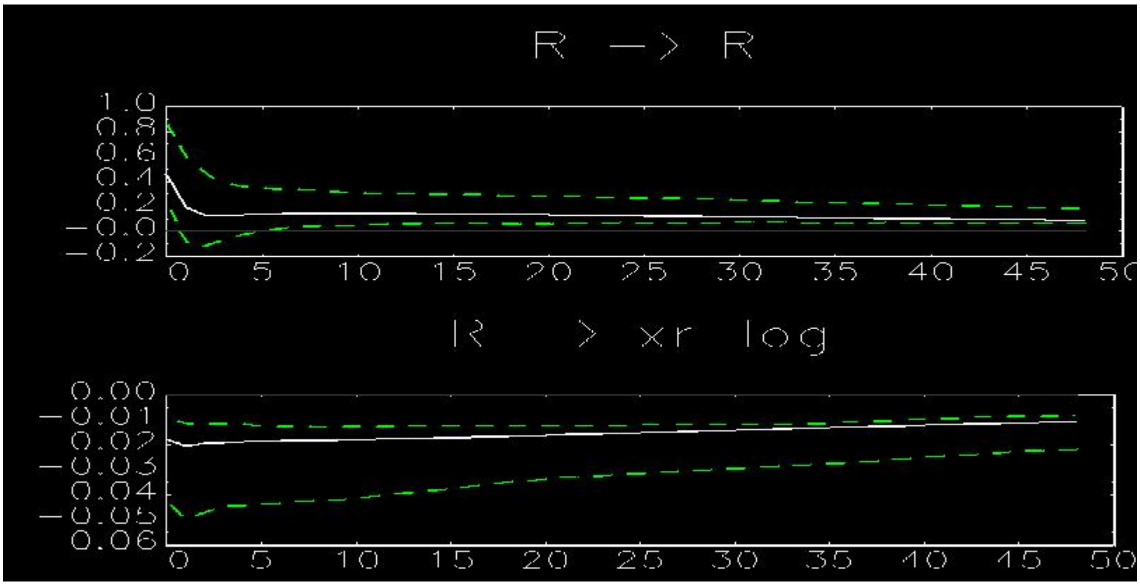
In Figure 5 we display the estimated impulse responses (over 48 months) for South Korea to a domestic monetary policy shock. The dashed lines represent the confidence intervals which are constructed with the Hall's percentile bootstrap method.

Figure 5

South Korea: Response to a monetary policy shock, using the structural VAR



[31] We start from 1987M1 due to the political instability in the previous years.



Note: 90% confidence intervals

Interest rate rise significantly in response to the money supply shock and afterwards it registers declining trend for a few months and then become flat remaining above its steady state value. M1 initially display a puzzle, but in less than 10 months starts to decline significantly, like in Canadian case.

Industrial production falls after the contractionary shock and the response becomes statistically significant from the first year. As for price level, it forms a hump-shape response, and the effect dissipates in about 30 months. In Muhammad Naveed Tahir (2012), the response of industrial production is zero, price level on the other hand fall persistently and significantly.

The exchange rate displays a similar pattern with the Canadian dollar, with the difference that the appreciation for the South Korea case is not impact. So we have a delayed overshooting and failure of UIP condition, which lasts for 2-3 months. In Muhammad Naveed Tahir (2012) study, the Korean exchange rate follows the same pattern as in this study, with the impact effect not being statistically significant.

Variance Decomposition

As in the other cases we proceed with variance decomposition analysis in table 5.

Table 5

Contribution of the monetary policy shocks to the forecast error variance

Horizon				
	1 year	2 year	3 year	4 year
IP	0.01	0.02	0.03	0.04
CPI	0.11	0.12	0.12	0.12
M1	0.07	0.07	0.11	0.14
R	0.09	0.12	0.14	0.16
XR	0.37	0.36	0.36	0.35

We can infer that like Canada, interest rate shock explain a small proportion of industrial production and price level fluctuations. This finding is similar to Muhammad Naveed Tahir (2012). Aleem and Lahiani found the proportion of price level variation due to monetary policy shock to be near zero after April 1998, when South Korea adopts inflation targeting. Concerning the exchange rate, monetary policy shocks explain a large share of exchange rate fluctuations as in Canada, but the proportion here is half of the respective response in the Canadian case.

4.7 Denmark

We will treat the Denmark economy in the same way as South Korea, so we assume that FFR, CPI U.S. and CPI advance are exogenous variables. The identification scheme is:

$$\begin{bmatrix} v_{MS} \\ v_{MD} \\ v_{IP} \\ v_{CPI} \\ v_{XR} \end{bmatrix} = \begin{bmatrix} 1 & g_{12} & 0 & 0 & g_{15} \\ g_{21} & 1 & g_{23} & g_{24} & 0 \\ 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & g_{43} & 1 & 0 \\ g_{51} & g_{52} & g_{53} & g_{54} & 1 \end{bmatrix} \begin{bmatrix} u_{R} \\ u_{M1} \\ u_{IP} \\ u_{CPI} \\ u_{XR} \end{bmatrix}$$

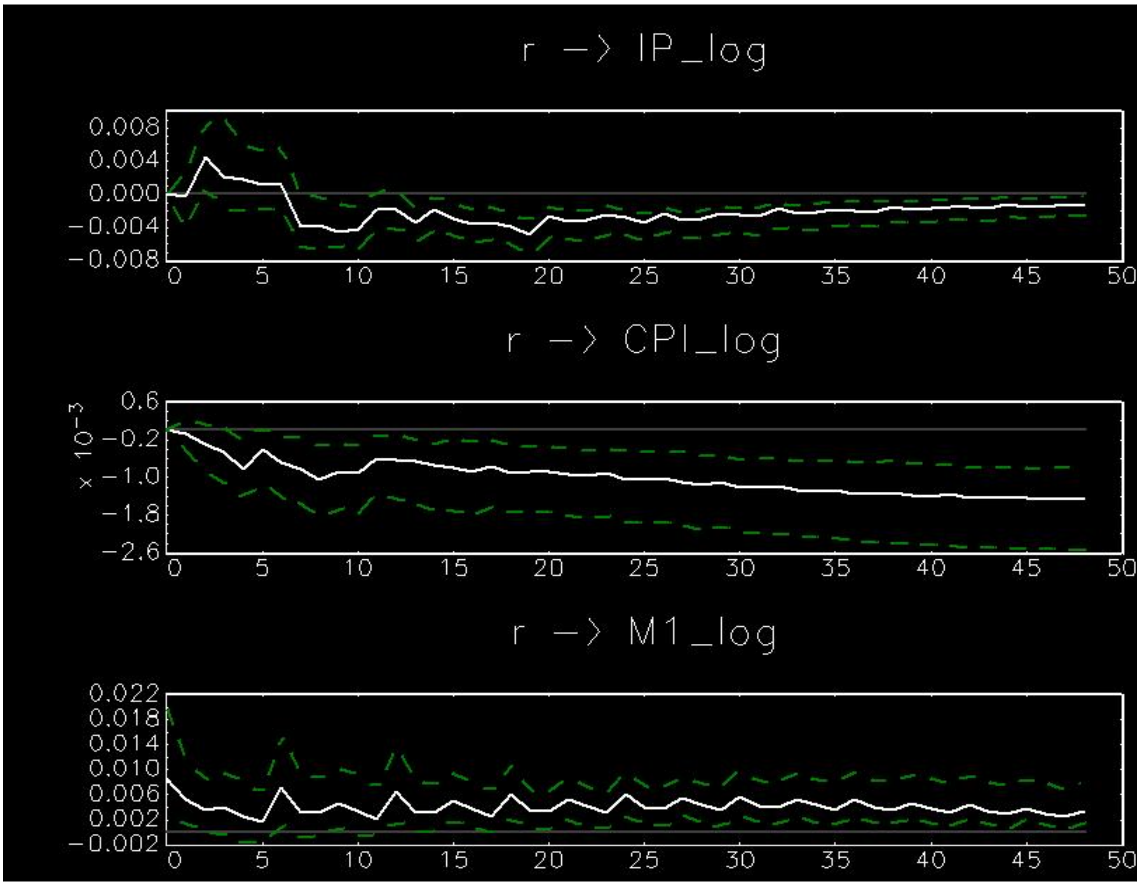
Impulse Responses

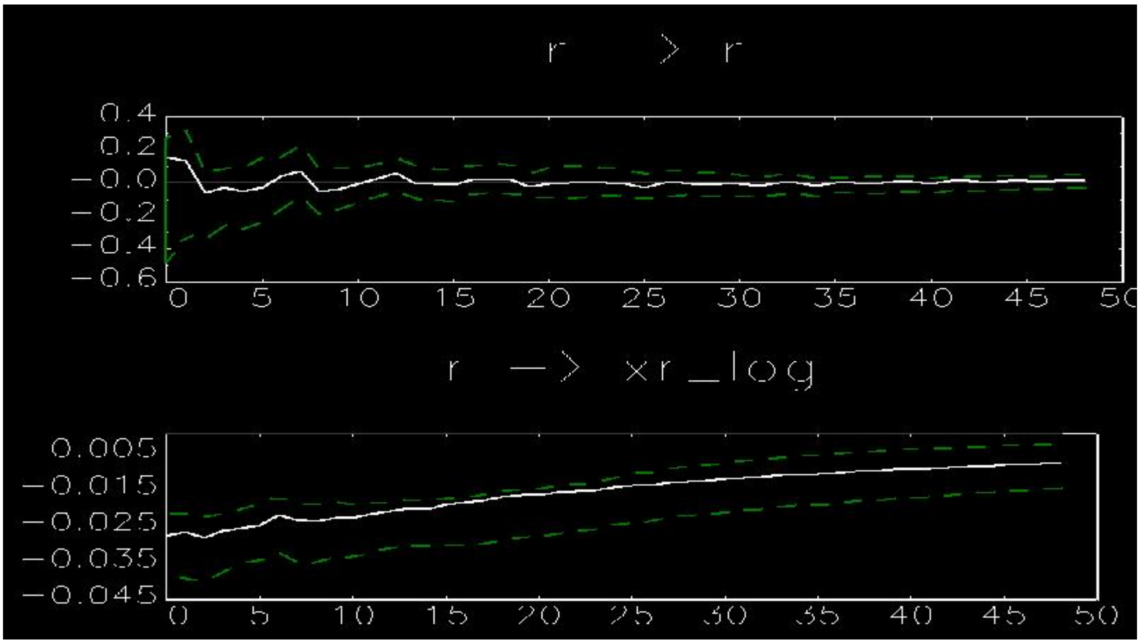
The sample period covers the post-Bretton Woods era 1975M1-2007M12. It is worth noting that Denmark monetary authority's preference is a fixed exchange rate regime in all its history after 1975. From 1999 Denmark Krone is in a fixed regime with Euro, so its monetary policy depends on European Central banks policy. Impulse dummy variables are included for the outliers in interest rate series in 1993M2 and 1993M8, probably due to the Scandinavian countries banking crises. Following the Akaike information criterion we choose 9 lags.

In Figure 6 we display the estimated impulse responses (over 48 months) for Denmark to a domestic monetary policy shock. The dashed lines represent the confidence intervals which are constructed with the Hall's percentile bootstrap method.

Figure 6

Denmark: Response to a monetary policy shock, using the structural VAR





Note: 90% confidence intervals

The Interest rate rises in response to money supply shock statistically insignificantly and afterwards declines steadily and after few months it returns to its steady state value. M1 display a puzzling behavior over the whole horizon because it increases on impact and remain above zero.

Price level initially responds sluggishly and then starts to decline. After less than 5 months the decline become statistically significant as theory predicts. Industrial production in the initial months displays a puzzling behavior by increasing slightly, but shortly after it turns negative and significant following a hump-shape response. The effect dies out in 4 years.

The response of the exchange rate is very interesting. The impact response is an appreciation such as South Korea and Canada and then it depreciates for a while then appreciating for a while and afterwards it depreciates over the whole period. So, it follows interest rate movements because it increases on impact then decrease for a while and then increases again for some time. Consequently, we have an overshooting but also for a very small time an appreciation is interfering. In forecast error variance decomposition we will see that a very large part of the variation in exchange rate is explained by interest rate shocks.

Variance Decomposition

In table 6 we present the forecast error variance decomposition analysis due to monetary policy shocks.

Table 6

Contribution of the monetary policy shocks to the forecast error variance

Horizon				
	1 year	2 year	3 year	4 year
IP	0.04	0.08	0.11	0.12
CPI	0.04	0.06	0.10	0.15
M1	0.09	0.12	0.15	0.16
R	0.01	0.01	0.01	0.01
XR	0.95	0.91	0.88	0.83

The forecast error variance decomposition for Industrial production and price level is in the same range with the preceding cases in this study. The notable result is concerning the exchange rate, where variation in the first two years is almost completely explained by interest rate innovations. In table 7, we present the contribution of exchange rate shocks to the forecast error variance of interest rate.

Table 7

Contribution of the exchange rate shocks to the forecast error variance

Horizon				
	1 year	2 year	3 year	4 year
R	0.56	0.55	0.55	0.55

Denmark is in a fixed exchange rate regime so it is expected that monetary authorities manipulate the policy instrument to absorb exchange rate shocks. From table 7 we see that exchange rate shocks explain half of the interest rate fluctuations in all horizons.

4.8 Sweden

We proceed with two Scandinavian small open economies. Starting with Sweden, the identification is slightly different because the monetary aggregate is not available. We assume that CPI U.S, CPI advance and FFR are exogenous because Sweden is a small country compared to its trading partners. Moreover, we allow the exchange rate to contemporaneously affect the price level, implying a significant pass-through from exchange rate to prices, according to Adolfson (1997) the pass through from exchange rates to import prices ranges from 20%-40% in the short run[32]. The identification scheme is the following:

$$\begin{bmatrix} v_{MS} \\ v_{IP} \\ v_{CPI} \\ v_{XR} \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & g_{14} \\ 0 & 1 & 0 & 0 \\ 0 & g_{32} & 1 & g_{34} \\ g_{41} & g_{42} & g_{43} & 1 \end{bmatrix} \begin{bmatrix} u_{R} \\ u_{IP} \\ u_{CPI} \\ u_{XR} \end{bmatrix}$$

Impulse Responses

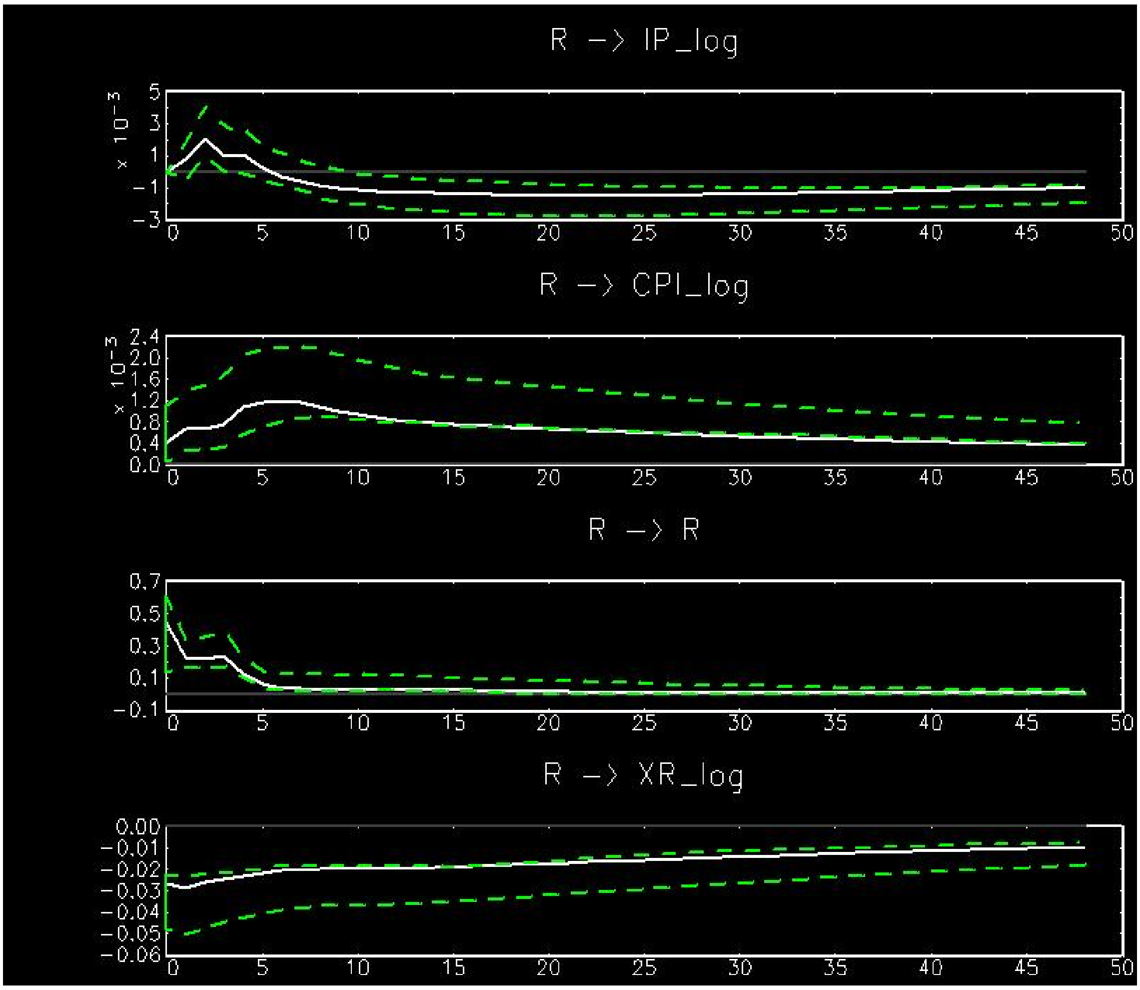
The sample period is 1985M1-2007M12[33]. The number of lags is 5 following the Akaike information criterion. We include dummy variables that reflect the turbulence in Swedish economy due to the banking crises in 1991-92[34], one shift dummy for exchange rate for the period 1998M3-1998M8 (we have a large depreciation of Swedish Krona) and one impulse dummy for interest rate in 1992M9.

In Figure 7 we display the estimated impulse responses (over 48 months) for Sweden to a domestic monetary policy shock. The dashed lines represent the confidence intervals which are constructed with the Hall's percentile bootstrap method.

[32] For the other small open economies the addition of this identification assumption has no influence on innovation accounting, the difference is that the initial magnitude of monetary policy shock to interest rate is much smaller, due to the immediate response of interest rate to exchange rate appreciation.
[33] From 1983 to 1985, we have the deregulation in credit markets in Sweden.
[34] See Englund (1999)

Figure 7

Sweden: Response to a monetary policy shock, using the structural VAR



Note: 90% confidence intervals

Interest rate response to monetary policy shock is similar to the preceding cases with an impact increase and a gradual decrease due to the ensuing recession. Here, there is an evident price puzzle. Price level rises immediately and for a 1 year in response to the interest rate innovation and afterwards decreases, the overall effect in price level is statistically significant for the whole 48 months horizon. Consequently as in the case of UK it is unlikely that the identified shock represent a monetary policy shock. As for IP, the response is similar to the Denmark's case, but in Sweden the IP does not return to the steady state, it remains below steady state for the whole horizon. Bjornland (2009) find no evidence of price puzzle, price level and output display the expected hump-shape response.

The exchange rate response to interest rate innovation is trivial. We have an impact appreciation lasting for few months and then a subsequent depreciation for the rest of the period. Consequently, there is evidence of delayed overshooting. The impact appreciation is attributed to the statistically significant increase in interest rate because the impact increase in price level is insignificant. When the price level increase becomes significant the exchange rate starts to depreciate. Bjornland (2009) finds a similar response of exchange rate to monetary policy shock.

Variance Decomposition

In table 8 we present the forecast error variance decomposition analysis due to monetary policy shocks.

Table 8

Contribution of the monetary policy shocks to the forecast error variance

Horizon				
	1 year	2 year	3 year	4 year
IP	0.02	0.07	0.10	0.12
CPI	0.11	0.14	0.15	0.16
R	0.33	0.29	0.28	0.40
XR	0.84	0.80	0.77	0.75

Forecast error variance decomposition for Industrial production and price level due to interest rate shocks is in line with the other cases, the estimated results are in the same interval as in the previous countries. The difference is that from the first year a 10 percent of the price level variation is explained from interest rate innovations, in the other countries the respective result is below 6 percent. As in the previous small open economies the interest rate shock explain a very large proportion of exchange rate fluctuations in all horizons. Bjornland (2009) also found a significant result (25 percent for the first quarter) but not in that magnitude.

4.9 Norway

The next Scandinavian country is Norway. The identification assumptions are the same as in Sweden case, but here g_{34}=0. If we include this assumption the difference is in Impulse response analysis where the rise in r is much smaller, but the other results are similar. So, we have the following identification scheme:

$$\begin{bmatrix} v_{MS} \\ v_{IP} \\ v_{CPI} \\ v_{XR} \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & g_{14} \\ 0 & 1 & 0 & 0 \\ 0 & g_{32} & 1 & 0 \\ g_{41} & g_{42} & g_{43} & 1 \end{bmatrix} \begin{bmatrix} u_{R} \\ u_{IP} \\ u_{CPI} \\ u_{XR} \end{bmatrix}$$

Impulse Responses

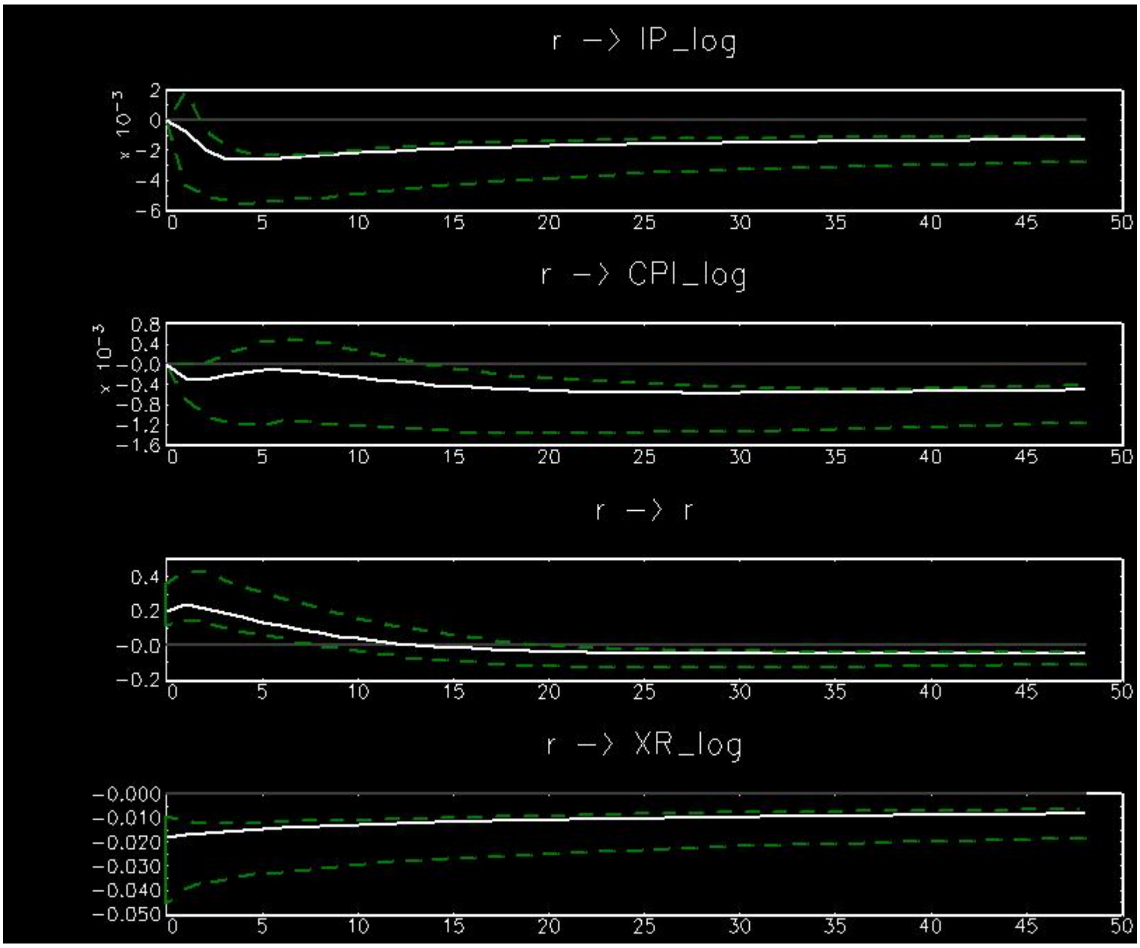
The sample period is 1993M1-2007M12, because before 1993 it is difficult to identify a stable monetary policy regime[35]. The number of lags is 2 following the Akaike information criterion. One shift dummy for exchange rate is included for the period 2002M1-2002M6 to take account of the appreciation of Norwegian krone against the U.S. dollar to record high levels due to the high interest rate and the high price of oil. Two additional shift dummies were included following Bjornland (2008). One for exchange rate in periods 1997M1-1997M8 due to the severe appreciation pressure against the Norwegian Krone in the first quarter of 1997, and the depreciation in the second quarter. The second dummy for the period 1996M5-1998M4, because of the fact that although monetary policy can be described as following the Taylor rule from 1993, from the late 1996 to 1998, deviations from this rule were observed as the exchange rate also targeted.

In Figure 8 we display the estimated impulse responses (over 48 months) for Norway to a domestic monetary policy shock. The dashed lines represent the confidence intervals which are constructed with the Hall's percentile bootstrap method.

[35] See Bjornland (2008).

Figure 8

Norway: Response to a monetary policy shock, using the structural VAR



Note: 90% confidence intervals

Monetary policy shock increases interest rate temporarily and then it declines smoothly. The nominal interest rate returns to its steady state value after a year and subsequently goes below the steady state. The responses of Industrial production and price level are in line with the Christiano, Eichenbaum and Evans (1996) qualitative features. Industrial production displays a hump-shape response lasting over the whole 48 months horizon and is statistically significant over the whole horizon. Price level initially responds sluggishly but then decline and remains to a new level. These results are similar with Bjornland (2008) (she used quarterly data).

The exchange rate response gives support to the overshooting hypothesis and the UIP condition. It responds to the monetary policy shock with an impact and statistically significant appreciation and afterwards a gradual depreciation which is significant as well. In Bjornland (2008) we have a delayed overshooting (the appreciation lasting for 8 months).

Variance Decomposition

In table 9 we present the forecast error variance decomposition of domestic variables due to monetary policy shocks.

Table 9

Contribution of the monetary policy shocks to the forecast error variance

Horizon				
	1 year	2 year	3 year	4 year
IP	0.07	0.10	0.12	0.13
CPI	0.01	0.05	0.09	0.12
R	0.33	0.29	0.29	0.30
XR	0.47	0.43	0.41	0.40

Monetary policy shocks explain a small proportion of the variation of Industrial production and price level, a result which is in accord with the other cases examined in this study. Also, as in the other small open economies, we observe that monetary policy shocks explain a substantial proportion of the exchange rate fluctuations, although relatively low and similar to South Korea. So, as a stylized fact, over 40 percent of exchange rate fluctuations are explained from interest rate shocks in small open economies.

4.10 A comment on the policy instrument

In this study as in others such as Bjornland (2009), Kim and Roubini (2000), Peersman and Smets (2001) and Eichenbaum and Evans (1995), the policy instrument is a short term nominal interest rate. However, variance decomposition analysis for all cases except Japan indicates that a small fraction of interest rate fluctuations is attributed to monetary policy shocks. To examine more thoroughly the validity of nominal interest rate as an indicator of monetary policy stance we present in table 10 the forecast error variance decomposition of interest rate due to monetary policy shocks.

Table 10

Contribution of the monetary policy shocks to the forecast error variance of interest rate

Country	1 Month	2 Months
Euro zone	0.88	0.82
Japan	0.90	0.88
U.K.	0.41	0.46
Canada	0.22	0.17
South Korea	0.25	0.13
Denmark	0.01	0.01
Sweden	0.32	0.37
Norway	0.52	0.51

If the short term interest rate is a considerable policy instrument, its variation in the first month should be explained by monetary policy shocks. However, at all countries but Japan and Euro zone the variation in interest rate in the first month is dominated from shocks to other economic variables instead of unsystematic monetary policy shocks. So, the interest rate responds more to economic variables than to unsystematic monetary policy shocks.

This inference is very important to monetary authorities, as well as market participants. Furthermore, it is in accordance with Christopher Sims belief, who in his speech[36] in Emory University at April 2012, mentions that most of the movements in interest rate are systematic response of monetary policy to the state of the economy. However, it seems that for Euro zone and Japan the interest rate is a valid policy instrument.

To sum up, from the SVAR analysis for the 8 industrialized countries, the commonly observed in the empirical literature price puzzle still exists for the cases of UK and Sweden. The main finding of the SVAR analysis is that

[36] The speech title is *"Statistical Modeling of Monetary Policy and It's Effects"*

delayed overshooting remains with the exception of Norway and Canada cases where exchange rate displays overshooting behavior.

Chapter 5

An alternative identification strategy

We will apply a different identification scheme as a comparison with the structural VAR. The second identification scheme is a standard Cholesky decomposition. VAR specification remains the same for all countries containing a constant and a trend. Moreover, the ordering of the variables is the same for all countries except a shift in the ordering between nominal interest rate (the policy instrument) and nominal exchange rate for Denmark, which will be discussed below. The ordering is not important, because in all cases the correlation coefficients are less than 0.2 (Appendix A) except for CPI indices where we have high correlation as expected.

5.1 Euro zone

The ordering of the variables is {CPI advance, FFR, IP, CPI, M1, R, XR}. It is a typical recursive ordering in VAR literature similar to Eichenbaum and Evans (1995), Peersman and Smets (2001) and Bjornland (2009), (2008). However for the three large open economies if we put XR before R the results are similar. CPI U.S. is considered as an exogenous variable.

At the top of the ordering are the variables of the foreign sector, then follow the domestic variables. The underlying assumption is that monetary policy shocks affect Industrial production, price level and money with a one period lag, but may affect exchange rate contemporaneously because exchange rate is an asset price. However, the policy interest rate does not contemporaneously respond to changes in the exchange rate. In SVAR we assume that the Industrial production and price level have no contemporaneous effect to interest rate. Here on the contrary we withdraw this assumption. According to Christiano, Eichenbaum and Evans (1998) “In our view the assumption that the

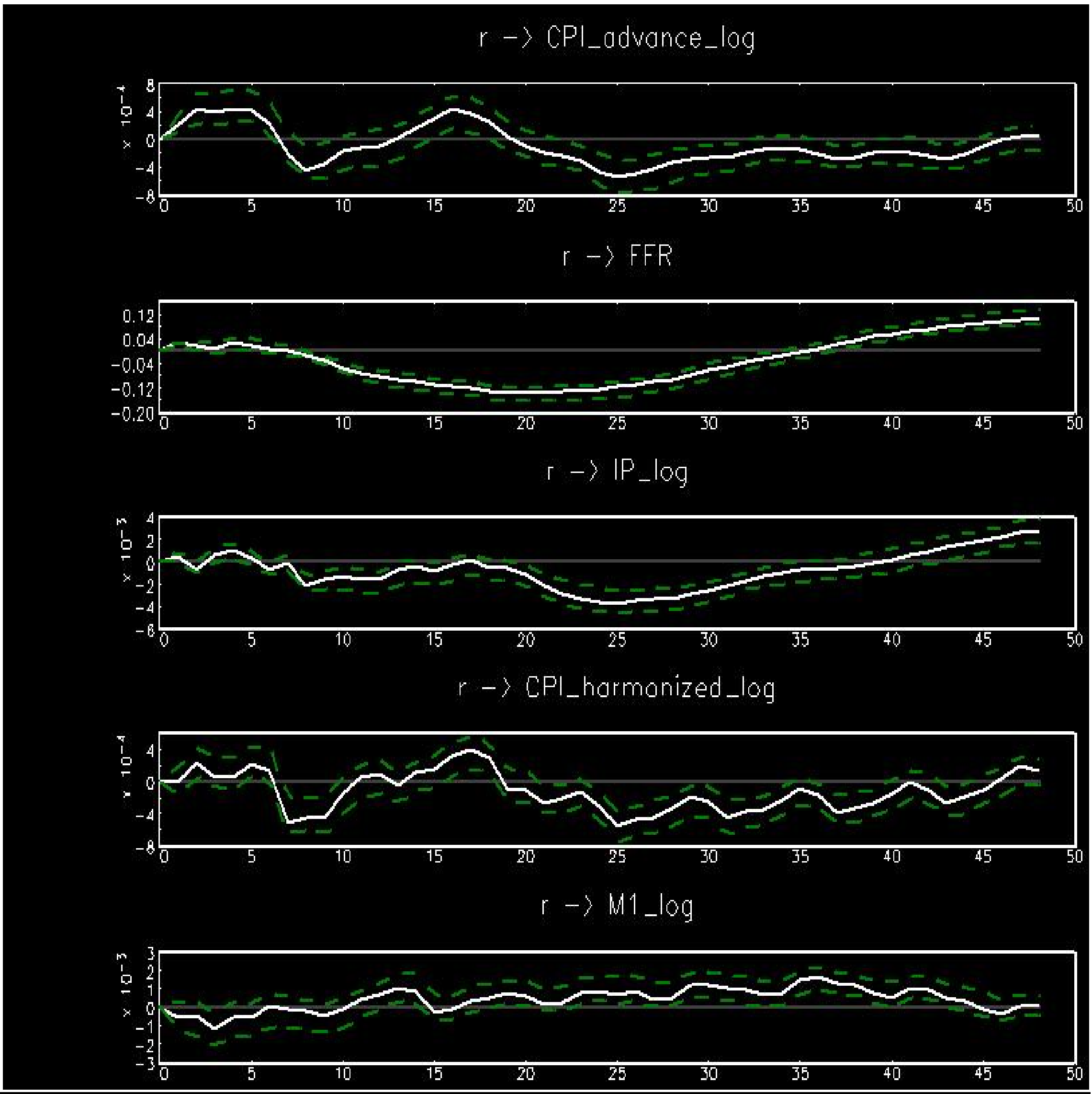
Fed sees Y_t and P_t when they choose the instrument of monetary authority seems at least as plausible as assuming that they don't. Following the same course as in SVAR we proceed with innovation accounting.

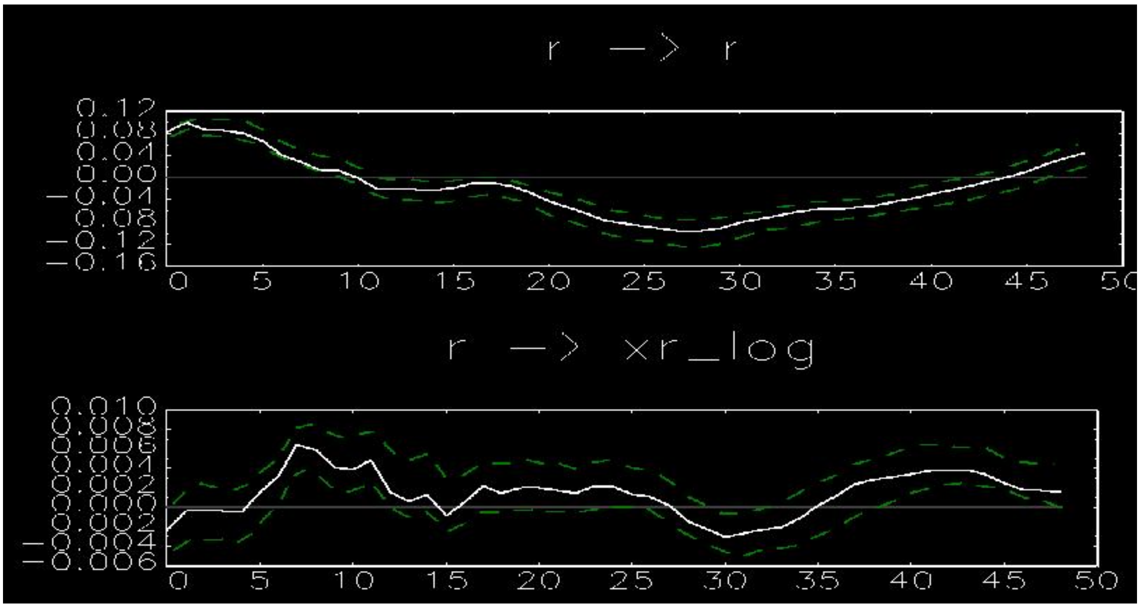
Impulse Responses

In Figure 9 we display the estimated impulse responses (over 48 months) for Euro zone to a domestic monetary policy shock. The dashed lines represent the confidence intervals which are constructed with the Hall's percentile bootstrap method. The number of lags is 10 following the Akaike information criterion.

Figure 9

Euro zone: Recursive impulse responses to a monetary policy shock





Note: 90% confidence intervals

The response of interest rate in both identification strategies is the same. The picture is quite different for M1, for the first year it responds sluggishly to monetary policy shock and then increases statistically significant. In contrast in SVAR decreases on impact significantly and then return to its steady state.

The effect of monetary policy shock on Industrial production and price level is similar. As for the foreign sector, CPI advance for the most periods over the 48 months horizon remains below zero. FFR also has the same behavior as in SVAR. In respect of the exchange rate, it displays the same behavior as in SVAR.

Variance Decomposition

In table 11 we present the forecast error variance decomposition of domestic variables due to monetary policy shocks.

Table 11

Contribution of the monetary policy shocks to the forecast error variance

Horizon				
	1 year	2 year	3 year	4 year
IP	0.04	0.06	0.14	0.14
CPI	0.03	0.04	0.08	0.08
M1	0.01	0.02	0.04	0.05
R	0.30	0.23	0.36	0.32
XR	0.03	0.03	0.03	0.05

So, for Euro zone except M1 the results in recursive ordering are in line with that of SVAR approach.

5.2 Japan

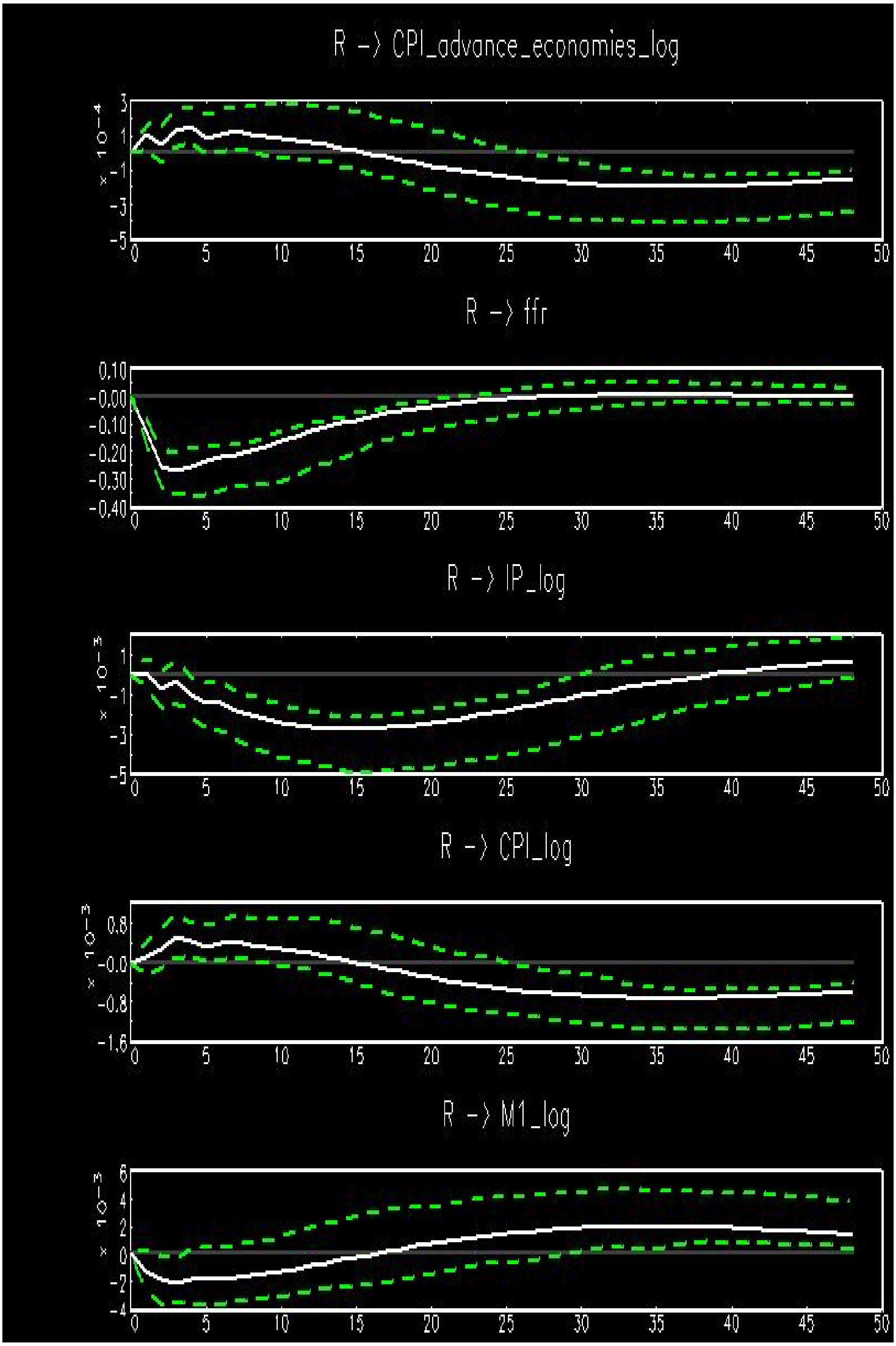
We treat Japan in exactly the same way as Euro zone.

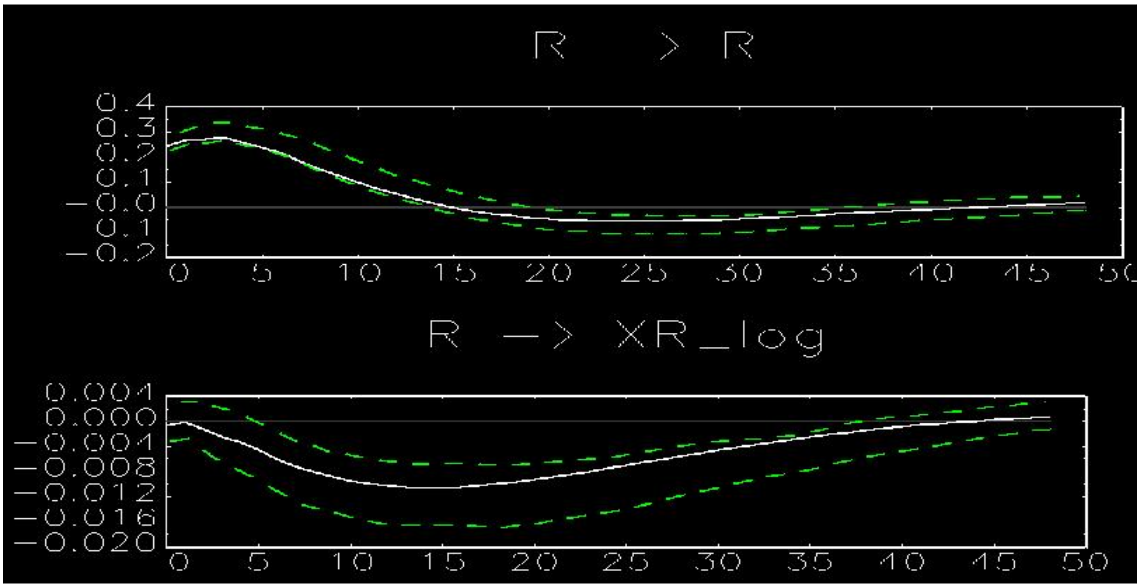
Impulse Responses

In Figure 10 we display the estimated impulse responses (over 48 months) for Japan to a domestic monetary policy shock. The dashed lines represent the confidence intervals which are constructed with the Hall's percentile bootstrap method. The number of lags is 4 following the Akaike information criterion.

Figure 10

Japan: Recursive impulse responses to a monetary policy shock





Note: 90% confidence intervals

The monetary policy shock increases the interest rate temporarily which reaches its steady state in about 15 months. The same behavior is displayed by the interest rate in the Structural VAR. On the contrary, M1 declines on impact and for some months the decline is statistically significant. This result is in line with the theory, but in the mid-term it starts to increase significantly as in SVAR.

The response of Industrial production and price level to monetary policy shock is similar to the first identification. Industrial production's response here is much stronger without a significant puzzle. The two foreign sector variables display common behavior in the two identification schemes.

Also, as in the other variables in the model, exchange rate's behavior in the two identification schemes is indistinguishable, displaying delayed overshooting and consequently a failure of UIP condition.

Variance Decomposition

We proceed with variance decomposition analysis in table 12.

Table 12

Contribution of the monetary policy shocks to the forecast error variance

Horizon				
	1 year	2 year	3 year	4 year
IP	0.04	0.07	0.06	0.06
CPI	0.01	0.01	0.03	0.05
M1	0.01	0.01	0.01	0.02
R	0.72	0.57	0.47	0.41
XR	0.05	0.12	0.13	0.13

Variance decomposition analysis is slightly different between the two identifications. First, after the second year the contribution of monetary policy shocks to price level fluctuations is about 5 percent more in SVAR. Also, shocks to monetary policy explain a larger share of M1 variation in SVAR.

The inference for Japan is almost the same either a researcher uses SVAR identification or recursive identification.

5.3 United Kingdom

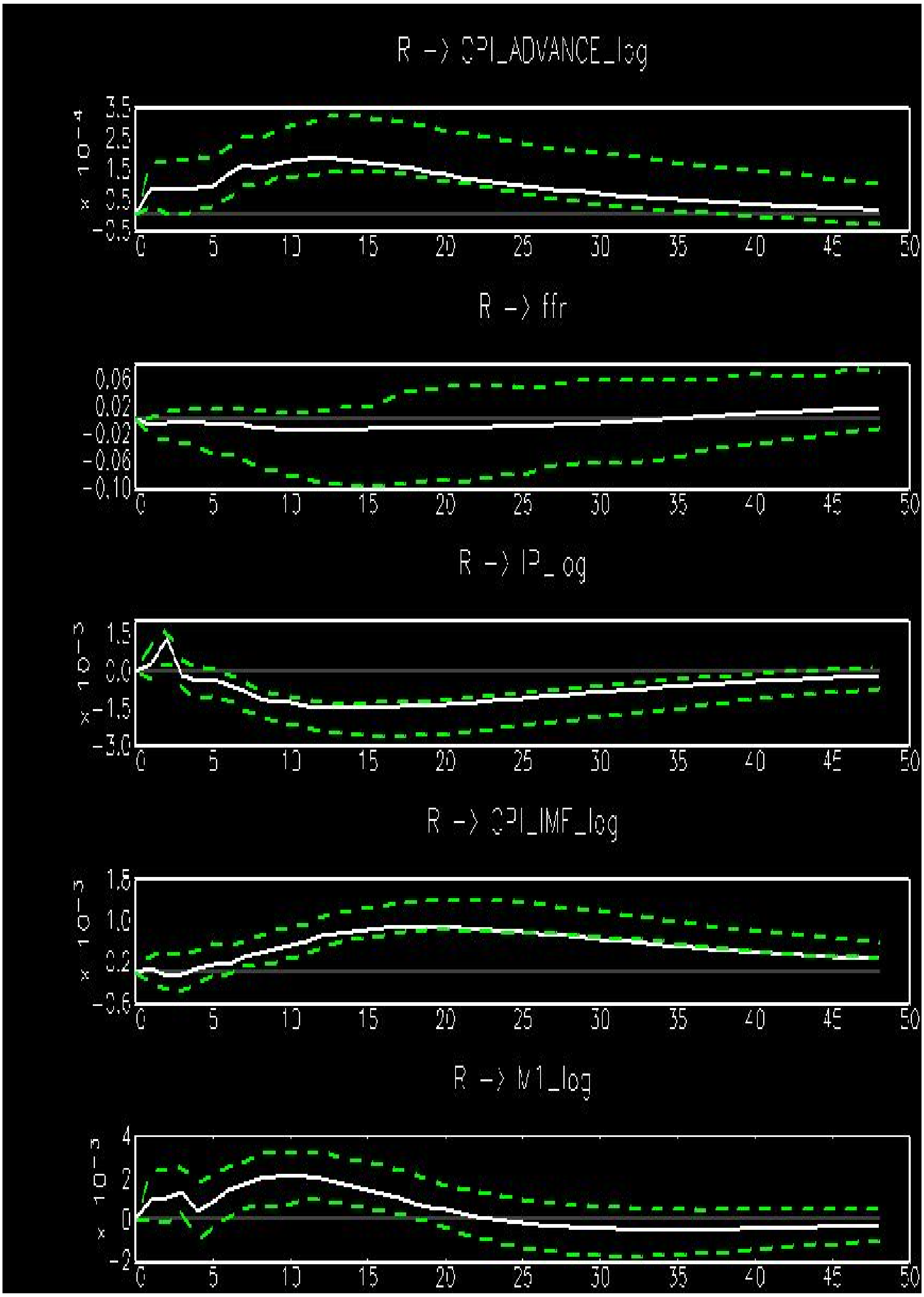
As we have already mentioned U.K. is a large open economy. The ordering of the variables is as previously {CPI advance, FFR, IP, CPI, M1, R, XR}.

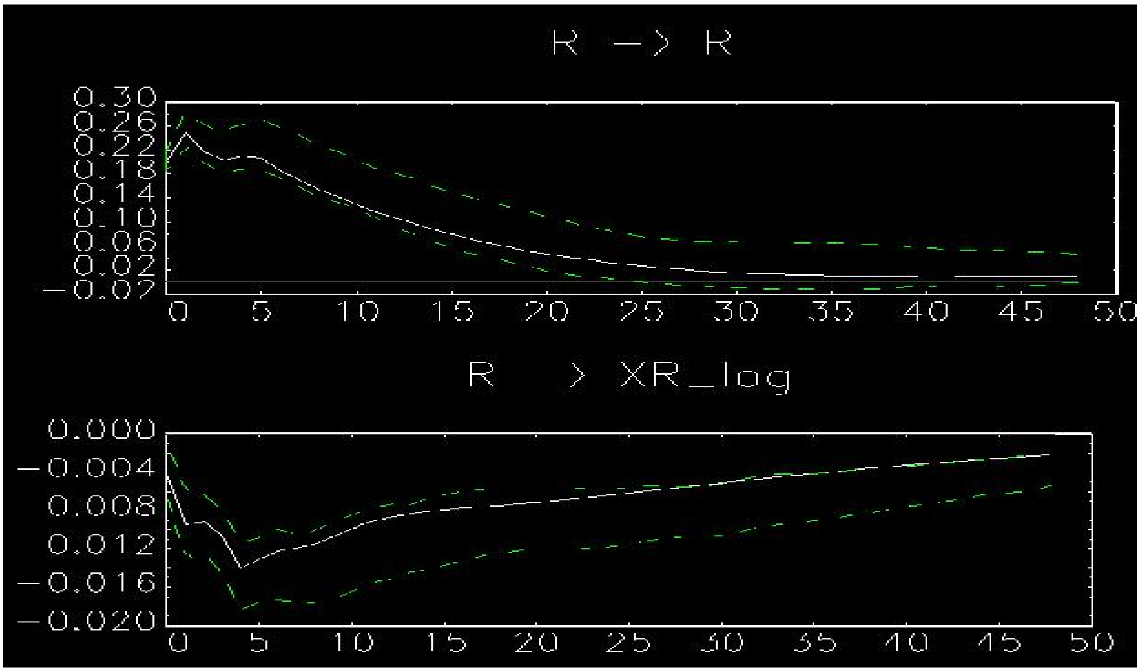
Impulse Responses

In Figure 11 we display the estimated impulse responses (over 48 months) for U.K. to a domestic monetary policy shock. The dashed lines represent the confidence intervals which are constructed with the Hall’s percentile bootstrap method. The number of lags is 5 following the Akaike information criterion.

Figure 11

U.K: Recursive impulse responses to a monetary policy shock





Note: 90% confidence intervals

The interest rate temporarily rises after the monetary policy shock and then smoothly returns to its steady state value. The response is the same with the SVAR, but the response in recursive identification is statistically significant for a much longer horizon. In contrast M1 displays a puzzle, increasing in the mid-term and decreasing after a year. In SVAR M1 decreases on impact and gradually return to its pre shock level.

As for Industrial production and price level the response of both of them is the same as in the SVAR with some little differences. Industrial production in recursive identification increases for a very short time in the initial months and price level increases statistically significantly earlier in the recursive structure.

Foreign sector variables also display similar pattern as in SVAR. The difference here is that the increase in CPI advance is statistically significant for a longer horizon.

The overall exchange rate response is the same as in SVAR as well. However, in the recursive identification the contemporaneous effect of monetary policy shock on exchange rate is a statistically significant appreciation. When we examine the SVAR, the impact appreciation was not significant.

Variance Decomposition

In table 13 we present the forecast error variance decomposition of domestic variables due to monetary policy shocks.

Table 13

Contribution of the monetary policy shocks to the forecast error variance

Horizon				
	1 year	2 year	3 year	4 year
IP	0.05	0.11	0.12	0.12
CPI	0.03	0.16	0.22	0.23
M1	0.03	0.05	0.04	0.04
R	0.66	0.49	0.44	0.44
XR	0.30	0.34	0.35	0.35

Comparing the above table with SVAR we see that the contribution of monetary policy shocks to exchange rate fluctuations is 10 percent higher in recursive identification; also the respective percentage is higher for price level after the first year.

In general, a very important inference we can make for researchers examining the monetary transmission mechanism with VAR models for large economies is that the two identification methods give similar results. Particularly for U.K., the recursive identification method may be preferable to a Structural VAR. The exception is M1, which in order to give plausible results it is vital to assume a contemporaneous impact of interest rate (policy instrument) to M1, as it was assumed in SVAR.

5.4 Canada

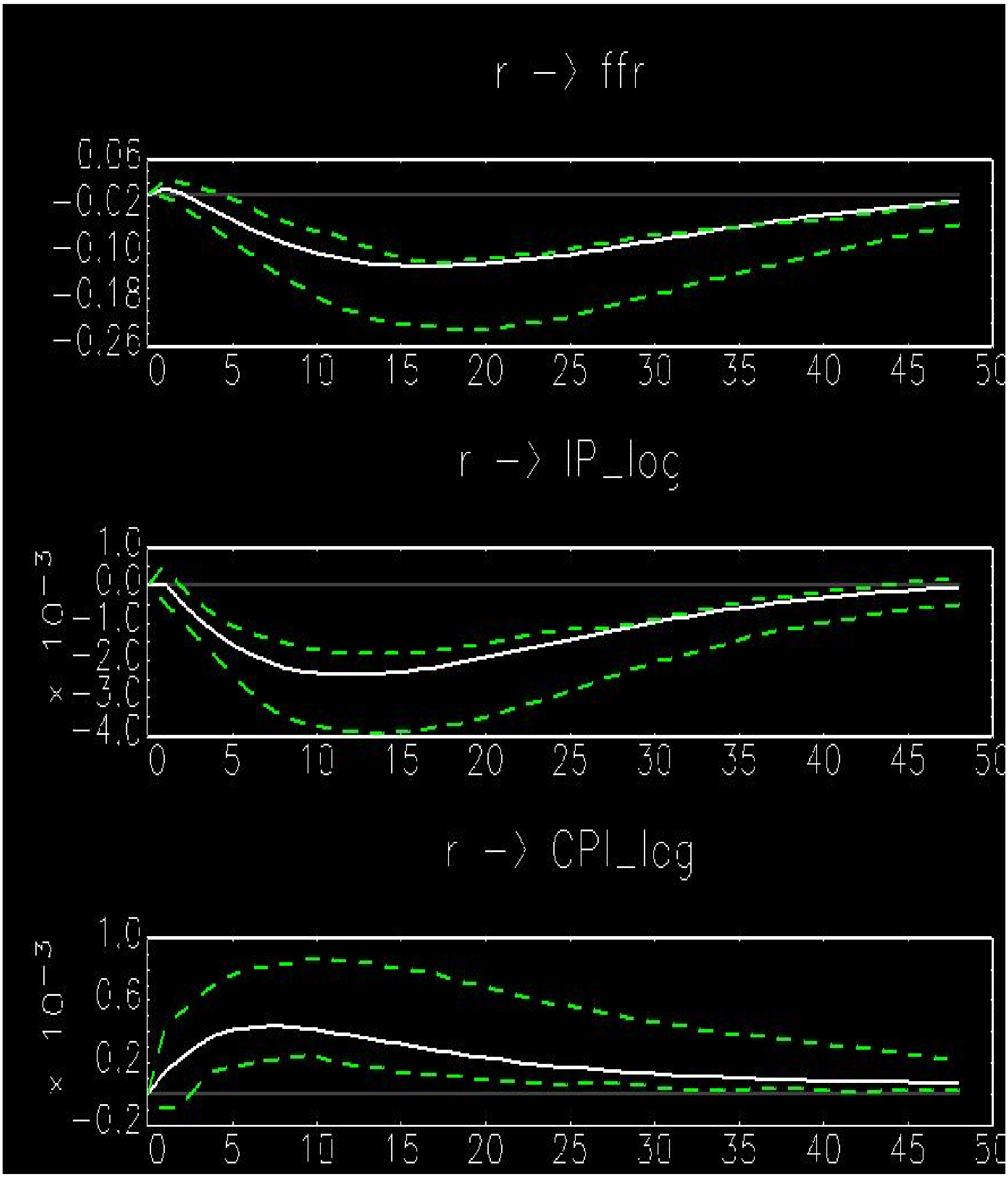
We turn our analysis to small open economies. The ordering of the variables is {FFR, IP, CPI, M1, R, XR} with CPI advance and CPI U.S. be the exogenous variables. If we put XR before R in small open economies the results are similar.

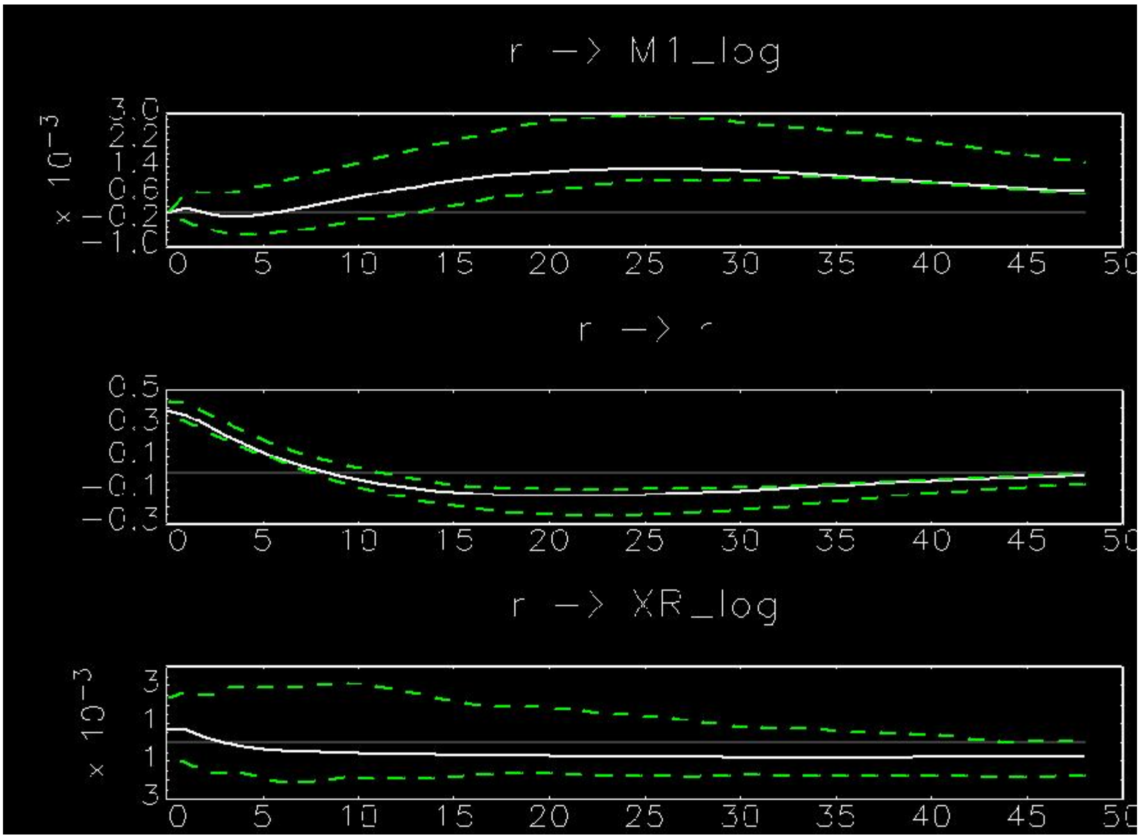
Impulse Responses

In Figure 12 we display the estimated impulse responses (over 48 months) for Canada to a domestic monetary policy shock. The dashed lines represent the confidence intervals which are constructed with the Hall's percentile bootstrap method. The number of lags is 2 following the Akaike information criterion.

Figure 12

Canada: Recursive impulse responses to a monetary policy shock





Note: 90% confidence intervals

The response of interest rate in recursive identification method to a contractionary shock is statistically significant over the whole period, while in the first identification the response of interest rate is insignificant. M1 displays the same puzzling behavior as in large economies. It responds sluggishly for the first 10 months and then starts to increase significantly for the whole horizon. On the contrary in SVAR M1 start to decline significantly after approximately 25 months.

In respect of Industrial production and price level, the former follows the theory but the latter increases, so a price puzzle emerges in recursive ordering. Another puzzle is that FFR decreases significantly for a prolonged period in contrast with SVAR where it increases. The first identification method gives the anticipated results.

As for the exchange rate, it does not respond statistically significantly to a monetary policy shock, a result that is in sharp contrast with our findings using the Structural VAR method.

Variance Decomposition

In table 14 we present the forecast error variance decomposition of domestic variables due to monetary policy shocks.

Table 14

Contribution of the monetary policy shocks to the forecast error variance

Horizon				
	1 year	2 year	3 year	4 year
IP	0.12	0.22	0.24	0.23
CPI	0.04	0.04	0.03	0.03
M1	0.00	0.03	0.04	0.05
R	0.39	0.28	0.27	0.27
XR	0.00	0.00	0.00	0.01

Variance decomposition analysis results are quite different from that of SVAR. The share of variation of Industrial production and price level that is explained by monetary policy shocks is much larger here especially for Industrial production. Furthermore, in SVAR over 50 percent of the variation of exchange rate is attributed to interest rate innovation, in recursive identification the respective percentage is zero. This result is due to the zero restriction on the contemporaneous effect of exchange rate on interest rate.

5.5 South Korea

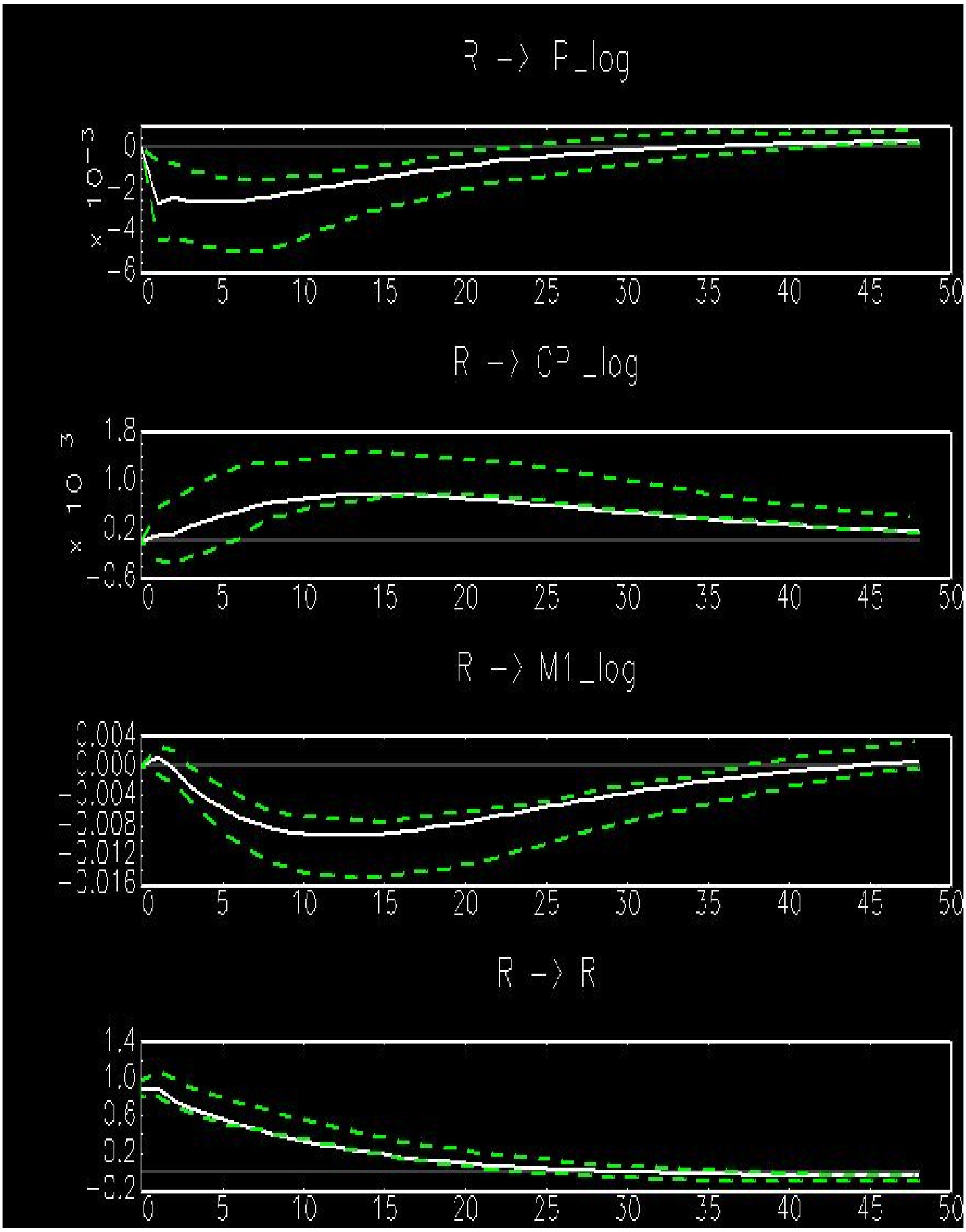
We proceed with South Korea. The ordering is {IP, CPI, M1, R, XR} with CPI advance, CPI U.S. and FFR as exogenous variables.

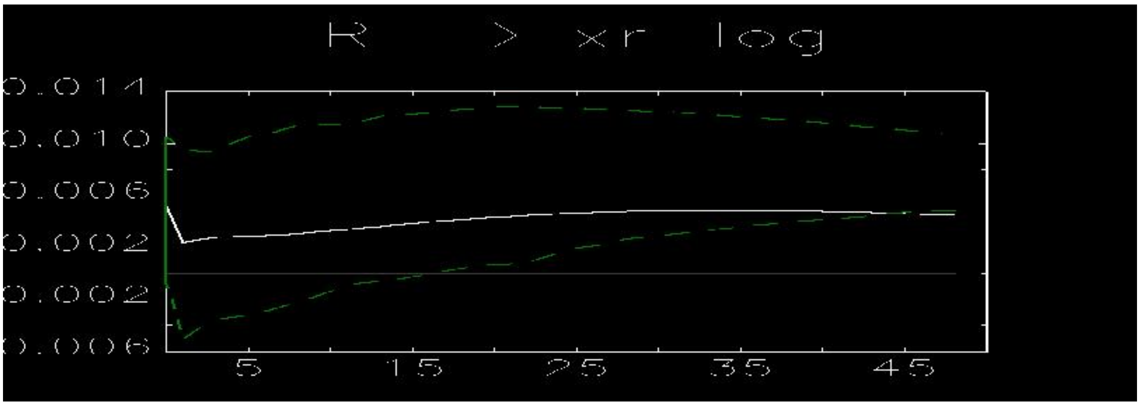
Impulse Responses

In Figure 13 we display the estimated impulse responses (over 48 months) for South Korea to a domestic monetary policy shock. The dashed lines represent the confidence intervals which are constructed with the Hall's percentile bootstrap method. The number of lags is 2 following the Akaike information criterion.

Figure 13

South Korea: Recursive impulse responses to a monetary policy shock





Note: 90% confidence intervals

The monetary policy shock increases the interest rate temporarily and then it returns smoothly to its steady state. M1 display a hump-shape response reaching its minimum at about a year. These two results are similar to SVAR. However, the decline of M1 takes place in the first months in recursive identification while in SVAR M1 declines after a year with a small increase in the first months. Also, in the SVAR, the interest rate reaches a new steady state.

Industrial production declines in response to a monetary policy shock and after approximately two years the response dies out. The difference in SVAR is that industrial production declines and remains in the same level for the whole period. On the other hand, the price level as at the preceding small open economy displays a puzzle, something that does not happen in the SVAR.

We also have an exchange rate puzzle. The exchange rate depreciates on impact and remains to the depreciated value over the whole 48 months horizon. This result is in sharp contrast with that of SVAR where we have delayed overshooting.

Variance Decomposition

In table 15 we present the forecast error variance decomposition of domestic variables due to monetary policy shocks.

Table 15

Contribution of the monetary policy shocks to the forecast error variance

Horizon				
	1 year	2 year	3 year	4 year
IP	0.06	0.07	0.07	0.07
CPI	0.02	0.06	0.07	0.08
M1	0.12	0.22	0.22	0.20
R	0.79	0.77	0.72	0.69
XR	0.01	0.02	0.02	0.03

The share of variation in Industrial production due to monetary policy shock is slightly larger here than in the first identification the reversal holds for price level. The main difference is in the proportion of variation of exchange rate that is explained from monetary policy shock, which in recursive identification is markedly lower. This result is due to the zero contemporaneous effect of exchange rate on interest rate in the second identification method.

5.6 Denmark

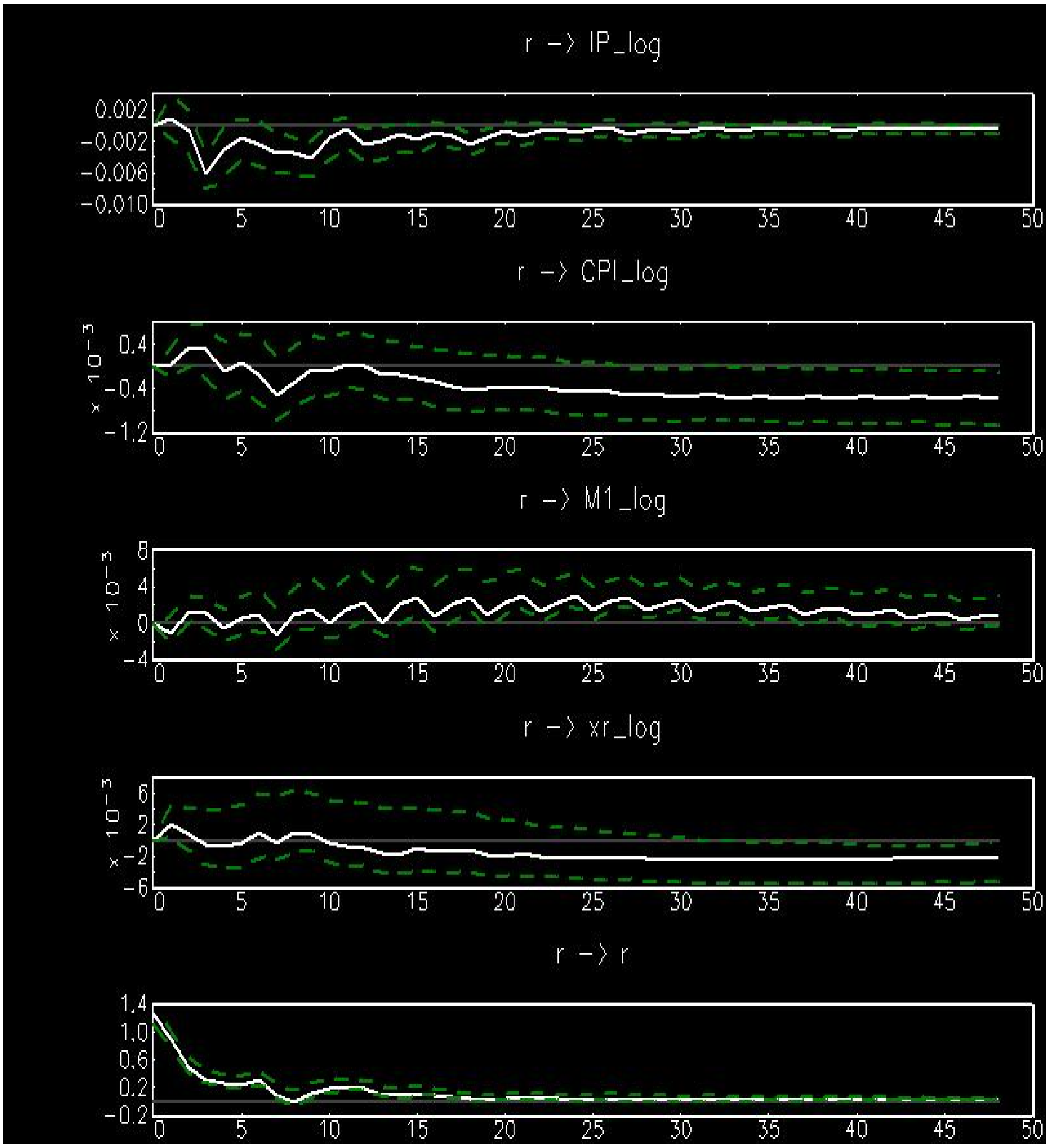
For Denmark the ordering is {IP, CPI, M1, XR, R} with CPI advance, CPI U.S. and FFR as exogenous variables. Denmark almost all the post-Bretton Woods period is in a fixed exchange rate regime, so monetary authorities respond immediately to exchange rate changes. For this reason we put exchange rate before interest rate in ordering.

Impulse Responses

In Figure 14 we display the estimated impulse responses (over 48 months) for Denmark to a domestic monetary policy shock. The dashed lines represent the confidence intervals which are constructed with the Hall's percentile bootstrap method. The number of lags is 9 following the Akaike information criterion.

Figure 14

Denmark: Recursive impulse responses to a monetary policy shock



Note: 90% confidence intervals

Interest rate rises in response to monetary policy shock and decline smoothly to its steady state value. In SVAR it follows the same course but the response is statistically insignificant. M1 increases significantly from the 20th month.

Industrial production and price level respond similarly as in the first identification. The exception for Industrial production is that in recursive identification there is no puzzling increase in the first months. Price level response in the second identification is similar to the first. In the SVAR the price level decrease becomes significant at the initial months, while in recursive method it becomes significant after about 25 months.

In respect of the exchange rate we observe a significant depreciation after three years. In SVAR identification the exchange rate response was as predicted from economic theory.

Variance Decomposition

In table 16 we present the forecast error variance decomposition of domestic variables due to monetary policy shocks.

Table 16

Contribution of the monetary policy shocks to the forecast error variance

Horizon				
	1 year	2 year	3 year	4 year
IP	0.05	0.06	0.06	0.06
CPI	0.01	0.02	0.03	0.03
M1	0.00	0.02	0.03	0.03
R	0.68	0.65	0.62	0.61
XR	0.00	0.00	0.01	0.01

As in the other small open economies the main difference with SVAR is the proportion of exchange rate fluctuations which is explained by monetary policy shocks that is eliminated.

5.7 Sweden

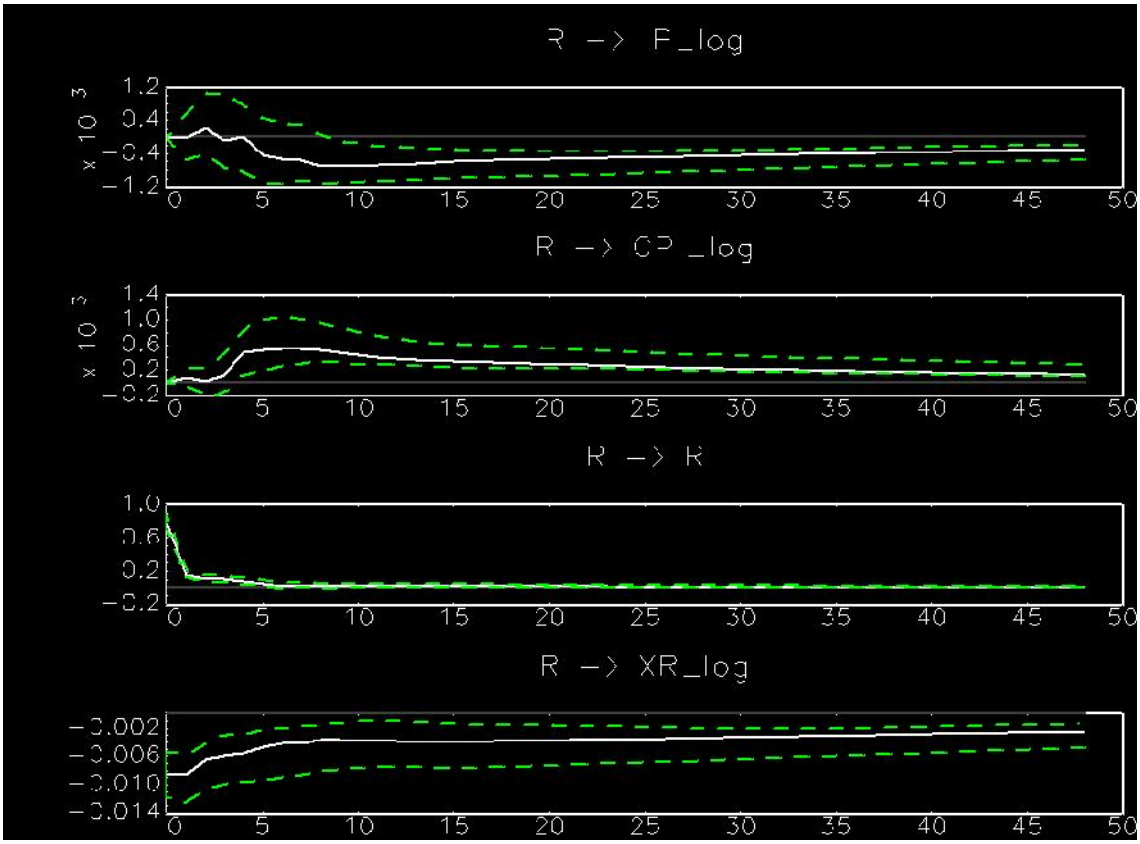
We proceed with the Scandinavian small open economies. The identification scheme is {IP, CPI, R. XR}.

Impulse Responses

In Figure 15 we display the estimated impulse responses (over 48 months) for Sweden to a domestic monetary policy shock. The dashed lines represent the confidence intervals which are constructed with the Hall's percentile bootstrap method. The number of lags is 5 following the Akaike information criterion.

Figure 15

Sweden: Recursive impulse responses to a monetary policy shock



Note: 90% confidence intervals

In Sweden there are no differences in Impulse response analysis between the two identification methods. So, we proceed with variance decomposition analysis.

Variance Decomposition

In table 17 we present the forecast error variance decomposition of domestic variables due to monetary policy shocks.

Table 17

Contribution of the monetary policy shocks to the forecast error variance

Horizon				
	1 year	2 year	3 year	4 year
IP	0.02	0.07	0.10	0.12
CPI	0.11	0.14	0.15	0.16
R	0.33	0.29	0.28	0.27
XR	0.84	0.80	0.77	0.75

Variance decomposition analysis is the same with SVAR as well. The only difference is that the forecast error variance decomposition of R attributed to its own shocks is 20 percent higher in the 4 year.

5.8 Norway

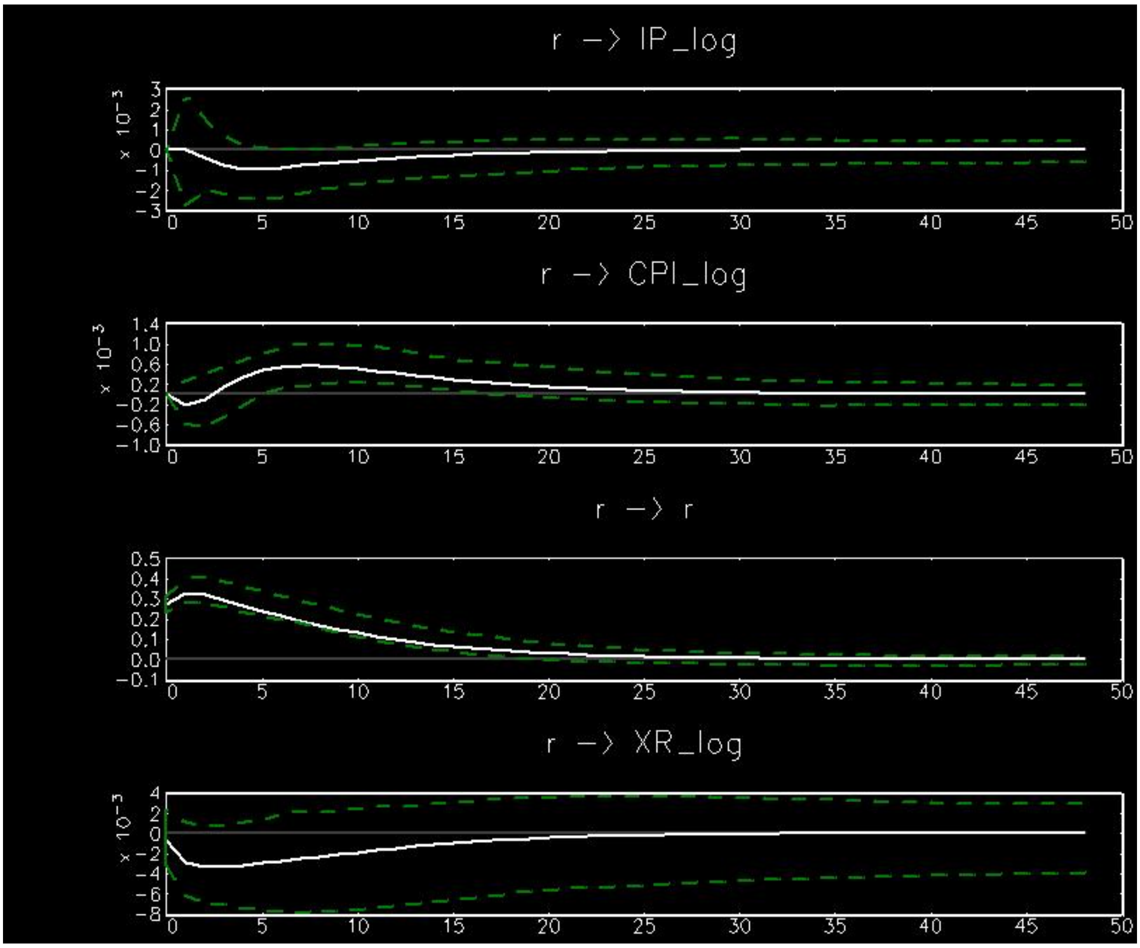
We follow exactly the same identification scheme as in Sweden.

Impulse Responses

In Figure 16 we display the estimated impulse responses (over 48 months) for Sweden to a domestic monetary policy shock. The dashed lines represent the confidence intervals which are constructed with the Hall's percentile bootstrap method. The number of lags is 2 following Akaike information criterion.

Figure 16

Norway: Recursive impulse responses to a monetary policy shock



Note: 90% confidence intervals

Monetary policy shock increases the interest rate temporarily and then it returns to its steady state in both identification schemes. Industrial production responds sluggishly and insignificantly for all periods. In SVAR it decreases significantly for the whole 40 months horizon. As for the price level, it displays a price puzzle.

The response of the exchange rate is much weaker and statistically insignificant, it displays delayed overshooting. On the contrary in Structural VAR we find evidence supporting the overshooting model.

Variance Decomposition

In table 18 we present the forecast error variance decomposition of domestic variables due to monetary policy shocks.

Table 18

Contribution of the monetary policy shocks to the forecast error variance

Horizon				
	1 year	2 year	3 year	4 year
IP	0.01	0.01	0.01	0.01
CPI	0.04	0.04	0.04	0.03
R	0.87	0.78	0.70	0.65
XR	0.01	0.01	0.01	0.01

In respect of Industrial production and price level, in recursive identification the forecast error variance due to monetary policy shocks is lower than the first identification method. Exchange rate variation due to monetary policy shock is eliminated as in the other small open economies but Sweden.

Examining small open economies with the two identification methods inference is confusing. Only for Sweden the two identification methods give quite similar results. The picture is different for the rest small open economies in this study, where a number of puzzles emerge. So for Canada, South Korea, Denmark and Norway the SVAR is preferable.

It is evident that if we examine a small open economy our decision either to let exchange rate shocks to affect contemporaneously interest rate or not determines our inferences. According to Bjornland (2009) and Kim and Roubini (2000) the interdependence of XR and R is a plausible identification assumption.

5.9 A comment on the policy instrument

In structural identification examining the forecast error variance of interest rate due to monetary policy shocks, we infer that interest rate responds more to the state of the economy than to unsystematic monetary policy shocks. Table 19 present the contribution of the monetary policy shocks to the forecast error of interest rate.

Table 19

Contribution of the monetary policy shocks to the forecast error variance of interest rate

Country	1 Month	2 Months
Euro zone	0.68	0.63
Japan	0.95	0.91
U.K.	0.96	0.96
Canada	0.96	0.91
South Korea	0.93	0.83
Denmark	0.99	0.95
Sweden	0.99	0.93
Norway	0.99	0.97

It is evident that for all countries monetary policy shocks explain the total variation of interest rate in the first and second month. This conclusion is in sharp contrast with our previous results. This contrast occurs from the identifying assumption that exchange rate shocks contemporaneously have zero effect on interest rate. However, in the absence of the zero assumption we observe that the interest rate responds heavily to exchange rate appreciation. This is first detected by Faust and Rogers (2003).

Price puzzle in recursive identification is evident for the majority of the countries, namely UK, Canada, South Korea, Sweden and Norway. We have exchange rate puzzle only for South Korea and generally the response of exchange rate in recursive ordering is much weaker. For Sweden, Norway, UK and Japan we observe delayed overshooting.

Chapter 6

The U.S. Case

In this chapter we investigate overshooting hypothesis for U.S. as a separate case using the two policy instruments: Federal Funds rate and non borrowed reserves (a narrower monetary aggregate).

6.1 Data Description

The set of variables we use for both structural VARs is {WPO, IP Japan, R Japan, IP, CPI, FFR, NBR, XR}. WPO[37] is the world price of oil, IP Japan is the industrial production of Japanese economy, R Japan is the money market rate of Japan, IP is the industrial production index of U.S., CPI is the consumer price index for U.S., FFR is the federal funds rate, NBR is non borrowed reserves and XR is the end of period nominal exchange rate expressed as units of Japanese yen for one unit of U.S. dollars. All variables are monthly time series and are transformed into logarithm form except interest rates. Also, aggregates are seasonally adjusted. The data source is International Financial Statistics except NBR which is taken from Federal Reserve Economic Data (FRED).

6.2 Federal Funds Targeting

We begin with a federal funds targeting regime which mean that the federal funds rate does not react contemporaneously to the other monetary variables. Accordingly, in a non borrowed reserves targeting regime it is NBR that does not react contemporaneously to the other two monetary policy shocks[38].

[37] The inclusion of world price of oil is essential to solve the price puzzle.
[38] Favero (2001)

As for the identification assumptions, the world price of oil is treated as exogenous[39]. We assume a recursive structure as Eichenbaum and Evans (1995). The ordering of the variables is {IP Japan, R Japan, IP USA, CPI USA, FFR, NBR, XR}. We put first in the ordering the foreign sector variables and then the domestic variables.

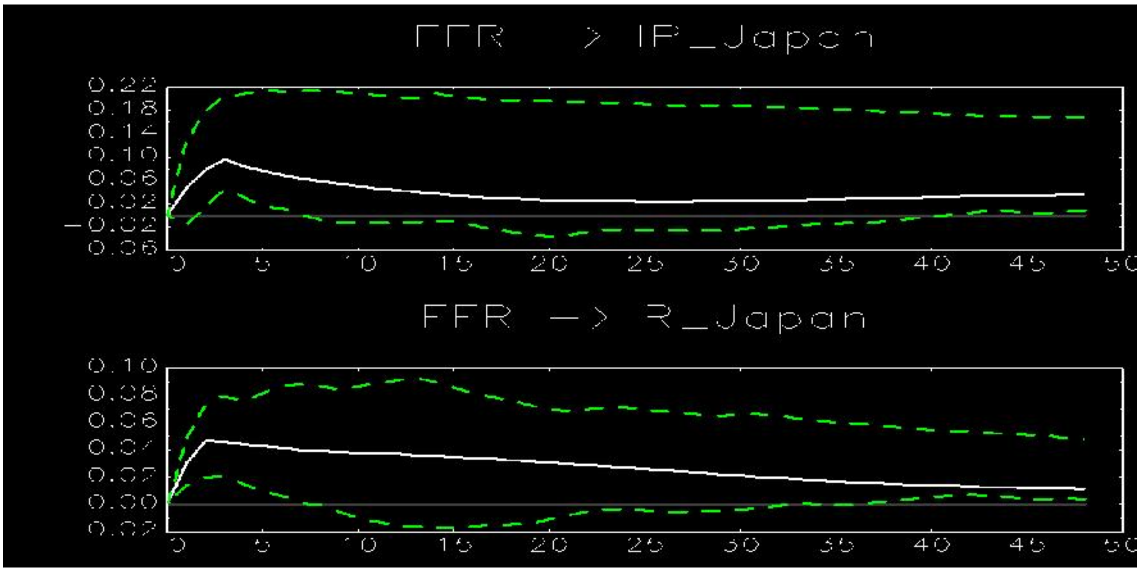
Impulse Responses

We proceed with impulse response analysis. The data sample is 1975M1-2007M12 with monthly data. The number of lags is 3 according to Akaike information criterion.

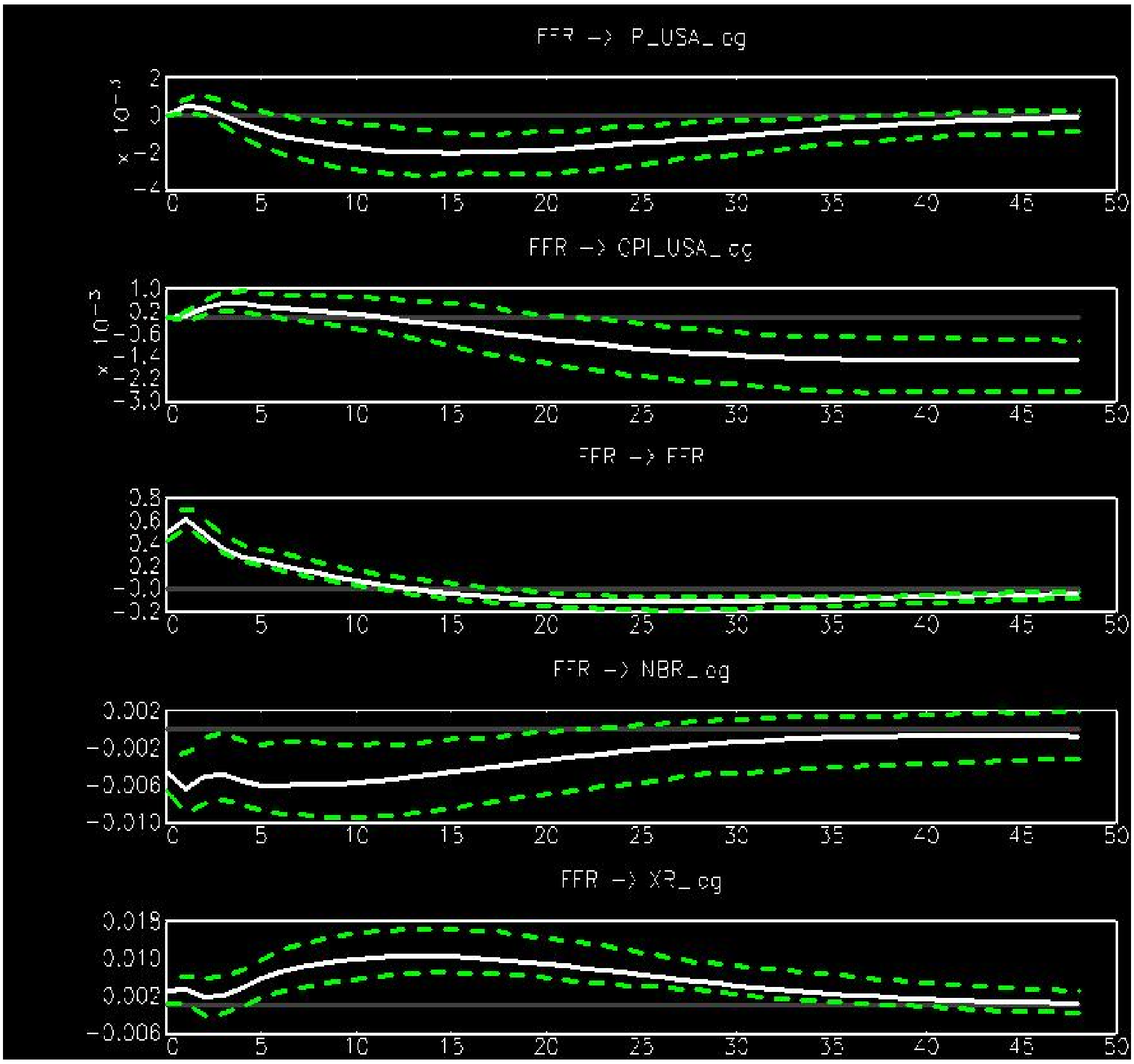
In Figure 17 we display the estimated impulse responses (over 48 months) for U.S. to a domestic monetary policy shock. The dashed lines represent the confidence intervals which are constructed with the Hall's percentile bootstrap method.

Figure 17

U.S: Response to a monetary policy shock, using a structural VAR



[39] Wpo is excluded from the Structural VAR in order to save degrees of freedom. Even if it is included the overall effect of the monetary policy shock to wpo is insignificant.



Note: 90% confidence intervals

The response of FFR to a contractionary policy shock is increasing first, then decreasing smoothly and finally become negative. Non borrowed reserves also follow an anticipated pattern decreasing on impact, remain below zero for a year and afterwards it returns to its steady state. So, as we see from the figure 17 the contractionary monetary policy shock has significant effects to both FFR and NBR.

In respect of Industrial production and price level the results are in line with Christiano, Eichenbaum and Evans (1996) qualitative features for VAR models of monetary transmission mechanism. Industrial production decreases after the contractionary shock forming a hump-shape response and reaching each minimum at approximately 1 year. Price level results are in line with the theory, with the exception of the first months where there is a small increase attributed to the cost channel of interest rate, but after 20 months the price level falls significantly. Bouakez and Normandin (2010) found similar response to monetary policy shock for industrial production and price level (in their study the monetary policy shock is expansionary).

Concerning the response of the money market rate of Japan, it increases significantly for the initial months, as the two country Mundell - Fleming model for a large country predicts. The Japanese industrial production initially increases statistically significantly due to the depreciation of yen, but the rest of the response is insignificant.

The exchange rate displays the commonly observed delayed overshooting with the peak response of exchange rate to the monetary policy shock to be in about a year. Bouakez and Normandin (2010) found a peak response between 8 and 10 months. In contrast Eichenbaum and Evans (1995) found a peak response in approximately 2 years.

Variance Decomposition

In table 20 we present the forecast error variance decomposition of domestic variables due to monetary policy shocks.

Table 20

Contribution of the monetary policy shocks to the forecast error variance

Horizon				
	1 year	2 year	3 year	4 year
IP	0.04	0.10	0.11	0.11
CPI	0.01	0.02	0.04	0.06
NBR	0.05	0.05	0.04	0.04
FFR	0.50	0.39	0.38	0.38
XR	0.07	0.13	0.13	0.13

The contribution of a monetary policy shock to Industrial production and price level variation is similar to that of Euro zone and Japan with very small divergence. As for the exchange rate, the share of its fluctuations which is explained by monetary policy shock is similar to Japan. In Euro zone, it is almost zero. Also it is worth mentioning that the share of FFR variation that is explained in the 1st month from monetary policy shock is 93 percent, so it is almost unresponsive to other economic variables in the first month and a good indicator of monetary policy stance.

6.3 Non Borrowed Reserves Targeting

We turn to a non borrowed reserves targeting[40] regime. The identification scheme is similar to that of Federal Reserve targeting, but here we put NBR above FFR, because it is the policy instrument. The ordering of the variables is {IP Japan, R Japan, IP USA, CPI USA, NBR, FFR, XR}.

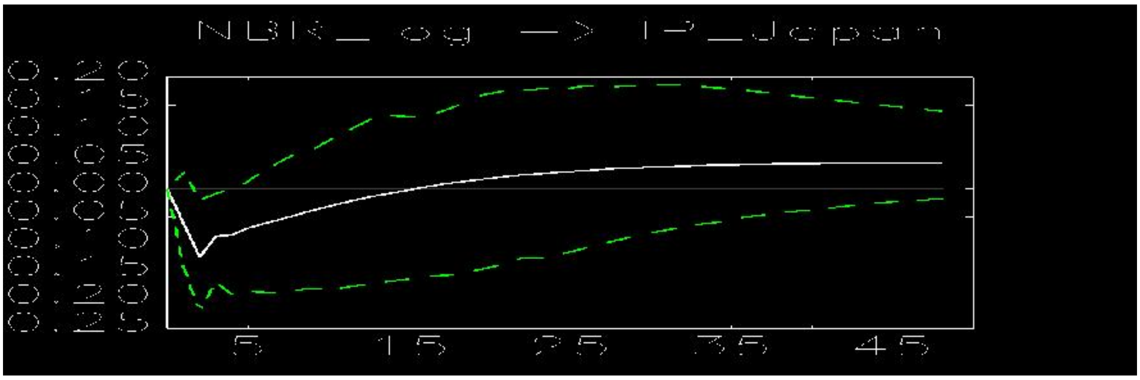
<u>Impulse Responses</u>

We use the same sample. The number of lags is 3 following the Akaike information criterion as well. The monetary policy shock here is <u>expansionary</u>.

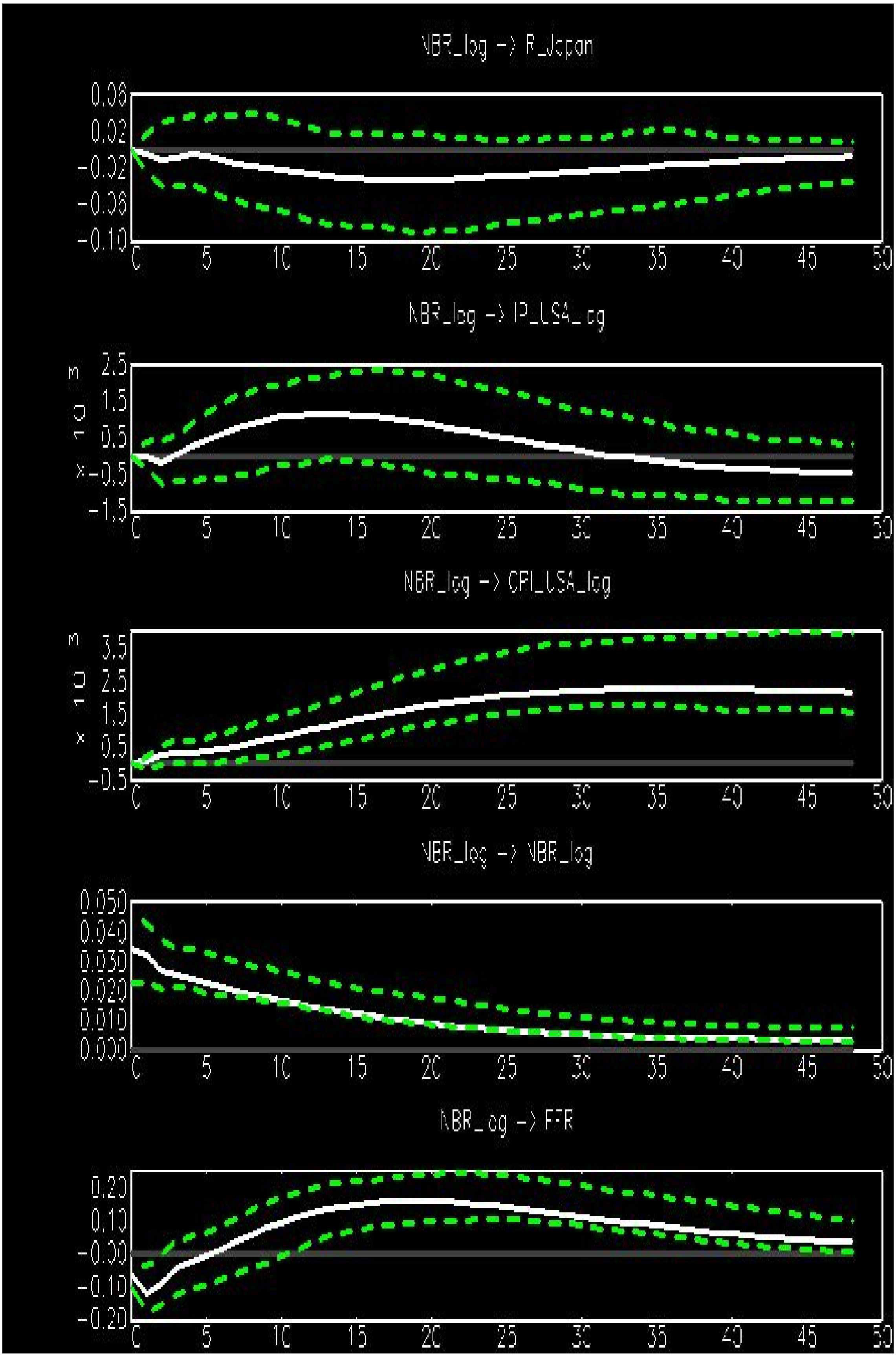
In Figure 17 we display the estimated impulse responses (over 48 months) for U.S. to a domestic monetary policy shock. The dashed lines represent the confidence intervals which are constructed with the Hall's percentile bootstrap method.

Figure 17

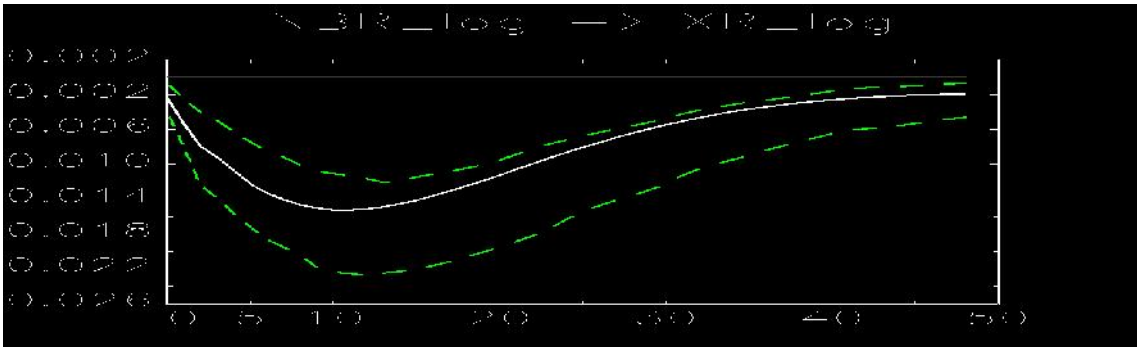
U.S: Response to a monetary policy shock, using a structural VAR



[40] If we use instead of NBR the ratio of NBR to TR, as Strongin (1995) proposed the results are very puzzling.



NBR_log -> R_Japan
NBR_log -> IP_USA_log
NBR_log -> CPI_USA_log
NBR_log -> NBR_log
NBR_log -> FFR



Note: 90% confidence intervals

The expansionary monetary policy shock increases NBR temporarily and afterwards it returns to a steady state after approximately 3 years. FFR decreases on impact statistically significantly (liquidity effect) and remain below zero for a few months, and then it starts to increase significantly and remains above steady state for the whole period. The reason for this rapid increase is the immediate rise in price level (Taylor's rule indicates that interest rate rise in response to price increase).

So, the price level increases in response to an expansionary monetary policy shock statistically significantly for the whole 48 months horizon. Industrial production initially responds sluggishly and then starts to increase but the whole result over Industrial production is insignificant.

The domestic monetary policy shock has no effect on the Japanese Industrial production except a very small decrease in the initial months due to the yen appreciation. Furthermore, the US monetary contraction has an insignificant effect to Japanese interest rate. This result is puzzling because the money market rate of Japan is not following the FFR as the two country Mundell-Fleming model for a large country predicts.

As for the exchange rate, it depreciates on impact significantly with the peak depreciation taking place in about 10 months. Thereafter, it appreciates until it reaches its steady state. So, with NBR as a policy instrument delayed overshooting remains. Eichenbaum and Evans (1995) using NBR as a policy instrument found the peak response of exchange rate at about the same time as using FFR as a policy instrument.

Variance Decomposition

In table 21 we present the forecast error variance decomposition of domestic variables due to monetary policy shocks.

Table 21

Contribution of the monetary policy shocks to the forecast error variance

Horizon				
	1 year	2 year	3 year	4 year
IP	0.01	0.03	0.03	0.03
CPI	0.02	0.09	0.15	0.18
NBR	0.85	0.73	0.66	0.61
FFR	0.04	0.10	0.13	0.14
XR	0.21	0.27	0.28	0.27

Comparing variance decomposition in both targeting regimes we see that in NBR targeting regime the NBR shocks explain a larger share of price level fluctuations than FFR in federal funds targeting regime. The opposite result holds for Industrial production. So, FFR has bigger impact on industrial production. Also, in NBR targeting regime the proportion of exchange rate variation that is explained by monetary policy shocks is two time higher than the relevant proportion in FFR targeting regime.

6.4 A comparison between the policy instruments

A very useful inference for the monetary authorities is that the NBR is a better indicator of monetary policy stance, because the share of fluctuations that is explained by monetary policy shocks is much higher than the results when we use FFR as a policy instrument. In the 1st month the proportion of NBR fluctuations attributed to monetary policy shocks is 98 percent.

Conclusions

This study attempts to investigate the overshooting hypothesis for 9 industrialized countries. Our analysis has revealed some interesting conclusions.

We find support of overshooting hypothesis only for Canada and Norway. Concerning Japan, U.S. and South Korea the nominal exchange rate displays the commonly observed in empirical literature delayed overshooting. The peak appreciation takes place from few months in some cases to one year in others. For UK and Sweden the identified shock is not a monetary policy shock but a reaction of policymaker to a forthcoming negative supply shock. Denmark's exchange rate response is somewhat puzzling.

In respect of variance decomposition analysis to Structural VARs it is evident that in small open economies a large proportion of exchange rate fluctuations (over 40 percent) is explained by interest rate innovations, in contrast to large economies where the relative fraction is much smaller. As for the policy instrument in the SVAR, the short term interest rate variance is explained mostly by fundamental variables and less by systematic monetary policy, except for Euro zone, Japan and U.S. These are very important news to market participants and policymakers. Furthermore, examining the U.S. economy we conclude that non borrowed reserves is a better indicator of monetary policy stance.

Moreover, we proceed with a comparison between Structural VAR and recursive identification scheme and obtain some useful results. The results in both identification methods are identical for the three large open economies and for Sweden, but the picture is different for the other small open economies where identification using economic theory should be preferred. A very useful inference from the comparison is that the decision to let exchange rate shocks to affect contemporaneously interest rate or not play a significant role in innovation accounting.

Another very important inference to researchers is that money is not neutral as Real Business Cycle (RBC) models support. This is the result of the price stickiness in the short-run. In both identification methods Industrial production responds statistically significantly to the change in the money supply. However, monetary policy shocks play a small role on industrial production variation.

In this study and in many others, small scale identified VARs are used in order to examine the effects of an autonomous monetary policy shock on the economy. Nevertheless, it is important to construct large scale, multicounty Bayesian VAR models to take into account possible international interdependence that may not be captured in small scale VAR models used usually in empirical studies of monetary transmission mechanism. Bayesian methods permit estimation of larger systems which can include a longer list of variables, such as more indicators of economic activity (like residential construction) or other financial market variables (like asset prices).

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Appendix

A. Residual Cross Correlations

U.S.A

	LIP_JAPAN	R_JAPAN	LIP	LCPI	LNBR	FFR	LXR
LIP_JAPAN	1.000000	0.095783	0.117207	-0.091809	-0.075408	-0.012889	-0.059820
R_JAPAN	0.095783	1.000000	-0.117320	0.045337	-0.013168	0.116263	-0.026800
LIP	0.117207	-0.117320	1.000000	0.014759	-0.065290	0.248533	0.071954
LCPI	-0.091809	0.045337	0.014759	1.000000	0.129412	0.095752	-0.041875
LNBR	-0.075408	-0.013168	-0.065290	0.129412	1.000000	-0.126813	-0.077812
FFR	-0.012889	0.116263	0.248533	0.095752	-0.126813	1.000000	0.072480
LXR	-0.059820	-0.026800	0.071954	-0.041875	-0.077812	0.072480	1.000000

Euro zone

	LCPI advance	FFR	LIP	LCPI	LM1	R	LXR
LCPI advance	1.000000	-0.133860	-0.026061	0.519726	-0.114738	0.002223	-0.138748
FFR	-0.133860	1.000000	0.027155	-0.091105	-0.076578	0.304794	-0.059035
LIP	-0.026061	0.027155	1.000000	-0.071625	-0.036743	0.369918	-0.018998
LCPI	0.519726	-0.091105	-0.071625	1.000000	0.356397	-0.116029	-0.148770
LM1	-0.114738	-0.076578	-0.036743	0.356397	1.000000	-0.175336	-0.063530
R	0.002223	0.304794	0.369918	-0.116029	-0.175336	1.000000	-0.141796
LXR	-0.138748	-0.059035	-0.018998	-0.148770	-0.063530	-0.141796	1.000000

Japan

	LCPI advance	FFR	LIP	LCPI	LM1	R	LXR
LCPI advance	1.000000	0.109061	-0.012412	0.603569	-0.046546	-0.041928	-0.094019
FFR	0.109061	1.000000	0.063828	-0.009835	0.036939	0.090097	0.099964
LIP	-0.012412	0.063828	1.000000	-0.027312	-0.155003	0.062872	-0.053620
LCPI	0.603569	-0.009835	-0.027312	1.000000	-0.054809	-0.138637	-0.073515
LM1	-0.046546	0.036939	-0.155003	-0.054809	1.000000	0.070766	-0.011943
R	-0.041928	0.090097	0.062872	-0.138637	0.070766	1.000000	-0.019014

LXR	-0.094019	0.099964	-0.053620	-0.073515	-0.011943	-0.019014	1.000000

United Kingdom

	LCPI advance	FFR	LIP	LCPI	LM1	R	LXR
LCPI advance	1.000000	0.068720	-0.011692	0.575431	-0.049392	0.155525	-0.097877
FFR	0.068720	1.000000	0.093537	0.125786	-0.098701	0.018304	0.050058
LIP	-0.011692	0.093537	1.000000	0.012183	0.024667	0.088128	0.089960
LCPI	0.575431	0.125786	0.012183	1.000000	-0.068292	0.022807	-0.148264
LM1	-0.049392	-0.098701	0.024667	-0.068292	1.000000	0.083162	0.213417
R	0.155525	0.018304	0.088128	0.022807	0.083162	1.000000	-0.000478
LXR	-0.097877	0.050058	0.089960	-0.148264	0.213417	-0.000478	1.000000

Canada

	FFR	LIP	LCPI	LM1	R	LXR
FFR	1.000000	0.136407	0.042532	0.050640	0.198992	0.023608
LIP	0.136407	1.000000	-0.013709	-0.099340	-0.006477	-0.067789
LCPI	0.042532	-0.013709	1.000000	0.093319	0.128197	-0.009859
LM1	0.050640	-0.099340	0.093319	1.000000	-0.098597	0.168368
R	0.198992	-0.006477	0.128197	-0.098597	1.000000	0.038591
LXR	0.023608	-0.067789	-0.009859	0.168368	0.038591	1.000000

South Korea

	LIP	LCPI	LM1	R	LXR
LIP	1.000000	-0.040190	0.135475	-0.137243	-0.007277
LCPI	-0.040190	1.000000	-0.041702	0.139020	0.196991
LM1	0.135475	-0.041702	1.000000	-0.177182	-0.010680
R	-0.137243	0.139020	-0.177182	1.000000	0.308249
LXR	-0.007277	0.196991	-0.010680	0.308249	1.000000

Denmark

	LIP	LCPI	LM1	R	LXR
LIP	1.000000	0.014763	0.109683	0.041301	0.018501
LCPI	0.014763	1.000000	-0.190801	0.079616	-0.002550
LM1	0.109683	-0.190801	1.000000	-0.170363	-0.003303
R	0.041301	0.079616	-0.170363	1.000000	-0.119793
LXR	0.018501	-0.002550	-0.003303	-0.119793	1.000000

Sweden

	LIP	LCPI	R	LXR
LIP	1.000000	0.011460	-0.116185	0.018740
LCPI	0.011460	1.000000	0.173820	-0.155210
R	-0.116185	0.173820	1.000000	-0.022531
LXR	0.018740	-0.155210	-0.022531	1.000000

Norway

	LIP	LCPI	R	LXR
LIP	1.000000	0.036493	-0.113167	-0.020109
LCPI	0.036493	1.000000	-0.093998	-0.091299
R	-0.113167	-0.093998	1.000000	-0.038233
LXR	-0.020109	-0.091299	-0.038233	1.000000