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Monetary policy and the illusionary exchange rate puzzle

by

Hilde C. Bjørnland

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Monetary Policy and the Illusionary Exchange Rate Puzzle

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Abstract

Dornbusch's exchange rate overshooting hypothesis is a central building block in international macroeconomics. Yet, empirical studies of monetary policy have typically found exchange rate effects that are inconsistent with overshooting. This puzzling result has developed into a "styled facts" to be reckoned with in policy modelling. However, many of these studies, in particular those using VARs, have disregarded the strong contemporaneous interaction between monetary policy and exchange rate movements by placing zero restriction on them. By instead imposing a long-run neutrality restriction on the real exchange, thereby allowing the interest rate and the exchange rate to react simultaneously to any news, I find that the puzzles disappear. In particular, a contractionary monetary policy shock has a strong effect on the exchange rate that appreciates on impact. The maximum effect occurs immediately, and the exchange rate thereafter gradually depreciates to baseline, consistent with the Dornbusch overshooting hypothesis and with few exceptions consistent with UIP.

Keywords: Dornbusch overshooting, VAR, monetary policy, exchange rate puzzle, identification.

JEL-codes: C32, E52, F31, F41

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1 Introduction

Dornbusch's (1976) well known exchange rate overshooting hypothesis is a central building block in international macroeconomics; stating that an interest rate increase leads to an immediate appreciation in the nominal exchange rate, in line with uncovered interest parity (UIP). Its influence is evident in the rapidly growing "New Open Economy Macroeconomics" (NOEM) literature, (see Obstfeld and Rogoff, 1995, 2000, for seminal contributions and Lane, 2001, for survey), as well as in practical policy discussions spanning far outside the academic sphere (Rogoff, 2002). With what seems like an ever-increasing number of publications citing Dornbusch (1976), the paper has been described as one the most important papers in international economics over the entire twentieth century (Rogoff, 2002).

When confronted with data, however, few empirical studies analysing the effects of monetary policy have found support for Dornbusch overshooting. Instead, they have found that following a contractionary monetary policy shock, the real exchange rate either depreciates, or, if it appreciates, it does so only gradually and for a prolonged period of up to three years, thereby giving a hump-shaped response that violates UIP. In the literature, the first phenomenon has been termed the *exchange rate puzzle*, whereas the second has been referred to as *delayed overshooting* or *forward discount puzzle,* see Cushman and Zha (1997).[1]

The dominant approach for establishing the quantitative effects of monetary policy shocks has been the vector autoregressive (VAR) approach initiated by Sims (1980).[2] Most of the recent VAR studies of the open economy, including Eichenbaum and Evans (1995) and Kim and Roubini (2000) for the G7 countries, Peersman and Smets (2003) and Favero and Marcellino (2004) for the aggregate Euro area, Mojon and Peersman (2003) for individual Euro area countries and Lindé (2003) for Sweden have found evidence of at least one of these puzzles. On the other hand, evidence of these puzzles has been so persuasive that the puzzles themselves are now about to be considered consensus, as is evident from the following quote in Adolfson et al. (2005, p. 37):

"Although the nominal frictions in the model provides some persistence in the real exchange rate following a policy shock, ***it is evident that the model does not provide us with a hump-shaped response of the real exchange rate which is a persuasive feature of estimated VARs***" (author's emphasis).

The quoted paper is one of an increasing number that try to match impulse responses of a theoretical "Dynamic Stochastic General Equilibrium" (DSGE) model with those from an empirical VAR that exhibits a pronounced delay overshooting puzzle in the real exchange rate. The seminal paper by Smets and Wouters (2002) for the Euro area is a prominent example. Murchison et al. (2004) for Canada and Lindé et al (2004) for Sweden are other examples, of which the last paper goes a long way in suggesting ways to incorporate the exchange rate puzzle into the theoretical model.

[1] The finding that UIP does not hold is not new; see Fama (1984) for a contribution to the international finance literature and Engel (1996) for survey. However, the VAR literature focuses on whether UIP holds conditionally with respect to monetary policy.

[2] For the role of VAR models in central bank's policy analysis, see for instance Greenspan (2005).

In this paper I argue that puzzling results are due to inadequate treatment of the simultaneity problem between monetary policy and the exchange rate. In particular, most VAR studies of open economies (including those referred to above), deal with this simultaneity problem by either (i) placing zero restriction on the contemporaneous response of the systematic interest rate setting to an exchange rate shock or by (ii) restricting the exchange rate from reacting immediately to a monetary policy shock. Both of these restrictions are inconsistent with established theory and also in contrast to how practitioners view the relationship between the interest rate and the exchange rate. In particular, in an open economy, the exchange rate is an important transmission channel for foreign shocks that the central bank may respond to within the month or quarter which is the usual sampling frequency in these studies. The exchange rate, being an asset price determined in foreign markets, will also react instantaneously to monetary policy surprises. Hence, the structural shocks cannot be recovered using either of these recursive restrictions on the parameters.

To solve the simultaneity problem, this paper suggests instead an alternative identification that restricts the long run multipliers of the shocks, but leaves the contemporaneous relationship between the interest rate and the exchange rate intact. Identification is achieved by assuming that monetary policy shocks can have no long run effect on the level of the real exchange rate. In the short run, however, monetary policy is free to influence the exchange rate. Eventually though, the effect dies out and the real exchange rate returns to its initial level. This is a standard neutrality assumption that holds for a large class of models in the monetary policy literature (see Obstfeld, 1985; Clarida and Gali, 1994).

Once allowing for a contemporaneous relationship between the interest rate and the exchange rate, the remaining VAR can be identified using standard recursive zero restrictions on the impact matrix of shocks; assuming a lagged response in domestic variables (such as output and inflation) to monetary policy shocks. These restrictions are less controversial and studies identifying monetary policy without these restrictions have found qualitatively similar results, see for example Faust et al. (2004) and the references therein. More importantly however, the assumption of a delayed response in output and inflation combined with a long run neutrality restriction on the real exchange rate following a monetary policy surprise, are core assumptions underlying the Dornbusch's overshooting model; consistent with NOEM implications (Lane, 2001) and are empirically realistic (Rogoff, 2002).

The results using this alternative identification strategy are striking. Contrary to the recent consensus, a contractionary monetary policy shock has a strong effect on the exchange rate which appreciates on impact. The maximal impact occurs immediately, and the exchange rate thereafter gradually depreciates back to baseline; consistent with the Dornbusch overshooting hypothesis and with few exceptions consistent with UIP. Hence, I find no evidence of any exchange rate puzzle.

This paper is not the first one that attempts to find another approach to the simultaneity problem than imposing a zero contemporaneous restriction in the VAR. In a recent paper, Faust and Rogers (2003) relax the recursive contemporaneous restrictions and impose sign restrictions (using only weak implications from theory) to identify monetary policy shocks. By dropping one after one of what they call dubious restrictions, they can test

whether the key results are robust to alternative identification. By doing so, they find that the delayed overshooting result is sensitive to the assumptions. Their results allow for an early peak in the exchange rate, which might give a role for the conventional overshooting model. However, the effect is not precisely identified, so no robust conclusions can be drawn with regard to the exact timing of the peak response of the exchange rate. Furthermore, they also find that monetary policy shocks lead to large UIP deviations. Similar results are also found in Scholl and Uhlig (2005), using a related procedure to that of Faust and Rogers (2003), although they find in addition that the exchange rate actually depreciates on impact following a contractionary monetary policy shock

There are two major problems related to this alternative identification strategy. *First*, although the approach effectively illustrates the sensitivity of results to recursive restrictions, applying sign restrictions is not sufficient for identifying monetary policy shocks. To be able to calculate the exact responses in the other variables to these shocks, additional identifying restrictions are required. *Second*, by dropping the recursive restrictions, the authors may no longer be able to identify the same monetary policy shocks that have previously been studied in the literature (a point the authors themselves acknowledge).[3]

An alternative (non-VAR) approach to studying the *impact* of monetary policy shocks on the exchange rate is through event studies. These measure the immediate response of the exchange rate to shocks associated with particular policy actions in real time, thereby avoiding the issue of identification altogether. In sharp contrast to the majority of VAR studies, the event studies find that a surprise monetary policy shock has a substantial effect on the exchange rate. For instance, Zettelmeyer (2004) and Kearns and Manners (2005) find that a surprise monetary policy shock that increases the interest rate has a significant appreciating effect on the exchange rate. This link between surprise monetary policy actions and initial exchange rate responses is therefore a feature that properly identified VAR models should be able to replicate. A study like Scholl and Uhlig (2005) which finds that the exchange rate instead depreciates following a contractionary monetary policy shock seems then less plausible.

Event studies, with their exclusive focus on the immediate response, cannot answer questions about overshooting. To do so, one needs to identify monetary policy shocks in a system like the structural VARs as is done in the present study. However, I find it comforting that the present results are consistent with the major finding of the event studies.

The analysis is applied to a set of small open economies; Australia, Canada, New Zealand, Sweden and UK, which although diverse, have all had a fairly long period of floating exchange rates.[4] In addition, all of them have recently adopted an inflation targeting framework for monetary policy. Small open countries are chosen to illustrate the point, as the exchange rate is expected to be both an important transmission channel for shocks and a

[3] For instance, Scholl and Uhlig (2005) identify contractionary monetary policy shocks by restricting among others domestic prices from rising, thereby avoiding "price puzzles" by construction. Although a reasonable assumption, they find puzzling responses in the other variables, as real output rises and the real exchange rate initially depreciates, which seems inconsistent with what they have assumed for prices. Hence, one might question whether their identified monetary policy shock may be a hybrid of shocks, lacking clear economic interpretation.
[4] See also Bjørnland (2005) for a detailed analysis of Norway that finds corroborate results.

variable the central bank may want to react to (Taylor, 2001). Further, focusing on small countries simplifies the identification, as one can assume that domestic shocks will have no effect on the foreign interest rates, as is also assumed in Dornbusch's model.

The paper is organised as follows. Section 2 discusses the VAR methodology used to identify monetary policy shocks and section 3 presents the empirical results. Section 4 provides robustness checks and Section 5 concludes.

2 The identified VAR model

The variables in the VAR model are chosen to reflect the theoretical set up of a New-Keynesian small open economy model, such as that described in Clarida et al. (2001) and Svensson (2000). In particular, the VAR model comprises log of real GDP (y_t), log of the quarterly changes in the consumer price index (CPI) (π_t) – referred to hereafter as inflation, the three month domestic interest rate (i_t), the trade-weighted foreign interest rate (i_t*) and the log of the real trade-weighted exchange rate (e_t) (see appendix A for details).

This paper builds on the traditional closed economy VAR literature (Sims, 1980; Christiano et al., 1999, 2005, among many others), in that a standard recursive structure is identified between macroeconomic variables and monetary policy, so that macroeconomic variables such as output and inflation do not react contemporaneously to monetary shocks, whereas there might be a simultaneous feedback from the macro environment to monetary variables. That monetary policy affects domestic variables with a lag, is consistent with the transmission mechanism of monetary policy emphasised in the theoretical set up in Svensson (1997). Further, Bagliano and Favero (1998) show that when monetary policy shocks are identified in this recursive way on a *single* monetary policy regime, the responses of the shocks suggest a pattern for the monetary transmission mechanism that is consistent with the impulse responses of monetary policy shocks identified instead using financial market information from outside the VAR, as in Rudebusch (1998).

Where the present approach differs from the traditional method, is in that monetary policy shocks are restricted from having long-run effects on real exchange rates. As already emphasised, this is a standard neutrality assumption that holds for a large class of models in the monetary policy literature.[5] In particular, Clarida and Gali (1994) show that this kind of restriction on the real exchange rate is consistent with a stochastic version of the two country, rational expectations open-macro model developed by Obstfeld (1985). The model exhibits the standard Mundell-Fleming-Dornbusch results in the short run when prices reacts sluggishly, but in the long run, prices adjust fully to all shocks.

Theory has provided several reasons why one should avoid using a Cholesky decomposition that either i) restricts the (systematic) monetary policy from reacting contemporaneously to an exchange rate shock, or ii) restricts the exchange rate from reacting immediately to a monetary policy shock. The first restriction (initially adopted by Eichenbaum and Evans, 1995), is equivalent to assuming that the monetary authority ignores

[5] Bjørnland and Leitemo (2004) explore, in a similar vein, the use of short and long run restrictions in order to identify the interdependence of stock prices and monetary policy in a structural VAR of a closed economy.

any surprise movement in exchange rates that have occurred during the time in which decisions on the policy variables are made, which is highly unlikely. Not only is the exchange rate an important transmission channel for foreign exchange shocks. By being an asset price, the exchange rate is inherently a forward-looking and expectations-determined variable that will reflect expected future return on the asset. This may by itself provide important information about the expected development of the determinants of the targeting variables that the central bank may want to react to, see Obstfeld and Rogoff (1995) and Taylor (2001) for arguments, and Clarida et al. (1998) for empirical evidence.

The second set of restrictions commonly used, namely that the exchange rate can not react immediately to a monetary policy shock (i.e. Favero and Marcellino, 2004; Mojon and Peersman, 2003, among others), imposes a puzzle on the system *by definition*. The assumption seems also implausible, in particular in the post Bretton Woods era of managed float, where exchange rates have shown a volatile behaviour.

It is fair to say that several of the authors using traditional VARs have been concerned about the validity of these restrictions and have investigated their implications by rearranging the direction of causation between the interest rate and the exchange rate to see if that makes a difference.[6] However, this strategy seems unlikely to produce the correct impulse responses if there is a genuine simultaneous relationship between the two variables. Most likely it will lead to the effects of the shocks being underestimated, as a recursive ordering will always either a) disregard the simultaneous reaction of the monetary policy stance to the exchange rate shocks, or b) exclude the simultaneous reaction of the exchange rate to the monetary policy shocks. This will effectively be demonstrated below when the pitfalls of the standard recursive Cholesky restrictions are illustrated.

2.1 Identification

Throughout this paper, I follow what has now become standard practice in VAR analysis (see for example Christiano et al., 1999) and identify monetary policy shocks with the shock in an equation of the form

$$i_t = f(...)_t + \sigma\varepsilon_t^{MP}, \tag{1}$$

where i_t is the instrument used by the monetary authority (usually the interest rate) and f is a linear function that relates the instrument to the information set (feedback rule). The monetary policy shock ε_t^{MP} is normalised to have unit variance, and σ is the standard deviation of the monetary policy shock. ε_t^{MP} is assumed to be orthogonal to the elements in the information set (…). Having identified the feedback rule (from the variables that are in the information set) the VAR approach concentrates on deviations from this rule. Hence, such deviations provide researchers with an opportunity to detect the responses of macroeconomic variables

[6] Peersman and Smets (2003) tested robustness of their Cholesky identification by allowing for some degree of simultaneous response. However, in none of the tests did they allow the domestic interest rate to react contemporaneously to *all* shocks, which is an equally implausible assumption.

to monetary policy shocks that are not expected by the market. Obviously, I then assume that the market also knows the rule.

Define Z_t as the (5x1) vector of the macroeconomic variables discussed above, $Z_t = \left[i_t^*, y_t, \pi_t, i_t, \Delta e_t \right]'$, where all variables but the real exchange rate are assumed to be (trend-) stationary[7]. Z_t can be written in terms of its moving average (ignoring any deterministic terms)

$$Z_t = B(L)v_t, \tag{2}$$

where v_t is a (5x1) vector of reduced form residuals assumed to be identically and independently distributed, $v_t \sim iid(0,\Omega)$, with positive definite covariance matrix Ω. $B(L)$ is the (5x5) convergent matrix polynomial in the lag operator L, $B(L) = \sum_{j=0}^{\infty} B_j L^j$. Following the literature, the underlying orthogonal structural disturbances (ε_t) are assumed to be written as linear combinations of the innovations (v_t), i.e.,

$$v_t = S\varepsilon_t. \tag{3}$$

The VAR can then be written in terms of the structural shocks as

$$Z_t = C(L)\varepsilon_t, \tag{4}$$

where $B(L)S = C(L)$. Clearly, if S is identified, one can derive the MA representation in (4) since $B(L)$ can be calculated from a reduced form estimation. Hence, to go from the reduced form VAR to the structural interpretation, one needs to apply restrictions on the S matrix. Only then can one recover the relevant structural parameters from the covariance matrix of the reduced form residuals.

To identify S, the ε_t's are assumed to be normalised so they all have unit variance. The normalisation of cov(ε_t) implies that $SS' = \Omega$. With a five variable system, this imposes 15 restrictions on the elements in S. However, as the S matrix contains 25 elements, to orthogonalise the different innovations, ten more restrictions are needed.

With a five variables VAR, one can identify five structural shocks. The first two are of primary interest and are interpreted as monetary policy shocks (ε_t^{MP}) and real exchange rate shocks (ε_t^{ER}). I follow standard practice in the VAR literature and only loosely identify the last three shocks as inflation shocks (interpreted as cost push shocks) (ε_t^{CP}), output shocks (ε_t^{Y}) and foreign interest rate shocks (ε_t^{i*}). Ordering the vector of structural shocks as $\varepsilon_t = \left[\varepsilon_t^{i*}, \varepsilon_t^{Y}, \varepsilon_t^{CP}, \varepsilon_t^{MP}, \varepsilon_t^{ER} \right]'$ and following the standard economy literature in identifying

[7] This assumption is further discussed in the empirical analysis below.

monetary policy shocks, the recursive order between monetary policy shocks and the (domestic) macroeconomic variables implies the following restriction on the *S* matrix

$$\begin{bmatrix} i^* \\ y \\ \pi \\ i \\ \Delta e \end{bmatrix}_t = B(L) \begin{bmatrix} S_{11} & 0 & 0 & 0 & 0 \\ S_{21} & S_{22} & 0 & 0 & 0 \\ S_{31} & S_{32} & S_{33} & 0 & 0 \\ S_{41} & S_{42} & S_{43} & S_{44} & S_{45} \\ S_{51} & S_{52} & S_{53} & S_{54} & S_{55} \end{bmatrix} \begin{bmatrix} \varepsilon^{i^*} \\ \varepsilon^{Y} \\ \varepsilon^{CP} \\ \varepsilon^{MP} \\ \varepsilon^{ER} \end{bmatrix}_t . \tag{5}$$

The recursive Cholesky restriction used in the closed economy literature, namely to assume that domestic variables such as output and inflation do not simultaneously react to the policy variables, while the simultaneous reaction from the economic environment to policy variables is allowed for, is taken care of by placing the domestic variables above the interest rate in the ordering, and assuming zero restrictions on the relevant coefficients in the *S* matrix as shown in (5). By examining the relevant columns in S, one can interpret the two shocks somewhat further. In particular, while price shocks can affect all variables but output contemporaneously, output shocks can affect both output and prices contemporaneously. Hence, it seems reasonable to interpret a price shock as a cost push shock (moving prices before output), whereas output shocks will be dominated by both demand shocks and supply shocks. Furthermore, the foreign interest rate is placed on the top of the ordering, assuming it will only be affected by exogenous foreign monetary policy contemporaneously; a plausible small country assumption.[8] This provides nine contemporaneous restrictions directly on the *S* matrix.

However, the matrix is still one restriction short of identification. The standard practice in the VAR literature, namely to place the exchange rate last in the ordering and assuming $S_{45} = 0$, so that monetary variables are restricted from reacting simultaneously to the exchange rate shock, while the exchange rate is allowed to react simultaneously to all variables, would have provided enough restriction to identify the system, thereby allowing for the use of the standard Cholesky recursive decomposition.

However, if that restriction is not valid but is nonetheless imposed, the estimated responses to the structural shocks will be severely biased. Instead, the restriction that a monetary policy shock can have no long-run effects on the real exchange rate is imposed, which as discussed above, is a plausible neutrality assumption. This can be found by setting the values of the infinite number of relevant lag coefficients in (4), $\sum_{j=0}^{\infty} C_{54,j}$, equal to zero. By using this long-run restriction, there are enough restriction to identify and orthogonalise all shocks. Writing the long-run expression of $B(L)S = C(L)$ as

$$B(1)S = C(1), \tag{6}$$

[8] I have also experienced with alternating the order of the first three variables in Z, without much effects on results.

where $B(1) = \sum_{j=0}^{\infty} B_j$ and $C(1) = \sum_{j=0}^{\infty} C_j$ indicate the (5x5) long-run matrix of $B(L)$ and $C(L)$ respectively, the long-run restriction that $C_{54}(1) = 0$ implies

$$B_{51}(1)S_{14} + B_{52}(1)S_{24} + B_{53}(1)S_{34} + B_{54}(1)S_{44} + B_{55}(1)S_{54} = 0. \quad (7)$$

3 Empirical results

The model is estimated for Australia, Canada, New Zealand, Sweden and UK. Quarterly data from 1983Q1 to 2004Q4 are used, except for New Zealand. Using an earlier starting period than 1983 will make it hard to identify a stable monetary policy regime, as monetary policy prior to 1983 has experienced important structural changes and unusual operating procedures that would imply severe parameter instability (see for instance Bagliano and Favero, 1998; Clarida et al., 2000). For New Zealand, the start date is set to 1988 as the period 1983-1987 is characterised with a high degree of volatility when New Zealand changed from a closed and centrally controlled economy to one of the most open countries in the OECD (see Evans et al., 1996). Below, robustness checks are nevertheless performed for all countries by extending the sample backwards and forwards in time. There are no qualitative changes to the impact of the shocks.

Consistent with most other related studies, the variables, with the exception of the real exchange rate, are specified in levels.[9] This implies that any potential cointegrating relationship between the variables will be implicitly determined in the model (see Hamilton, 1994).[10] Sims, Stock and Watson (1990) also argue for using VAR in levels as a modelling strategy, as one avoids the danger of inconsistency in the parameters caused by imposing incorrect cointegrating restrictions; though at the cost of reducing efficiency. One may argue (Giordani, 2004) that following the theoretical model set up in Svensson (1997) as a data generating process, rather than including output in levels, one should either include the output gap in the VAR, or the output gap along with the trend level of output. However, as pointed out by Lindé (2003), a practical point that Giordani does not address is how to compute trend output (thereby also the output gap). I therefore instead follow Lindé (2003) and include a linear trend in the VAR along with output in levels. In that way I try to address this problem by modelling the trend implicit in the VAR. Also, the use of a trend in the VAR serves as a good approximation for ensuring that the VAR is invertible if the variables are non-stationary, in particular given the short span of data used.

The real exchange rate is clearly non-stationary and is differenced to obtain stationarity. By applying long-run restrictions to the first-differenced real exchange rate, the

[9] Based one the standard Augmented Dickey Fuller (ADF) unit root test, I can not reject that any of the variables except possibly inflation are integrated of first order. However, due to the low power of the ADF tests to differentiate between a unit root and a (trend-) stationary process, I can not rule out that most of the variables could equally well be represented in levels, but with a trend.

[10] There is little evidence of any cointegration relationship at the outset, with the hypothesis of one cointegration vector being at most accepted.

effects of monetary policy shocks on the *level* of the exchange rate will eventually sum to zero (c.f. Blanchard and Quah 1989).[11]

The lag order of the VAR-model is determined using the Schwarz and Hannan-Quinn information criteria and the F-forms of likelihood ratio tests for model reductions. Most tests suggested that three lags were acceptable for all countries, although some indicate four lags. With a relatively short sample, I therefore decided to use three lags in the estimation and check for robustness using alternative lag lengths. With three lags, the hypothesis of autocorrelation and heteroscedasticty is rejected for all countries, although some non-normality remained in the system. In a few cases impulse dummies (that take the value 1 in one quarter and 0 otherwise) were included, to take account of extreme outliers. That is, for Sweden, three dummies were included; 1992Q3, 1993Q1 and 1995Q4, where the first captures an exceptionally high interest rate increase (almost 500 percent) implemented by the Riksbank in order to defend the Swedish exchange rate (see also the discussion in Lindé 2003), the second reflects the subsequent floating of the Swedish krona and the final one captures additional turbulence in the exchange rate. For Australia two dummies were included; 1984Q1 and 2000Q3, that reflected a substantial decrease and increase in the inflation rate respectively. With these dummies incorporated, some non-normality nevertheless remained, although mainly in the foreign interest rate equation. However, the Chow break tests suggested that all countries had stable equations; hence I decided to ignore any remaining non-normality.[12]

3.1 Cholesky decomposition

For comparison, I start by discussing the results using a standard Cholesky ordering, before turning to the preferred structural decomposition in section 3.2 below. The purpose of this exercise is to show that by using similar identification schemes to what has been standard practice in the literature, one will get the same pattern of delayed overshooting that has been found in Kim and Roubini (2000) and Murchison et al. (2004) for Canada, Lindé (2003) and Lindé et al. (2004) for Sweden and Evans and Eichenbaum (1995) for the UK among others.[13] If there is strong simultaneity between monetary policy and the exchange rate, one would not expect that a Cholesky decomposition of the effects on shocks would pick up this simultaneity, since one of the shocks is assumed to have no immediate effect on one of the variables. This is illustrated in Figure 1 below, which shows the impulse responses for the interest rate and the exchange rate from a monetary policy shock, using two different Cholesky orderings. The solid line corresponds to the baseline Cholesky assumption that an exchange rate shock has no immediate effect on the interest rate, whereas the dotted line corresponds to an ordering where monetary policy shock has no immediate effect on the

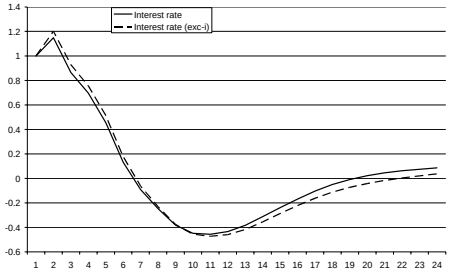
[11] Testing for unit roots in the real exchange rate yields the following ADF t-statistics for Australia, Canada, New Zealand, Sweden and the UK respectively: t_{ADF} = -1.806, t_{ADF} = -0.5625, t_{ADF} = -2.381, t_{ADF} = -2.631, t_{ADF} = -2.543 (using two lags in the estimation). Using alternative lag lengths or extending the sample backwards to 1973/78 does not change the results.

[12] Diagnostic tests can be obtained from the author on request.

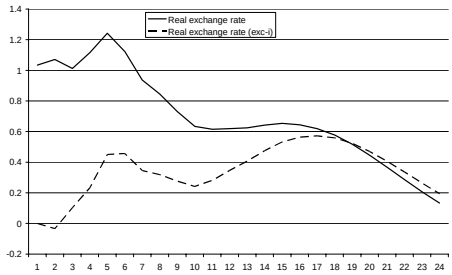
[13] To modify this statement somewhat, Kim and Roubini (2000) do allow for a simultaneous response between the interest rate and the exchange rate, but restrict instead the domestic interest rate from reacting contemporaneously to a foreign interest rate shock. I find these restrictions equally implausible as the standard ones, and as it turns out, delayed overshooting in still present in a few of the countries they study (e.g. Canada and Germany).

Figure 1. Response to a monetary policy shock, using two different Cholesky orderings[1]

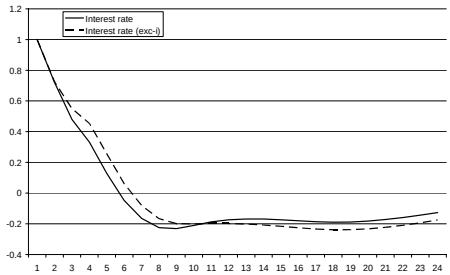
A1) Australia: *Interest rate*



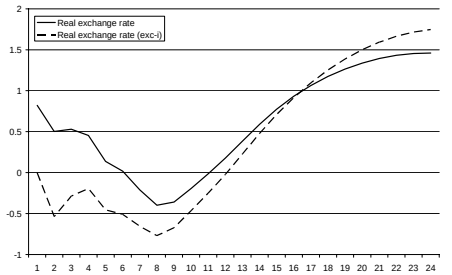
A2) Australia: *Real exchange rate*



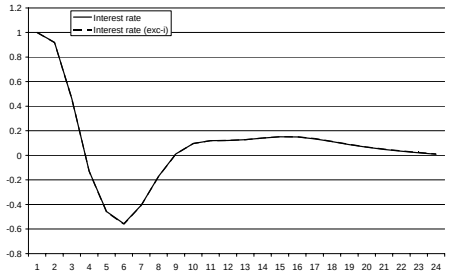
B1) Canada: *Interest rate*



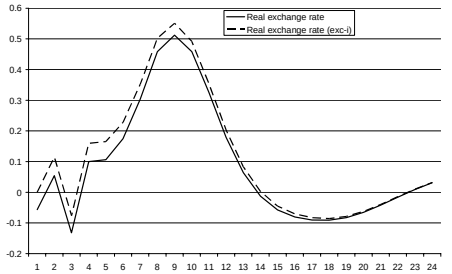
B2) Canada: *Real exchange rate*



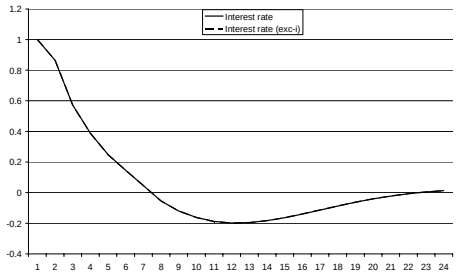
C1) New Zealand: *Interest rate*



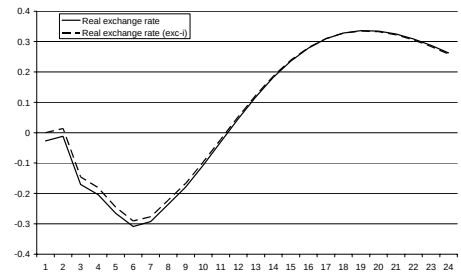
C2) New Zealand: *Real exchange rate*



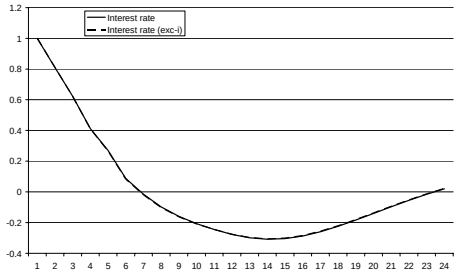
D1) Sweden: *Interest rate*



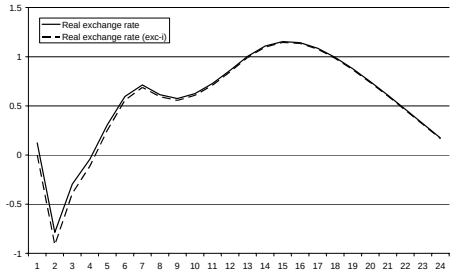
D2) Sweden: *Real exchange rate*



E1) UK: *Interest rate*



E2) UK: *Real exchange rate*



[1)] The solid line corresponds to the Cholesky decomposition where the interest rate is ordered before the exchange rate in the VAR. In the alternative ordering (exc-i), the interest rate and the exchange rate swap places. Note that an increase in the exchange rate implies depreciation.

real exchange rate. In the figures below, the effect of the monetary policy shock is normalised so that the interest rate increases by one percentage point the first quarter. Note that an increase/decrease in the real exchange rate implies depreciation/appreciation.[14]

The figure illustrates that a contractionary monetary policy shock that increases the interest rate temporarily, has a puzzling effect on the exchange rate. Using the baseline Cholesky ordering (solid line) there is evidence of an exchange rate puzzle and/or delayed overshooting for all countries. Most pronounced is the puzzle in Australia, where a monetary policy shock implies a continuous depreciation of the exchange rate of more than a year, before, contrary to common beliefs, it appreciates back to equilibrium. Similar results are also found for New Zealand, although the initial response is negative. For Canada and Sweden there is clear evidence of delayed overshooting (as well as an initial exchange rate puzzle in Canada), as the exchange rate appreciates for 1-2 years before it depreciates back to equilibrium. UK also displays puzzling results, with (a very small) initial depreciation, followed by a delayed appreciation, and then a substantial deprecation.

Using the alternative Cholesky ordering (dotted line), the initial effect of a monetary policy shock on the exchange rate is forced to zero, thereby generating a "puzzle" by assumption. For all countries except Australia and Canada the different orderings does not imply a lot of difference, since the initial effect identified with the baseline Cholesky ordering is close to zero nevertheless. For Australia and Canada, there is however clear difference between the two orderings initially, thereafter the alternative follows the baseline scenario.[15]

3.2 Structural identification scheme

I now turn to the preferred structural model that was outlined in Section 2 above. Figure 2-6 graph the impulse responses of a monetary policy shock on the interest rate, exchange rate, GDP and inflation for Australia, Canada, New Zealand, Sweden and UK respectively. The effect is again normalised so the response of the interest rate is 1 pp. the first quarter. The upper and lower dashed lines plotted in each graph are the one-standard-error bands.[16]

The figures (frame A) illustrates, as above, that a monetary policy shock increases interest rates temporarily. There is a degree of interest-rate inertia in the model, as a monetary policy shock is only offset by a gradual lowering of the interest rate. The nominal interest rate returns to its steady-state value just after 1-2 years and then goes below its steady-state value. Both the interest-rate inertia and the "reversal" of the interest rate stance are consistent with what has become considered to be good monetary policy conduct, see Woodford (2003).

Whereas the effect of a monetary policy shock on the interest rate (frame A) is consistent with what was found above using the Cholesky decomposition, the effect on the exchange rate (frame B) has now completely changed. Contrary to the results found above and in most other open economy studies, there is no evidence of any exchange rate puzzle in

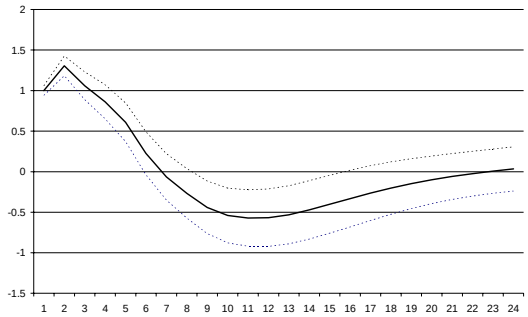
[14] For the Cholesky decomposition, all variables in the VAR are specified in levels, but with a trend. Specifications using no trend were also carried out; albeit with no overall change in the results.

[15] Standard deviation bands (can be obtained from the author on request) indicate that only for Australia and Canada are the initial responses significantly different using the two orderings.

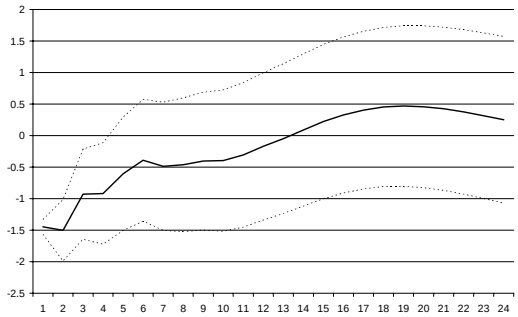
[16] They were generated from 2500 draws by Monte Carlo integrations following Sims and Zha (1999). This is a Bayesian method based on the natural conjugate prior. The draws are made directly from the posterior distribution of the VAR coefficients, as suggested in Doan (2004).

Figure 2. Australia: Response to a monetary policy shock, using the structural VAR

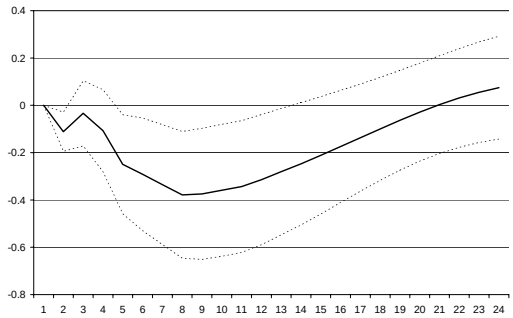
A) Interest rate (percentage point)



B) Real exchange rate (percentage)



C) GDP (percentage)



D) Inflation (percentage)

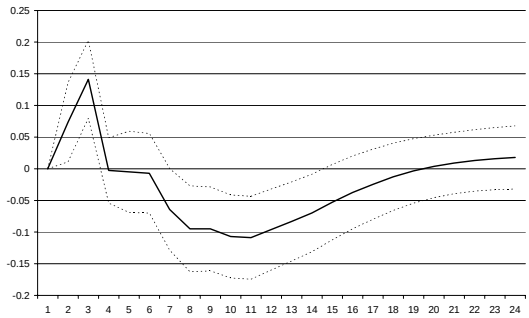
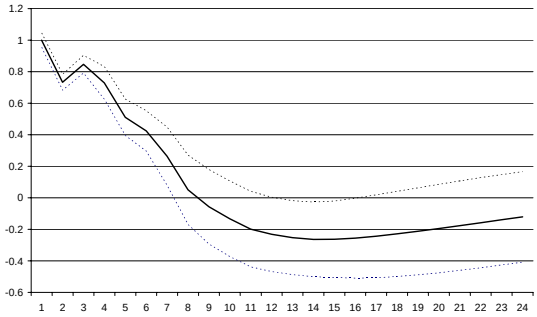
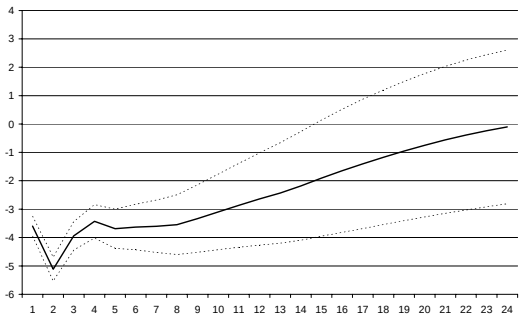


Figure 3. Canada: Response to a monetary policy shock, using the structural VAR

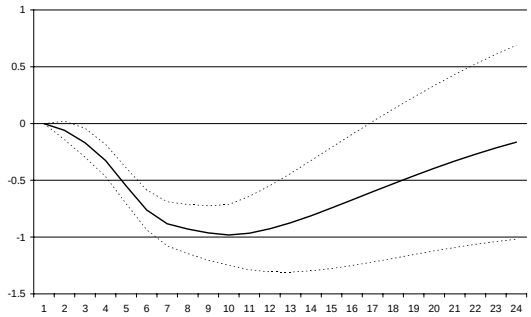
A) Interest rate (percentage point)



B) Real exchange rate (percentage)



C) GDP (percentage)



D) Inflation (percentage)

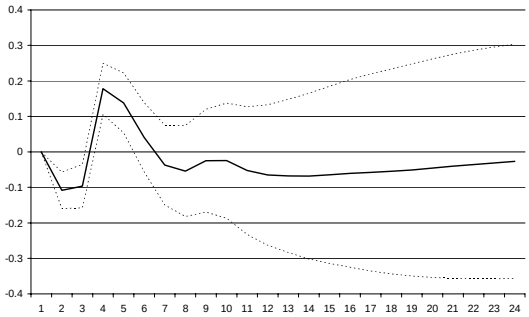
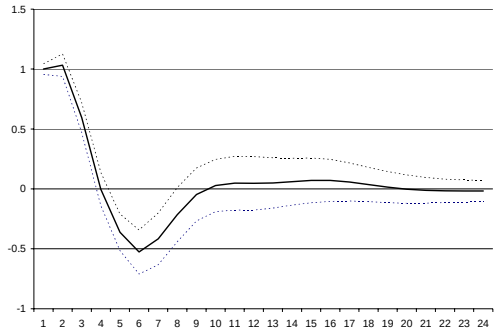
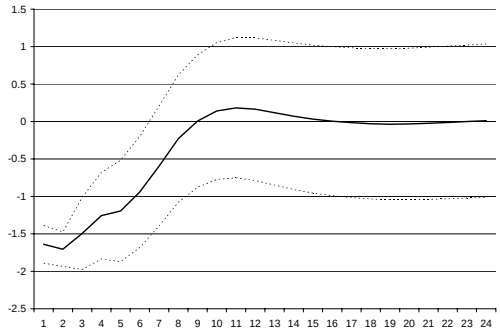


Figure 4. New Zealand: Response to a monetary policy shock, using the structural VAR

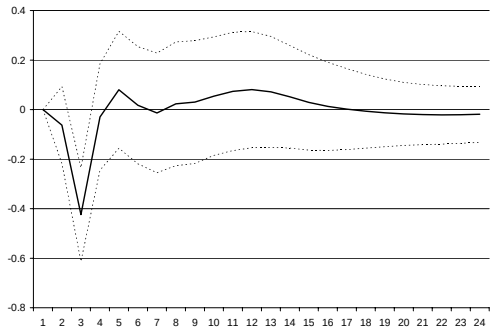
A) Interest rate (percentage point)



B) Real exchange rate (percentage)



C) GDP (percentage)



D) Inflation (percentage)

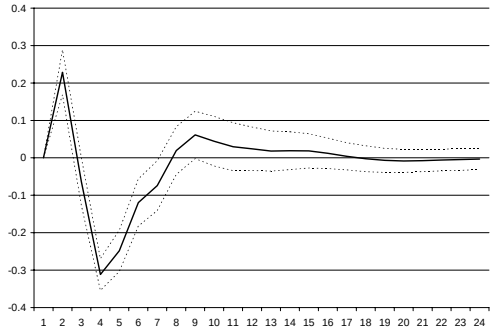
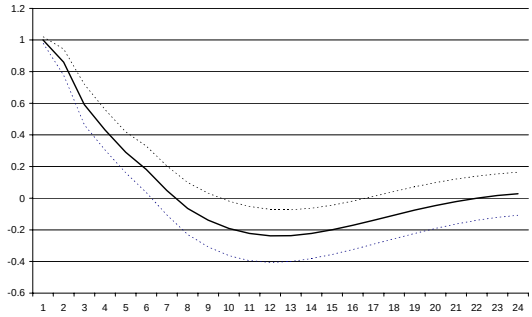
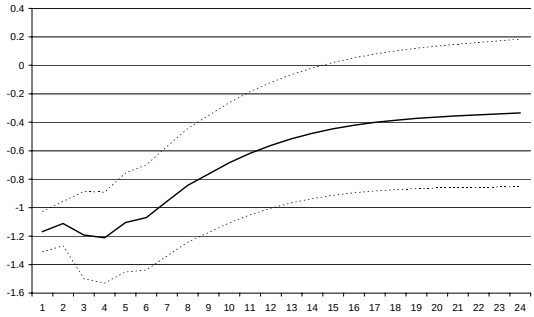


Figure 5. Sweden: Response to a monetary policy shock, using the structural VAR

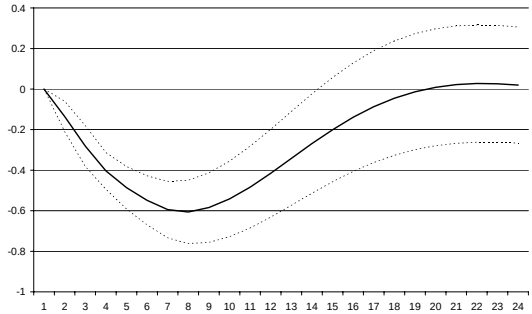
A) Interest rate (percentage point)



B) Real exchange rate (percentage)



C) GDP (percentage)



D) Inflation (percentage)

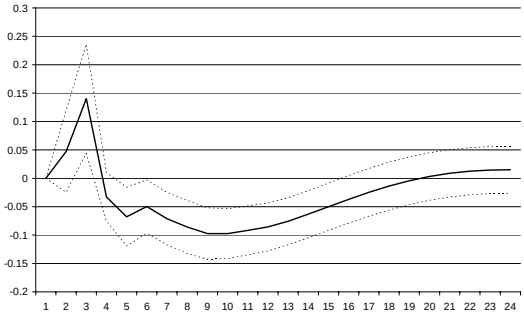
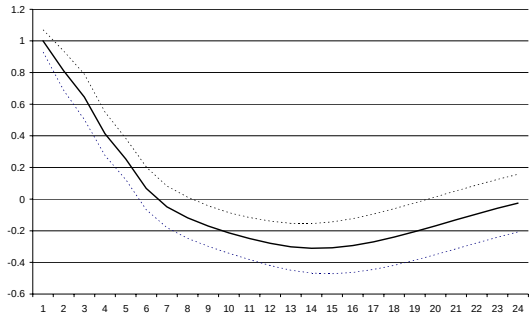
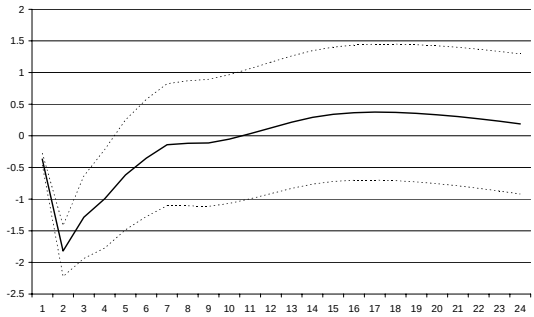


Figure 6. UK: Response to a monetary policy shock, using the structural VAR

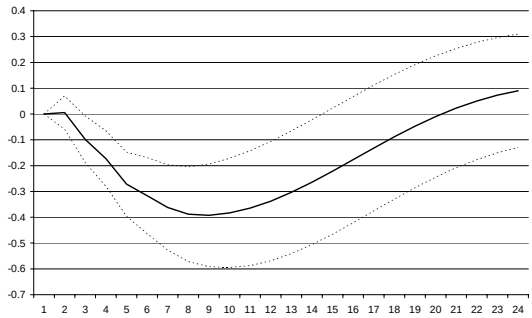
A) Interest rate (percentage point)



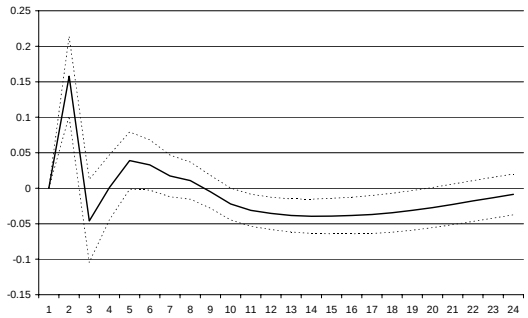
B) Real exchange rate (percentage)



C) GDP (percentage)



D) Inflation (percentage)



any of the countries. The monetary policy shock has a strong and immediate impact on the exchange rate, which now appreciates by 1-3 percent on impact. The maximal impact of the policy shock occurs contemporaneously, with the notable exception of UK and to a lesser extent Canada, where the maximal impact is delayed one quarter. However, the adjustment following the initial response is small compared to the impact effect, at least in Canada. Following the initial response, the exchange rate thereafter gradually depreciates back to baseline consistent the Dornbusch overshooting hypothesis. The path of adjustment will depend on the extent of nominal rigidities in the economy, since these influence the speed with which the economy adjusts in response to shocks.

Do the reported results appear reasonable? The initial effect seems consistent with what has been found in a series of event studies that measure the immediate response of the exchange rate to shocks associated with particular policy actions. For instance, Zettelmeyer (2004), analysing Australia, Canada and New Zealand using daily data, finds that a 1 pp contractionary shock will appreciate the exchange rate by 2-3 percent on impact. Kearns and Manners (2005) using intraday data for the same three countries plus the UK find similar results, although the magnitude of the effect of the shocks is somewhat smaller.

Finally, consistent with the strong impact on the exchange rate, output falls gradually and reaches a minimum after approximately 1.5-2 years. The effect thereafter quickly dies out. The effect on inflation is on the other hand small. With the exception of Canada and possibly Sweden (where the initial effect is not significantly different from zero), there is some evidence of an initial price puzzle (where inflation rises following a contractionary

monetary policy shock) which is commonly found in the literature. This initial increase has recently been explained (Ravenna and Walsh, 2003; Chowdhury et al., 2003) by a cost channel of the interest rate (i.e., the increased interest rate increases borrowing costs for firms and therefore prices) and is less of a puzzle.[17] The effect on inflation is thereafter significantly negative as expected, and peaks after 2-3 years. Overall, the small and sluggish effect on inflation is a persistent feature in many other studies of open economies, but also in conventional closed economy studies like Christiano et al. (1999, 2005).

Having asserted that the exchange rate behaviour is consistent with Dornbusch overshooting, I next turn to examine whether the subsequent response in the exchange rate is consistent with UIP. If UIP holds following a contractionary monetary policy shock, then the fall in the interest rate differential $(i_t^* - i_t)$ will be offset by an expected depreciation of the exchange rate between time t and $t+1$. To explore this issue in more detail, I follow Eichenbaum and Evans (1995) and define Ψ_t as the ex post difference in return between holding one period foreign or domestic bonds. Measured in domestic currency, excess return is then given by:

$$\psi_t = i_t^* - i_t + 4 * (s_{t+1} - s_t), \tag{8}$$

where s_t is the nominal exchange rate and s_{t+1} is the forecasted three-month ahead exchange rate response.[18] One implication of UIP is that the conditional expectations of the excess return should be zero:

$$E_t \psi_{t+j} = 0 \tag{9}$$

for all $j \geq 0$, where E_t denotes conditional expectations. Figure 7 reports the point estimates (and both one and two standard errors) of the dynamic response function of (9) on the basis of the estimated VARs. Note that as it is the real exchange rate that is included in the VAR, I have to adjust for the effect of monetary policy shocks on prices to obtain the effect on the nominal exchange rate; $s_t = e_t - p_t^* + p_t$.[19]

The figure shows that, with the exception of Canada and the UK, the responses essentially fluctuate around zero, consistent with UIP. For Canada and the UK, there are significant negative deviations from zero initially (as the exchange rate reacts with a delay of one quarter compared to the other countries), but thereafter these responses also essentially

[17] Eichenbaum (1992) argued that a price puzzle will appear when one (wrongly) omit a commodity price variable from the VAR that represents inflation pressure to which the central bank reacts (see also Sims 1992 and Leeper et al. 1996). However, recently Hanson (2004) has noted that the inclusion of the commodity index is less successful in alleviating the price puzzle in VAR models estimated with data for the past twenty years, thus leading me to leave out the variable altogether.

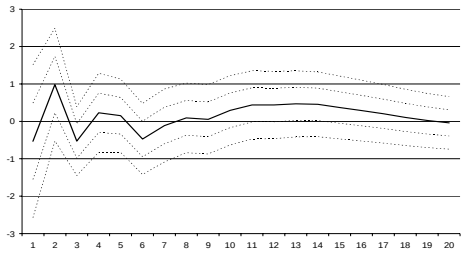
[18] The exchange rate is multiplied by four to be annualized, as the interest rate is measured in annual terms.

[19] To be precise, I can only correct for domestic inflation impulses as foreign prices are not among the endogenous variables in the VAR. This restriction is equivalent to assuming that domestic monetary policy have negligible effect on foreign prices, which is a common small open economy assumption used among other in Dornbusch (1976). The excess return calculated will therefore only be correct up to the point that this assumption is warranted.

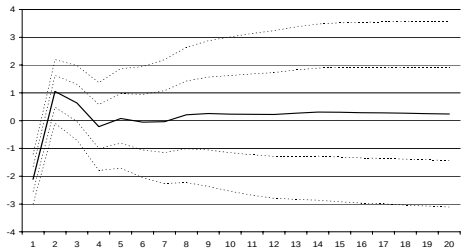
fluctuate around zero. Hence, I find basic confirmation of UIP, which contrasts with the results presented in the vast VAR literature including Eichenbaum and Evans (1995) using traditional recursive restrictions for identification and more recently Faust and Rogers (2003) using sign restrictions.[20]

Figure 7 Excess returns

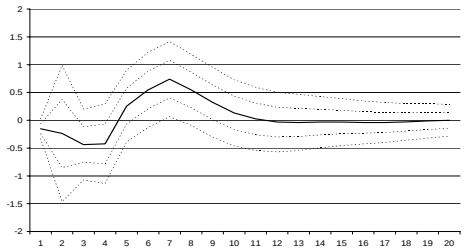
A) Australia



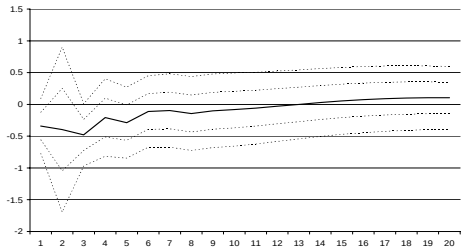
B) Canada



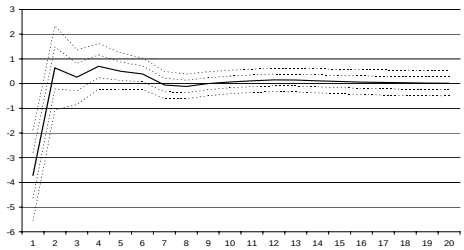
C) New Zealand



D) Sweden



E) UK



Finally, I turn to quantify the contribution of monetary policy shocks in explaining overall exchange rate fluctuations. This is summarized in the first row in Table 1, which shows the variance decomposition of the real exchange rate with respect to the monetary policy shocks for all five countries. In the second row in Table 1 the reverse question is asked, namely, what is the contribution of exchange rate shocks in accounting for the variation in interest rates? From the impulse responses (not reported), an exchange rate shock that depreciates the exchange rate leads to a temporary increase in the interest rates. This behaviour is consistent with the central banks reacting to the exchange rate to the extent that it affects output and inflation.[21] Given these responses, the variance decomposition may therefore provide us with

[20] Notable exceptions are Cushman and Zha (1997) and to a certain extent Kim and Roubini (2000), which by using a structural model find that UIP holds conditionally, despite evidence of delayed overshooting.

[21] These responses (can be obtained by the author on request) might be motivated both by the central banks concern about reducing the impact of the shock on aggregate demand by conducting a policy that will offset the exchange rate effects, but also by reducing the exchange rate shock's impact on exchange rate themselves – thereby diminishing the source of the problem.

more details on the importance of the exchange rate as an indicator for interest rate setting. The table summarize the variance decomposition for the first quarter where the maximum impact occurs, with the exception of Canada and the UK where the maximum impact is in the second quarter.

Table 1. Forecast error decomposition: Contribution of monetary policy- and exchange rate shocks to exchange rate and interest rate variation. Maximal impact, percentage.

	AUS	CAN	NZL	SWE	UK
Monetary policy shocks; **Contribution to *real exchange rate* variation**	5	39	11	14	7
Exchange rate shocks; **Contribution to *interest rates* variation**	16	41	10	15	3

Of the five countries, Canada displays by far the highest degree of interaction between interest rate settings and exchange rate dynamics, as monetary policy shocks explain approximately 40 percent of the exchange rate variation, with an equal amount of interest rare variation explained by exchange rate shocks. New Zealand and Sweden also display some degree of interaction, with monetary policy shocks and exchange rate shocks accounting for 10-15 percent of the exchange rate and interest rate variation respectively. For the remaining two countries, and in particular the UK, interaction is more modest, with exchange rate shocks accounting for three percent of the interest rate variation and monetary policy shocks accounting for seven percent of the exchange rate variation.

Hence, monetary policy shocks explain a significant share of the exchange rate variation for the majority of countries, and exchange rate shocks are important indicators for the interest rate setting. However, the response by the central banks to the exchange rate is no direct evidence of the stabilization of exchange rate independent of the less controversial objectives such as inflation and output. More likely, it is the result of the monetary policymaker reacting to exchange rates due to the monetary policy lag in influencing the objectives such as output and inflation, as was evident from figures 2-6.

The reported results seem to fall in between the boundaries of what has previously been reported. Furthermore, the finding that monetary policy shocks explain relatively more of the exchange rate variation in Canada than in the other countries seems to be a feature that is picked up in other studies. For instance, Kim and Roubini (2000) find monetary policy shocks to explain almost 60 percent of the exchange rate variation in Canada. However, whereas the effect found here is almost immediate, in Kim and Roubini the effect is accumulated for close to a year, as they find a pronounced delayed overshooting puzzle in the exchange rate.

With regard to the remaining variables in the model, monetary policy shocks explain approximately 5-15 percent of output and inflation variation after 1-3 years. These results are in line with what has previously been reported in the literature, although the exact magnitude

may be somewhat larger due to the considerable initial response in the real exchange rate reported here.[22]

4 Robustness of results

The robustness of the results reported above deserves further discussion on at least three issues with regard to specification: (i) Additional lags in the VAR, (ii) sample stability and (iii) choice of variables in the VAR. Below the results are presented with regard to the effect on the real exchange rate only, although where relevant, results for the other variables will be discussed. Impulse responses for all variables can be obtained from the author on request.

4.1 Specification - lags

When testing for lag reduction in the structural model, most models could be reduced to three lags, although reducing the VAR further to two lags could not be supported. However, in many of the cases test diagnostics were quite similar using either three or four lags, and to check the robustness of the results with regard to lag selections, all models were therefore re-estimated using now four lags. The results of a contractionary monetary policy shock (that increase the interest rate with 1 pp on impact) on the exchange rate are presented in Frame A in Figure 8 below. In each diagram, the baseline results using three lags (solid line) is plotted together with the alternative of four lags (dotted lines). Overall, the main results still prevail, although the exact magnitude of the effects of shocks has changed somewhat. In particular, for Sweden the impact effect is larger initially than in the baseline, but then declines in line with the baseline back to equilibrium. However, there is still no evidence of an exchange rate puzzle in any countries, as the exchange rate appreciates on impact, and thereafter (within a quarter) depreciates gradually and smoothly back to equilibrium.

4.2 Sample stability

To check for robustness with respect to sample stability, all models were re-estimated shifting the start date first back and then forwards with five years; 1978-2004 and 1988-2004. Although convenient dates due to the five year interval, the dates are not chosen randomly. The start date for the extended sample (1978) is chosen as this is the earliest start date common to all countries.[23] The start date for the more recent sample (1988) is chosen for two reasons. First, from 1988, price stability has been a more explicit focus in many countries; starting with Canada and New Zealand first referring to the desirability of inflation targeting in 1988 and with the others countries subsequently following (see Collins and Siklos, 2004, and the references stated therein).[24] Second and probably related to the first, Bagliano and Favero (1998) have found that with regard to mis-specification, starting the estimation in

[22] These variance decompositions can be obtained from the author on request.

[23] For Canada, data were available back to 1973, and the results are robust also to this extended period. Note that for New Zealand I use annual changes in CPI for the period 1978-2004, as quarterly changes showed a large degree of volatility in the period when New Zealand changed from a closed and centrally controlled economy to one of the most open economies. For Sweden, the three month interest rate was only available to 1982. I therefore used the Call Money Rate prior to 1982, and included a dummy to link the two interest rate series.

[24] For instance, in Australia, the aim at stabilising inflation had been included in the Bank's public statements for a number of years before formally adopted in 1993.

1988 is preferred to that of 1983 when analysing monetary policy, although the impulse responses using the two different periods may not be statistically different.

The results are presented in Frame B in Figure 8. The solid line corresponds to the baseline scenario; the dotted line to the period starting in 1978; the semi dotted line to the period starting in 1988. Overall, the main conclusions prevail. In particular, there is no evidence of an exchange rate puzzle in any countries, as following a monetary policy shock the exchange rates appreciate on impact. However, in some countries, the maximal response is delayed a quarter using the sample starting in 1978, which is not surprising as monetary policy shocks are now identified on a large sample that could potentially be confounding different monetary policy regimes. However, the adjustment following eventually is small compared to the initial adjustment.

The results using the more recent sample are also generally very supportive of the above findings; no evidence of an exchange rate puzzle as the exchange rates appreciate on impact. For some countries the effect is more pronounced, in particular for the UK where the maximum impact effect now comes the first quarter, indicating the importance of monetary policy shocks for exchange rate variation in more recent time.

4.3 Specification: Additional variables

VAR models have been criticised for not being robust to including additional variables (see Leeper et al., 1996, among others). A natural extension to the above model is therefore to include additional variables to test the robustness of results. In this regard, I examine inclusion of the oil price. The oil price is a natural choice as two of the countries in the sample are oil exporting countries (Canada and the UK), where the oil price may potentially explain a substantial part of the exchange rate variation.

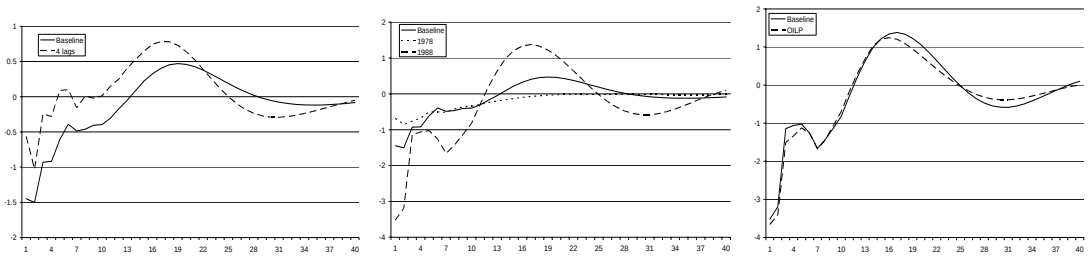
The results are presented in Frame C in Figure 8. The baseline 5-variable VAR is compared to a 6-variable VAR including oil price, where the oil price is placed first in the ordering. This implies that oil price shocks can affect all variables contemporaneously, while no other shock can affect the oil price contemporaneously. This is a plausible small country assumption. The model is estimated over the recent sample; 1988-2004, to avoid being dominated by the massive fall in oil prices in 1986 (and the subsequent adjustment in 1987). For comparison, the baseline VAR reported in frame C is also for the sample 1988-2004. The results are again supportive of the main findings; with the exception of Sweden where the overshooting is now delayed a few months.

Robustness of results with respect to the use of different measures of the variables in the VAR, have also been examined. In particular, robustness is tested with respect to using annual changes in prices (versus quarterly) and using bi-variate real exchange rates instead of trade weighted real exchange rates. The results are robust to these amendments. However, the price puzzle reported in figure 2-6 above becomes less pronounced using annual inflation rates in the VAR, and for Sweden there is no longer any price puzzle, as was also found in Lindé (2003), using an equivalent inflation measure.

Figure 8. Response in the exchange rate to a monetary policy shock, structural model

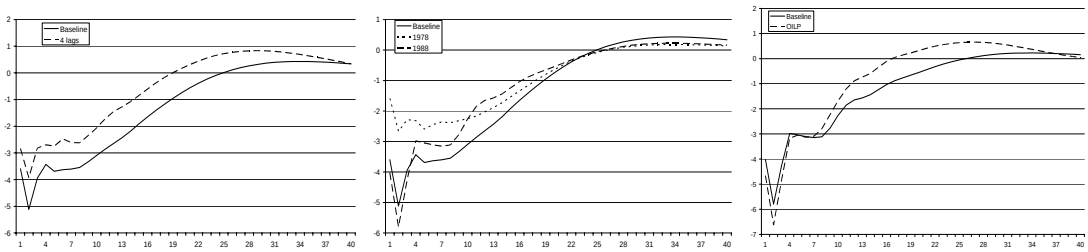
Australia

E1) 3 versus 4 lags *E2) Start: 1978, 1983, 1988* *E3) Oil price, 1988-2004*



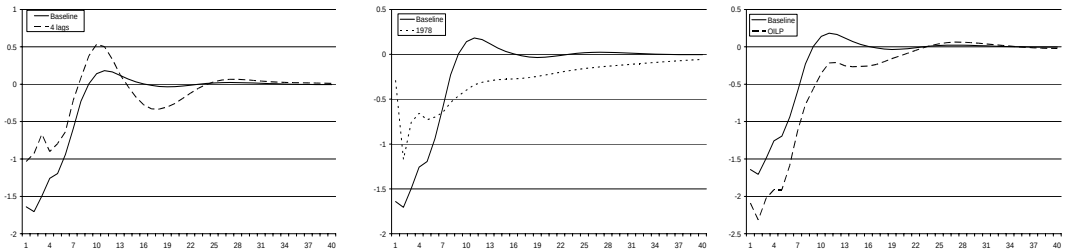
Canada

E1) 3 versus 4 lags *E2) Start: 1978, 1983, 1988* *E3) Oil price, 1988-2004*



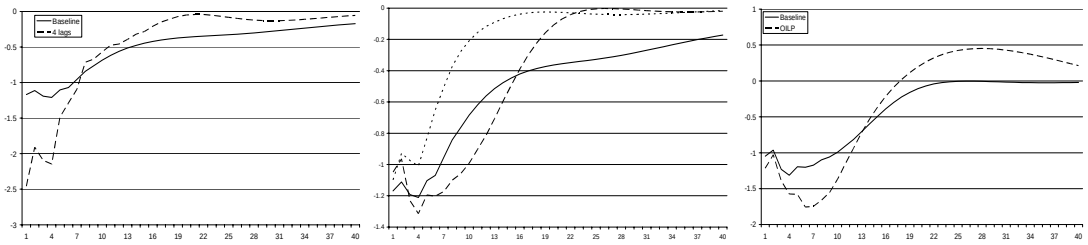
New Zealand

E1) 3 versus 4 lags *E2) Start: 1978, 1988* *E3) Oil price, 1988-2004*



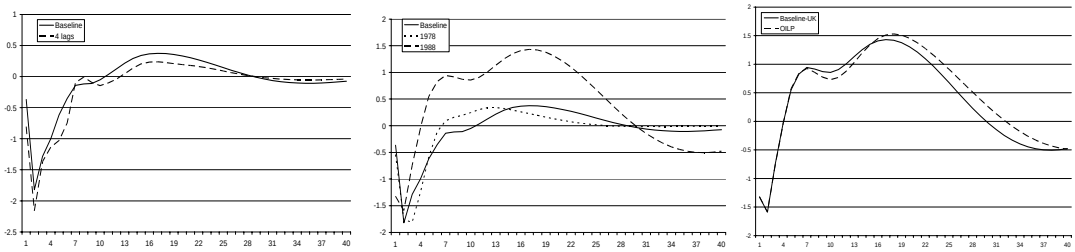
Sweden

E1) 3 versus 4 lags *E2) Start: 1978, 1983, 1988* *E3) Oil price, 1988-2004*



UK

E1) 3 versus 4 lags *E2) Start: 1978, 1983, 1988* *E3) Oil price, 1988-2004*



5 Concluding remarks

Dornbusch's (1976) well known exchange rate overshooting is a central building block in international macroeconomics, stating that the nominal exchange rate immediately appreciates with the increase in nominal interest rates, in line with uncovered interest parity (UIP). When confronted with data, however, very few empirical studies analysing the effects of monetary policy shocks have found support for Dornbusch overshooting. Instead they have found that following a contractionary monetary policy shock, the real exchange rate either depreciates, or, if it appreciates, it does so for a prolonged period of up to three years, thereby giving a hump-shaped response that violates UIP. These results have been so persuasive that the puzzles themselves are now about to be considered consensus, of which many recently developed DSGE models seek to replicate.

The majority of studies quantifying the effects of monetary policy shocks have used the vector autoregressive (VAR) approach. A major problem facing these studies is how to address the simultaneity of monetary policy and the exchange rate. Most of the studies of open economies are placing zero contemporaneous restrictions on the response of the systematic interest rate setting to an exchange rate shock, or vice versa. However, this is not consistent with established theory neither on monetary policy nor on exchange rate determination. Furthermore, Faust and Rogers (2003) have recently shown that the delayed overshooting feature of the open economy VAR is very sensitive to this kind of restriction. VAR models of the open economy should therefore seek to identify monetary policy without restricting the contemporaneous response.

This paper suggests an alternative identification that restricts the long run multipliers of the shocks, but leaves the contemporaneous relationship between the interest rate and the exchange rate unaltered. Identification is achieved by assuming that monetary policy shocks can have no long run effect on the level of the real exchange rate. This is a standard neutrality assumption that holds for a large class of models in the monetary policy literature. In the short run, however, monetary policy is free to influence the exchange rate.

Allowing for full simultaneity between monetary policy and the exchange rate, I find striking results; Contrary to the recent "consensus", a contractionary monetary policy shock has a strong effect on the exchange rate that appreciates on impact. The maximal impact occurs immediately, and the exchange rate thereafter gradually depreciates back to baseline. This is consistent with the Dornbusch overshooting hypothesis. Furthermore, the ensuing movement of the exchange rate is with few exceptions consistent with UIP. Hence, I have found no evidence of the typical hump-shaped response found in the empirical literature, where the maximal impact occurs after 2-3 years; (i.e. Eichenbaum and Evans, 1995).

Furthermore, the qualitative properties of a monetary policy with regard to domestic variables that have been found in the established literature still hold. In particular, a contractionary policy shock temporarily lowers output and has a sluggish but eventually negative effect on consumer price inflation.

References

Adolfson, M., Laséen, S., Lindé J., and M. Villani (2005), "Bayesian Estimation of an Open Economy DSGE Model with Incomplete Pass-Through," Sveriges Riksbank Working Paper Series No. 179.

Bagliano, F.C. and C.A. Favero (1998), "Measuring monetary policy with VAR models: An evaluation," *European Economic Review*, 42, 1069-1112.

Bjørnland, H.C. (2005), "Monetary Policy and Exchange Rate Interactions in a Small Open Economy," Manuscript, University of Oslo.

Bjørnland, H.C. and K. Leitemo (2004), "Identifying the Interdependence between US Monetary Policy and the Stock Market," Manuscript, University of Oslo.

Blanchard, O. and D. Quah (1989), "The Dynamic Effects of Aggregate Demand and Supply Disturbances," *American Economic Review*, 79, 655-73.

Christiano, L.J., Eichenbaum, M. and C.L. Evans (1999), "Monetary Policy Shocks: What Have we Learned and to What End?," in J.B. Taylor and M. Woodford, eds., *Handbook of Macroeconomics*. Volume 1A. New York: Elsevier Science, 65-148.

Christiano, L., Eichenbaum, M. and C.L. Evans (2005), "Nominal Rigidities and the Dynamic Effects of a Shock to Monetary Policy", *Journal of Political Economy* 113, 1-45.

Chowdhury, I., Hoffmann, M. and A. Schabert (2003), "Inflation Dynamics and the Cost Channel of Monetary Transmission," Manuscript University of Cologne.

Clarida R. and J. Gali (1994), "Sources of real exchange rate fluctuations: how important are nominal shocks?" *Carnegie-Rochester Conference Series on Public Policy*, 41, 1-56.

Clarida, R., J. Galí and M. Gertler (1998), "Monetary policy rules in practice," Proceedings, Federal Reserve Bank of San Francisco, March.

Clarida, R., J. Gali and M. Gertler (2000), "Monetary policy rules and macroeconomic stability: evidence and some theory," *Quarterly Journal of Economics,* 115, 147-180.

Clarida, R., J. Galí and M. Gertler (2001), "Optimal Monetary Policy in Open Versus Closed Economies: An Integrated Approach", *American Economic Review Papers and Proceeding*, 91, 248-252.

Collins, S. and P.L. Siklos (2004) "Optimal Monetary Policy Rules and Inflation Targets: Are Australia, Canada and New Zealand Different from the U.S.?", *Open Economies Review* 15, 347-362.

Cushman, D.O. and T. Zha (1997), "Identifying monetary policy in a small open economy under flexible exchange rates", *Journal of Monetary Economics*, 39, 433-448.

Doan, Thomas (2004), *Rats Manual*, Version 6, Estima, Evanston, IL.

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

Eichenbaum, M. (1992), "Comment on Interpreting the macroeconomic time series facts: the effects of monetary policy," *European Economic Review*, 36, 1001–1011.

Eichenbaum, M. and C. Evans (1995), "Some empirical evidence on the effects of shocks to monetary policy on exchange rates", *Quarterly Journal of Economics,* 110, 975-1010.

Engel, C. (1996), "The forward discount anomaly and the risk premium: a survey of recent evidence". *Journal of Empirical Finance*, 3, 123-191.

Evans, L. A. Grimes and B. Wilkinson (1996), "Economic Reform in New Zealand 1984-95: The Pursuit of Efficiency," *Journal of Economic Literature*, 34, 1856-1902.

Fama, E.F. (1984), "Forward and Spot Exchange Rates," *Journal of Monetary Economics*, 14, 319-338.

Faust, J. and J.H. Rogers (2003), "Monetary policy's role in exchange rate behaviour", *Journal of Monetary Economics*, 50, 1403-1424.

Faust, J., E.T. Swanson and J.H. Wright (2004), "Identifying VARS based on high frequency futures data", *Journal of Monetary Economics*, 51, 1107-1131.

Favero, C.A. and M. Marcellino (2004), "Large Datasets, Small Models and Monetary Policy in Europe", Manuscript, Bocconi University.

Giordani, P. (2004), "An alternative explanation of the price puzzle", *Journal of Monetary Economics*, 51, 1271-1296.

Greenspan, A. (2005) "Reflections on central banking", Symposium sponsored by the Federal Reserve Bank of Kansas City, Jackson Hole, Wyoming, August 26, 2005.

Hamilton, J.D. (1994), *Time Series Analysis*, Princeton University Press, New Jersey.

Hanson, M.S. (2004), "The "price puzzle" reconsidered," *Journal of Monetary Economics*, 51, 1385-1413.

Kearns, J. and P. Manners (2005) "The Impact of Monetary Policy on the Exchange Rate: A Study Using Intraday Data", Reserve Bank of Australia Research Discussion Papers 2005-02.

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

Lane, P.R. (2001), "The new open economy macroeconomics: a survey," *Journal of International Economics*, 54, 235-266.

Leeper, E.M., Sims, C.A. and T. Zha, (1996), "What does monetary policy do?" *Brookings Papers on Economic Activity*, 2, 1-78.

Lindé, J. (2003), "Monetary Policy Shocks and Business Cycle Fluctuations in a Small Open Economy: Sweden 1986-2002", Sveriges Riksbank Working Paper Series No.153.

Lindé, J. M. Nessen and U. Söderström (2004), "Monetary Policy in an Estimated Open-Economy Model with Imperfect Pass-Through", CEPR Discussion Paper No. 4531.

Mojon B. and G. Peersman (2003), "A VAR description of the effects of monetary policy in the individual countries of the Euro area", In I. Angeloni, A. Kashyap and B. Mojon (eds), *Monetary policy transmission in the Euro area*, Cambridge University Press, Part 1, 56-74.

Murchison, S., A. Rennison and Z. Zhu (2004), "A Structural Small Open-Economy Model for Canada", Bank of Canada Working Paper 2004-4.

Obstfeld, M. (1985), "Floating Exchange Rates: Experience and Prospects" *Brookings Papers on Economic Activity*, 2, 369-450.

Obstfeld, M. and K. Rogoff (1995), "Exchange rate dynamics redux", *Journal of Political Economy*, 103, 624-660.

Obstfeld, M. and K. Rogoff (2000), "New Directions for Stochastic Open Economy Models," *Journal of International Economics*, 50, 117-153.

Peersman, G. and F. Smets (2003) "The monetary transmission mechanism in the euro area: more evidence from VAR analysis", In I. Angeloni, A. Kashyap and B. Mojon (eds), *Monetary Policy Transmission in the Euro Area*, Cambridge University Press, Part 1, 36-55.

Ravenna, F. and C.E. Walsh (2003), "The Cost channel in a New Keynesian Model: Evidence and Implications", University of California, Santa Cruz.

Rogoff, K. (2002), "Dornbusch's Overshooting Model after Twenty-Five Years", IMF Working Paper 02/39.

Rudebusch, G.D. (1998), "Do Measures of Monetary Policy in a VAR Make Sense?", *International Economic Review*, 39, 907-931.

Scholl, A. and H. Uhlig (2005), "New Evidence on the Puzzles. Results from Agnostic Identification on Monetary Policy and Exchange Rates", Mimeo Humboldt University.

Sims, C.A. (1980), "Macroeconomics and Reality," *Econometrica*, 48, 1-48.

Sims, C.A. (1992), "Interpreting the Macroeconomic Time Series Facts: The Effects of Monetary Policy", *European Economic Review*, 36, 975-1011.

Sims, C.A., J.H. Stock, and M.W. Watson (1990) "Inference in Linear Time Series Models with Some Unit Roots", *Econometrica*, 58, 113-144.

Sims, C.A. and T. Zha, (1999), "Error bands for impulse responses", *Econometrica*, 67, 1113-1157.

Smets, F. and R. Wouters (2002), "Openess, imperfect exchange rate pass-through and monetary policy", *Journal of Monetary Economics*, 49, 947-981.

Svensson, L.E.O. (1997), "Inflation Forecast Targeting: Implementing and Monitoring Inflation Targets," *European Economic Review* 41, 1111-46.

Svensson, L.E.O. (2000), "Open-Economy Inflation Targeting," *Journal of International Economics,* 50, 155-183.

Taylor, J.B. (2001), "The role of the Exchange Rate in Monetary-Policy Rules", *American Economic Review*, 91, 263-67.

Woodford, M. (2003), "Optimal Interest-Rate Smoothing," *Review of Economic Studies,* 70, 861-86.

Zettelmeyer, J. (2004), "The impact of monetary policy on the exchange rate: evidence from three small open economies", *Journal of Monetary Economics,* 51, 635-652.

Appendix A

All data are taken from the OECD database, except the Fed Funds rate that is taken from Eco Win. GDP and inflation are seasonally adjusted (s.a) by the official sources, the remaining series are unadjusted. The following data series are used:

(π_t) Inflation, measured as quarterly changes in the consumer price index (CPI) except for UK where the harmonized CPI is used (the only series available s.a.)

(y_t) Log real GDP, deflated by the official sources

(e_t) [CCRETT01.IXOB.Q] Log of the real effective exchange rate, measured against a basket of trading partners. The exchange rate is specified so that an increase implies depreciation.

(i_t) [IR3TBB01.ST.Q] Three month domestic interest rate.

(i_t*) Trade-weighted foreign interest rate. For Canada and the UK, the foreign interest rate is represented by the Federal Funds rate, as the US comprises more than 50 percent of the foreign trade weight.[25] For Australia, New Zealand and Sweden, the foreign interest is an weighted average of the interest rate in the major trading partners, source: Reserve Bank of Australia (http://www.rba.gov.au/), Reserve Bank of New Zealand (http://www.rbnz.govt.nz/) and Sveriges Riksbank (http://www.riksbank.com/) respectively

[25] For Canada, more than 80 percent of its export goes to the US.

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