Oslo
December 14, 2005

Working Paper

Research Department

Monetary policy and exchange rate interactions in a small open economy

by

Hilde C. Bjørnland

NORGES BANK

Working papers fra Norges Bank kan bestilles over e-post:
posten@norges-bank.no
eller ved henvendelse til:
Norges Bank, Abonnementsservice
Postboks 1179 Sentrum
0107 Oslo
Telefon 22 31 63 83, Telefaks 22 41 31 05

Fra 1999 og senere er publikasjonene tilgjengelige som pdf-filer
på www.norges-bank.no, under "Publikasjoner".

Working papers from Norges Bank can be ordered by e-mail:
posten@norges-bank.no
or from Norges Bank, Subscription service,
P.O.Box. 1179 Sentrum
N-0107Oslo, Norway.
Tel. +47 22 31 63 83, Fax. +47 22 41 31 05

Working papers from 1999 onwards are available as pdf-files on the bank's
web site: www.norges-bank.no, under "Publications".

ISSN 0801-2504 (printed) 1502-8143 (online)

ISBN 82-7553-338-4 (printed), 82-7553-339-2 (online)

Monetary policy and exchange rate interactions in a small open economy

Hilde C. Bjørnland*
University of Oslo and Norges Bank

May 2005 (Revised version December 2005)

Abstract

This paper analyses the transmission mechanisms of monetary policy in a small open economy like Norway through structural VARs, paying particular attention to the interdependence between the monetary policy stance and exchange rate movements in the inflation-targeting period. Previous studies of the effects of monetary policy in open economies have typically found small or puzzling effects on the exchange rate; puzzles that may arise due to the recursive restrictions imposed on the contemporaneous interaction between monetary policy and the exchange rate. By instead imposing a long-run neutrality restriction on the real exchange rate, thereby allowing the interest rate and the exchange rate to react simultaneously to any news, the interdependence increases considerably. In particular, following a contractionary monetary policy shock, the real exchange rate appreciates immediately and thereafter depreciates back to baseline. Furthermore, output and consumer price inflation fall gradually as expected; thereby also ruling out any price puzzle that has commonly been found in the literature. Results are compared and found to be consistent with among other the findings from an "event study" that focuses on immediate responses in asset prices following a surprise monetary policy decision.

Keywords: VAR, monetary policy, open economy, identification, event study.
JEL-codes: C32, E52, F31, F41

* Department of Economics, University of Oslo. *E-mail*: h.c.bjornland@econ.uio.no.
The author thanks Leif Brubakk, Steinar Holden, Kai Leitemo, Jesper Lindé, Sharon McCaw, Kjetil Olsen, and participants at the University of Oslo workshop on "Model evaluation in macroeconomics" for helpful comments. Thanks to Li Chen and Magne Østnor for collecting the data used in section 4. The views expressed in this paper are solely those of the author and do not necessarily reflect those of Norges Bank.

1 Introduction

Understanding the transmission mechanism of monetary policy is imperative for the implementation of an efficient monetary policy strategy in the many countries that have recently adopted inflation-targeting. For a small open economy, the exchange rate plays a central role in relation to monetary policy. It plays a significant part in the formulation of monetary policy (being an important influence on the overall level of prices), and is itself also influenced by monetary policy. Hence, monetary policy and exchange rate interactions may be substantial. Furthermore, by adopting inflation-targeting, many countries have had to abandon a (long-lasting) regime of fixed exchange rates, into one where the exchange rate now floats, thereby effectively loosing an anchor for the exchange rate. This may have rendered the exchange rate more volatile in response to shocks than previously experienced. Hence, exact knowledge of the exchange rate reaction to monetary policy in the inflation-targeting period becomes crucial for an efficient policy implementation.

This paper analyses the transmission mechanism of monetary policy in Norway, being one of the last countries in Europe (so far) to adopt inflation-targeting. While research on the monetary transmission mechanism in the Euro area has been substantial, there have been very few empirical studies trying to analyse the effects of monetary policy in the small open economies outside the Euro area; Norway being a compelling example.

The quantitative studies of the monetary transmission mechanism have to a large extent been addressed in terms of vector autoregressive (VAR) models, initiated by Sims (1980). However, although successful in providing a consensus with regard to the effects of monetary policy in the closed economy, VAR studies of the open economy have provided many puzzles, in particular with regard to the effects on the exchange rate. Whereas the Dornbusch's (1976) exchange rate overshooting hypothesis predicts an instant appreciation of the exchange rate in response to a contractionary monetary policy shock, VAR studies have instead found that if the real exchange rate appreciates, it does so for a prolonged period of up to three years, thereby giving a hump shaped behaviour that violates the uncovered interest parity (UIP) condition.[1]

A major challenge in the VAR literature is how to properly address the simultaneity between monetary policy and the exchange rate. Most of the VAR studies of open economies (including among others Eichenbaum and Evans, 1995; Peersman and Smets, 2003; Mojon and Peersman, 2003; Lindé, 2003; Favero and Marcellino, 2004), deal with a possible simultaneity problem by placing recursive, contemporaneous restrictions on the interaction between monetary policy and exchange rates. However, by not allowing for simultaneity effects in the identification of monetary policy shock, they may have produced a numerically important bias in the estimate of the degree of interdependence. This has been emphasised recently by Faust and Rogers (2003), which show that the effects on the exchange rate will be very sensitive to the zero short-run restriction between monetary policy and the exchange rate.

To allow for simultaneity, I will use 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

[1] This phenomenon has also been referred to as delayed overshooting, see Cushman and Zha (1997).

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). The restriction has also recently been found to be highly successful in alleviating the exchange rate puzzle in several other open economies, see Bjørnland (2005).

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 used in the closed economy literature; 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.

To my knowledge, there have been no studies of monetary policy in Norway that compares.[2] However, it is only recently that Norway abandoned a regime of targeting the exchange rate and instead adopted inflation-targeting. This paper therefore contributes to the literature on how monetary policy can be identified and analysed in a small open economy, as well as establishing some stylized facts on the effects of monetary policy in Norway.

The focus of interest will be on the inflation-targeting period. However, as there will be an added uncertainty on the transmission mechanism for a country like Norway that has just adopted inflation-targeting, the experience prior to inflation-targeting will have to be addressed, so as to reduce uncertainty about the transmission mechanism of monetary policy. Furthermore, the VAR analysis will be complemented with results using an "event study", where immediate responses in the exchange rate (as well as in other asset prices; stock prices in particular) associated with particular policy actions are analysed. This avoids the issue of identification altogether, but at the cost of ignoring any subsequent dynamic adjustments. I argue that this link between surprise monetary policy actions and initial exchange rate responses should be a feature that properly identified VAR models at least on impact should be able to replicate.

I find that a contractionary monetary policy shock has the usual effects identified in other international studies: temporarily increasing the interest rate, lowering output and a sluggish but negative effect on consumer price inflation. On the other hand, contrary to recent consensus, I find a substantial effect on the exchange rate which appreciates on impact. The maximal impact occurs almost immediately, and the real exchange rate thereafter gradually depreciates back to baseline; consistent with the Dornbusch overshooting hypothesis. Hence, there is no evidence of any exchange rate puzzle. Furthermore, by complementing the VAR analysis with an event study, I find further support for the hypothesis that asset prices react

[2] There have been a few studies trying to estimate interest rate rules for Norway; see for instance Olsen et al. (2002) and Akram et al. (2005). However, the focus is there on the systematic interest rate response, rather than on studying the effects of the (unsystematic) monetary policy shocks – which is also focus in VAR studies.

immediately to news, with exchange rates (as well as stock prices) responding strongly to a contractionary monetary policy shock.

In Section 2, the VAR methodology used to identify monetary policy shocks is explained whereas in Section 3 I discuss the empirical results. Section 4 discusses robustness of results with respect to the recent inflation-targeting period; using both VAR and event analysis, and Section 5 concludes.

2 The identified VAR model

The choice of variables in the VAR reflects the theoretical set up of a New-Keynesian small open economy model, such as that described in Svensson (2000) and Clarida et al. (2001). In particular, the VAR model comprises the log of the annual changes in the domestic consumer price index (π_t) – referred to hereafter as inflation, log of real GDP (y_t), the three month domestic interest rate (i_t), the (trade weighted) foreign interest rate (i_t*) and the log of the real exchange rate against a basket of trading partners (e_t) (see appendix A).[3]

In this paper I build 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 the real exchange rate. As already emphasised, this is a standard neutrality assumption that holds for a large class of models in the monetary policy literature. 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. Furthermore, Bjørnland (2005) has recently shown that by replacing the contemporaneous restriction with such a long run restriction on the real exchange rate, she effectively eliminates any exchange rate puzzle in the many diverse countries she studies.

[3] However, as is demonstrated below, other variables are also tried out.

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

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

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 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[4]. The reduced form VAR can be written in matrix form as (ignoring any deterministic terms in the following exposition)

$$A(L)Z_t = v_t, \qquad (2)$$

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. $A(L)$ is the (5x5) convergent matrix polynomial in the lag operator L, $A(L) = \sum_{j=0}^{\infty} A_j L^j$ and A_0=I. Assuming A(L) to be invertible, (2) can be written in terms of its moving average

$$Z_t = B(L)v_t, \qquad (3)$$

where $B(L)=A(L)^{-1}$. 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.,

$$v_t = S\varepsilon_t. \qquad (4)$$

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

---

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

$$Z_t = C(L)\varepsilon_t, \tag{5}$$

where $B(L)S = C(L)$. Clearly, if S is identified, one can derive the MA representation in (5) since $B(L)$ can be calculated from a reduced form estimation (2). 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 (or 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 monetary policy shocks, the recursive order between monetary policy shocks and the (domestic) macroeconomic variables implies the following restriction on the S matrix

$$\begin{bmatrix} i^* \\ y \\ \pi \\ i \\ \Delta e \end{bmatrix}_t = B(L) \begin{bmatrix} S_{11} & 0 & 0 & 0 & 0 \\ S_{21} & S_{22} & 0 & 0 & 0 \\ S_{31} & S_{32} & S_{33} & 0 & 0 \\ S_{41} & S_{42} & S_{43} & S_{44} & S_{45} \\ S_{51} & S_{52} & S_{53} & S_{54} & S_{55} \end{bmatrix} \begin{bmatrix} \varepsilon^{i*} \\ \varepsilon^{Y} \\ \varepsilon^{CP} \\ \varepsilon^{MP} \\ \varepsilon^{ER} \end{bmatrix}_t . \tag{6}$$

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 (6). However, 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. Finally, 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.[5] This provides nine contemporaneous restrictions directly on *S*.

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 (5), $\sum_{j=0}^{\infty} C_{54,j}$, equal to zero. By using this long-run restriction, there are enough restrictions to identify and orthogonalise all shocks. Writing the long-run expression of $B(L)S = C(L)$ as

$$B(1)S = C(1), \tag{7}$$

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

$$B_{51}(1)S_{14} + B_{52}(1)S_{24} + B_{53}(1)S_{34} + B_{54}(1)S_{44} + B_{55}(1)S_{54} = 0. \tag{8}$$

3 Empirical results

The model is first estimated using quarterly data from 1993Q1 to 2004Q3. Using an earlier starting period will make it hard to identify a stable monetary policy regime, as the Norwegian krone has been fixed to a series of different currencies; 1978-1990, vis-à-vis a trade weighted currency basket, and 1990-1992, vis-à-vis the ECU exchange rate. In periods, the Central Bank of Norway (Norges Bank) then increased the interest rate when there was depreciating pressure, and reduced the interest rate when there was an appreciation pressure. An increase in the interest rate differential has therefore often coincided with a weaker exchange rate, while an interest rate increase may have prevented the exchange rate from falling even further (see Norges Bank, 2000; p. 16).

By the end of 1992, however, the Norwegian krone was floated. Since then, the krone has had a managed float where monetary policy has been specified at maintaining a stable krone exchange rate against the ECU exchange rate (and from 1999, the Euro exchange rate), albeit without any fluctuations margins or any obligations for the central bank to intervene in the foreign exchange market. Eventually, in 2001 Norges Bank was given the mandate of targeting inflation. Although adopted late, Norges Bank had for some years already oriented

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

monetary policy instruments to bring price inflation down towards European levels, so as to achieve exchange rate stability against the Euro exchange rate. Consistent with this, Olsen et al. (2002) argue that with the exception of the brief period 1996/7-1998, monetary policy can be described as following close to some kind of Taylor rule from 1993. Hence, in the following I will estimate the baseline model for the period 1993-2004, and then in Section 4 focus explicitly on the inflation-targeting period.

To take account of extreme outliers, three impulse dummies (that take the value 1 in one quarter and 0 otherwise) were included for the following periods; 1997Q1, 1997Q2 and 2002Q2. The dummies represent respectively a severe appreciation pressure against the Norwegian krone in the first quarter of 1997; subsequent depreciation in the second quarter, and finally a severe appreciation of the Norwegian krone in 2002 in excess of its fundamentals (see Bjørnland and Hungnes, 2005). In addition, I also included a dummy that takes the value 1 in the period 1996Q4-1998Q1, and 0 otherwise. The dummy accounts for the fact that although monetary policy can be described as following a Taylor rule from 1993, from late 1996 to early 1998, one observed deviations from this rule, (i.e. Olsen et al., 2002). The dummy turns out to be significantly negative in the interest rate equation, implying that the interest rate should have been higher had the rule been followed over the whole period.

Consistent with most other related studies, the variables, with the exception of the real exchange rate, are specified in levels.[6] This implies that any potential cointegrating relationship between the variables will be implicitly determined in the model (see Hamilton, 1994). 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.[7] By applying long-run restrictions to the first-differenced real exchange rate, the effects of monetary policy shocks on the *level* of the exchange rate will eventually sum to zero (c.f. Blanchard and Quah, 1989).

[6] Based one the 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 possibly with a trend).

[7] Testing for unit roots in the real exchange rate yields the ADF t-statistics t_{ADF} =-3.089 (using two lags in the estimation). Using alternative lag lengths or extending the sample backwards does not change this result.

Finally, 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. A lag reduction to two lags could be accepted at the one percent level by all tests. Using two lags in the VAR, there is no evidence of autocorrelation, heteroscedasticity or non-normality in the model residuals.[8] Chow break tests also suggested stable equations.

3.1 Structural identification scheme

Before turning to the results using the structural model, Figure B1-B.2 in appendix B display the impulse responses of a monetary policy shock using the Cholesky decomposition. The figures clearly illustrates that in all cases will a monetary policy shock lead to puzzling behaviour in the exchange rate, thereby motivating the use of the structural VAR model.

Figure 1 below instead displays the impulse responses using the structural model. The figure graphs the response in the interest rate, real exchange rate, GDP and inflation to a monetary policy shock (normalised so that the response of the interest rate is 1 pp. the first quarter). The results are graphed with a one standard error band.[9]

The 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 a year and then goes below steady state. Both the interest-rate inertia and the "reversal" of the interest rate stance are consistent with what has become considered known to be good monetary policy conduct. As Woodford (2003) shows, interest-rate inertia is known to let the policymaker smooth the effects of policy over time by affecting private sector expectations. Moreover, the reversal of the interest rate stance, though arriving late, is consistent with the policymaker trying to offset the adverse effects of the initial policy deviation from the systematic part of policy.

Turning to the effect on the real exchange rate, there is no evidence of any exchange rate puzzle. Instead, the monetary policy shock has a strong and immediate impact on the exchange rate, which appreciates (falls) by around 0.8 percent following a 1 percentage point increase in the interest rate. The exchange rate remains appreciated for two quarters, before it gradually depreciates back to baseline. However, the initial response is large compared to the subsequent appreciation, thereby essentially confirming Dornbusch overshooting. These results are also consistent with what has recently been found in a study of other open economies using a similar identification scheme, see Bjørnland (2005).

Consistent with the appreciated exchange rate, output starts to fall gradually and reaches a minimum after a year. The effect thereafter quickly dies out. Inflation falls by little initially, but then gradually declines and reaches a minimum after approximately two years.

---

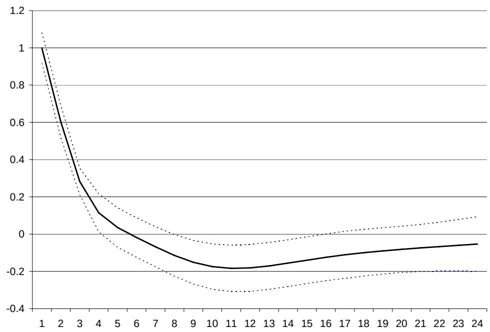
[8]Vector AR 1-4 test: F(100,38)=2.05 [0.01], Vector Normality test: Chi^2(10)=6.35 [0.78], Vector hetero test: Chi^2(300)=320.80 [0.1956]. Additional diagnostic tests can be obtained from the author on request.

[9] 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).

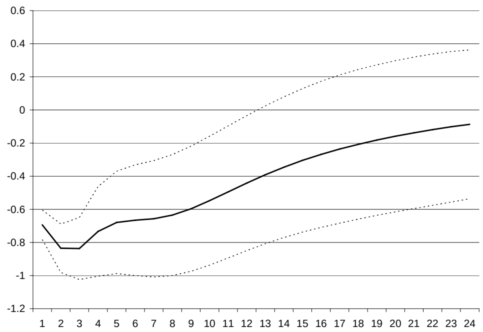
Interestingly, there is no evidence of any price puzzle (where prices actually increase initially) which has commonly been found in the literature (see Eichenbaum, 1992).

Figure 1. Response to a monetary policy shock, using the structural VAR (quarterly data)

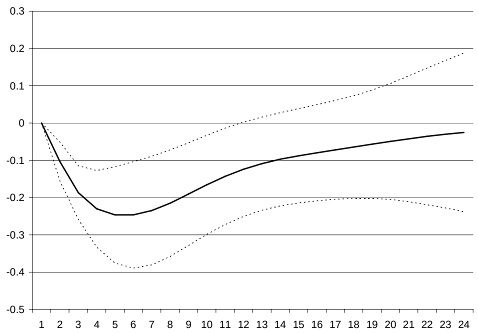
A) Interest rate (percentage point)



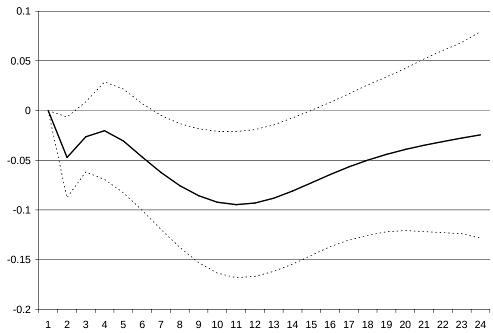
B) Real exchange rate (percentage)



C) GDP (percentage)



D) Inflation (percentage point)



The effect of the other shocks (can be obtained from the author on request) are as expected. In particular, an exchange rate shock that depreciates the exchange rate with 10 percent leads to a temporary increase in the interest rate of 10-15 basis points. Note, however, that although the central bank responds to the exchange rate, this 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 Figure 1.

How do these results compare to other studies of monetary policy in Norway? To my knowledge, there have been no other studies analysing monetary policy shocks that compares. Akram et al. (2005) have investigated interest rate rules using a small econometric model of the Norwegian economy. Given this rule, they study the response in key variables to a one percentage point rise in the short term interest rate. Whereas the responses of GDP and inflation are comparable to those reported here, the exchange rate displays a more u-shaped behaviour, which also fluctuates a lot. This leads me to suspect that the interest rate change studied may reflect other factors than just monetary policy, and/or that the study is performed on different monetary policy regimes, thereby essentially commingling effects.

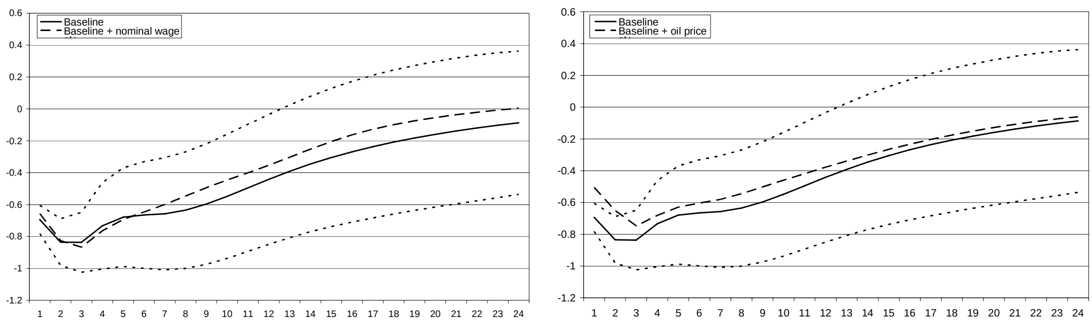
Finally, variance decompositions (can be obtained form the author on request) show that monetary policy shocks (that explains 70 percent of the interest rate variation initially) explains relatively little of the overall variability in the model, with no more than five percent of the variation in either the exchange rate, output or inflation being accounted for. The exchange rate shock (explaining almost 90 percent of the exchange rate variation initially) also explains a modest share of the variance in the other variables.

3.2 Additional variables

Leeper et al. (1996) and Faust (1998) have criticised the VAR approach for lack of robustness when adding additional variables to the model. Before turning to the recent inflationary period in more detail, the robustness of the above results will be investigated with respect to omitted variables. In particular, I augment the baseline structural VAR with, first, the nominal wage and second, the oil price.

Figure 2. Response in the real exchange rate to a monetary policy shock, structural VAR augmented with nominal wage and oil price, (quarterly data).[1]

A) VAR augmented with nominal wage (pct.)   B) VAR augmented with oil price (pct.)



1) The dotted lines are one standard error bands based on the baseline structural VAR.

The nominal wage is chosen as it is an important variable indicating inflation pressure that Norges Bank may want to respond to. Hence, omitting the variable may lead to biased results. When included in the VAR below, the nominal wage will be placed after inflation in the ordering, reflecting the fact that nominal wages may be a mark up on inflation.

Including the oil price serves multiple purposes. First, the oil price is an asset price that the central bank may want to respond to, as a higher oil price will feed into higher prices, via the cost channel. Second, and probably more important, Norway is a net oil exporter, where higher oil prices historically has tended to coincide with a higher level of activity in the domestic economy as well as an appreciation pressure of the domestic currency (see Haldane, 1997). Although the petroleum income has since 2001 been regulated to be phased into the economy on par with the development in expected return on the Government Petroleum Fund, the oil price is still an important asset price affecting the economy in a cyclical way. In the VAR model, the oil price will be placed first in the ordering, reflecting a plausible small country assumption. In that way, the central bank can respond immediately to oil price shocks, but the oil price will only be affected by oil price shocks contemporaneously.

Figure 2A graphs the effect on the real exchange rate following a monetary policy shocks using the VAR that has added the nominal wage, whereas Figure 2B displays the effect when the oil price is included. In both figures, the baseline structural VAR with a one standard error band is included for comparisons. Clearly, the effect remains virtually unchanged, with an initial appreciation that gradually depreciates back to equilibrium.[10]

4 Inflation-targeting period; 1999-2004

The analysis has so far been conducted for the (floating) period 1993-2004, using quarterly data. From March 2001, however, Norges Bank was given the new mandate of targeting inflation. Although officially adopted in 2001, the central bank announced already in 1999 (see Gjedrem, 1999; Norges Bank, 1999) that the best way to achieve exchange rate stability against the Euro, was to orient monetary policy instruments so price inflation was brought down towards the corresponding aim for inflation for the European Central Bank. In the VAR analysis below, I therefore examine the monetary transmission mechanism during the recent inflation-targeting period, defined broadly as the period 1999-2004. However, as the period is fairly short and may render imprecise estimates, the VAR analysis will eventually be complemented with results using an "event study", where immediate responses in the exchange rate (as well as in other asset prices) associated with particular policy actions are analysed on a daily basis.

4.1 Monthly data in the VAR

The focus here is to examine the transmission mechanism of monetary policy during the recent inflation-targeting period. In particular, I want to examine whether the results reported above appear to be robust to the institutional change of monetary target, or whether the transmission mechanism has changed in any important way. Due to the relatively short sample, monthly data are used. This exercise therefore also tests robustness with respect to observational frequency, albeit at a shorter sample.[11] Furthermore, as GDP is not available on a monthly frequency, the unemployment rate is instead included; reflecting a measure of overall economic activity.

Figure 3A displays the results for the unemployment rate and inflation, whereas Figure 3B graphs the results for the real exchange rate.[12] The results confirm in some important ways the transmission mechanism reported above. Following a contractionary monetary policy shock (that increases the interest rate with one percentage point the first

[10] The effects of an oil price shock on the other variables are as expected in an oil producing country; a shock that increases the oil price implies an appreciation of the real exchange rate, an increase in output (that quickly dies out) and a gradual increase in inflation. Consistent with the higher level of activity, the interest rate is raised with 10 basis points (after a year) for an initial 10 percent increase in the oil price.

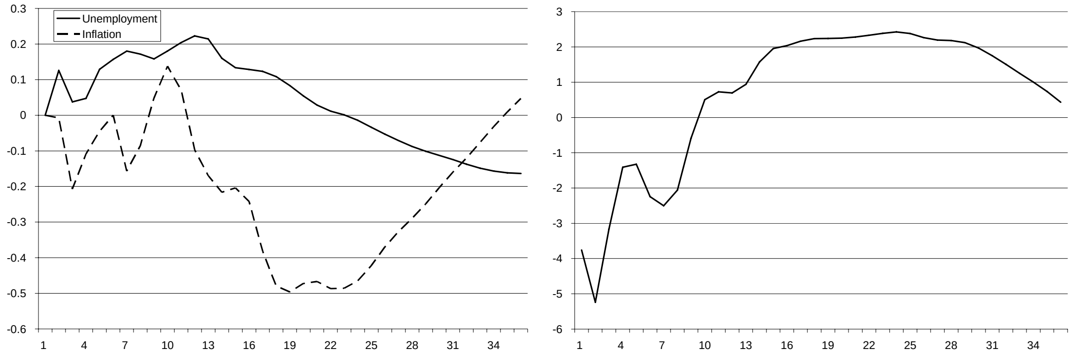
[11] Using monthly data for 1993-2004 confirm the results from above, although the magnitude of responses are slightly larger initially, which is not surprising given the more noisy characteristics of monthly data.

[12] To be consistent with the baseline model, the VAR is estimated using six lags (correspondingto two lags for quarterly data), a constant, trend and a dummy that takes the value 1 in 2002M5-6. Using six lags, there is no evidence on any residual misspecifications.

month), unemployment increases gradually, until it reaches a maximum after just a year. Throughout this period inflation responds very little; essentially fluctuating around zero, until after 13 months it falls considerably. Minimum is reached after 19-23 months.

Figure 3. Response to a monetary policy shock using the structural VAR, (monthly data).

A) Unemployment and inflation (perc. point) B) Real exchange rate (percentage)



Consistent with the results reported above, the real exchange rate immediately appreciates following a contractionary monetary policy shock. However, the effect is much larger initially than in the baseline model estimated above; with an immediate adjustment of just less than four percent. This is not surprising, given that the exchange rate is now floating. However, the exact magnitude of response may also to some extent reflect the fact that I use monthly data that display more volatility.[13] Following the initial response, the exchange rate depreciates back to equilibrium, implying that there is no evidence of any delayed overshooting.

Overall then, the transmission mechanism to monetary policy shocks in the inflation-targeting period is in line with what I found in the baseline model (1993-2004); an immediate effect in the exchange rate, followed by a hump shaped response in the domestic variables. However, the speed of adjustment to shocks is a little quicker and the impact effect is amplified somewhat.

What is the contribution of monetary policy shocks to overall variability? Variance decompositions (can be obtained from the author on request) show that monetary policy shocks now explains almost 20 percent of the exchange rate variation the first two months. The effect then quickly dies out. The effect on unemployment is also quite substantial; 20 percent of the unemployment variation is explained by monetary policy shocks the first 1-2 years, before the effect gradually dies out. Despite this, the contribution to inflation variability is still quite modest, with less than 10 percent of the variability explained after 2-3 years. Hence, the exchange rate volatility with respect to monetary policy has clearly increased in the present inflation-targeting period, but with the overall variance in the variables still explained by other shocks than monetary policy shocks. Interestingly though, the contribution of monetary policy shocks to interest rate variation has declined, explaining no more that 60 percent of the initial variation; declining to less than 10 percent already after six months.

[13] Results using shorter lag length essentially confirm the above results, although the magnitude of the responses are reduced somewhat. These results can be obtained from the author on request.

Hence, monetary policy has become more predictable in the inflation-targeting period, with the interest rate responding more to economic variables, and less to the unsystematic monetary policy shocks.

4.2 Event analysis

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 conventional 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.

Therefore, as an alternative to the VAR analysis, I specify an event analysis for the official inflation-targeting period (2001-2004). Following Zettelmeyer (2004), the immediate (i.e. the same day) response of the exchange rate to specific monetary policy actions is studied. Since it is the unanticipated content of these policy actions that are of interest, I measure the reaction of the three month interest rate. The choice of the three month interest rates as the policy measure reflects the fact that they are sufficiently "short" to reflect the policy targets, but at the same time "long" enough to react only to the extent that changes is the policy rate were unanticipated. Hence, the following regression is specified

$$\Delta s_t = \alpha + \beta \Delta i_{3m,t} + \varepsilon_t \qquad (9)$$

where $\Delta i_{3m,t}$ is the change in the three month interest rate on the day of the policy announcement and Δs_t is the change in the nominal exchange rate the same day.[14] A constant is also included to capture any trend depreciation, but it will generally be insignificant.

Note that the regression of (9) will only result in unbiased estimates of the impact effect of monetary policy shocks if there are no other shocks that affect market interest rates on the same day.[15] To deal with the problem that interest rates may also reflect other shocks that happened to coincide with monetary policy actions (i.e. news about interest rates abroad),

[14] Ideally, one would measure the same day responses. However, decisions on interest rate changes are announced in the afternoon at 2 p.m., whereas the daily observation of the 3-month interest rate (NIBOR) and the exchange rates are reported at 12 am. and 2:15 pm. respectively. Hence, all the adjustment in the interest rate and close to all the adjustment in the exchange rate will be observed to take place one the day following the interest rate decisions. Hence, for both variables, I will have to study changes in the interest rate on the day succeeding the monetary policy announcement. However, for the exchange rate, I will have to include the adjustment also for the policy day, since some of the adjustment will be observed to take place from 2 p.m. to 2:15 p.m. on that day.

[15] Unbiased estimates also require monetary policy actions not to be endogenous to exchange rate movements or other news that also affected exchange rates on the day of the policy announcement. However, the short sample used here makes it easy to establish that these conditions are satisfied. In particular, there are no indications that the policy may have reacted to contemporaneous exchange rate movements, by for instance intervening in the foreign exchange market on the day of the policy announcement.

I could control for those shocks directly. This is possible only to the extent that these shocks are observable and measurable. Instead, I therefore follow a more straightforward approach that is laid out in Zettelmeyer (2004). That is, I to use the underlying change in the monetary policy target as an instrument in regression (9). This instrument is correlated with the change in the three month interest rate on the day of the policy announcement. If the policy action is not endogenous to same-day economic news, then it will also be uncorrelated with any noise that might affect the interest rate on the day of the announcement.

Table 1. Coefficient estimates on the response in the *Euro/NOK* exchange rate from event study, (t- value in parenthesis).

	Announcement followed by a change in target rate		**All announcements**
	OLS	IV	OLS
β t-stat	-1.77 (-1.02)	-3.41 (-0.99)	-1.37 (-2.42)

Table 1 reports the coefficient on β using equation (9) for the daily change in the Euro/NOK exchange rate following a change in the three month interest rate on the day of a policy decision for the period 2001-2004. There have been 34 interest rate meetings during this period. However, only 12 of these resolved in an announcement of a change in the interest rate. Since this is a fairly short sample, I investigate both the response to announcements of interest rate changes and the response to all announcements, as the latter may very well be a surprise to the market; either for a lack of response from the central bank when one is expected or because the announcement give strong indications of future interest rate changes.

Table 1 emphasises that in all cases will a surprise monetary policy shock lead to an immediate appreciation of the exchange rate. The exchange rate response lies in the interval of 1.5 - 3 percent for each percentage point change in the interest rate which is in line with the results reported above. However, unless the whole sample is used, the effect is not significant. Given that we have only 12 observations, this is not very surprising.

If the monetary policy announcement is a true surprise to the market, then one should expect all asset prices (stock prices in particular) to react immediately to the news. This has been demonstrated by among others Rigobon and Sack (2004) and Bernanke and Kuttner (2004) using event type studies; finding stock prices in the U.S. to fall significantly following an increase in the target rate.[16] For comparison, I therefore finally examine the responses in stock pries (sp_t) in Norway (OSEBX) to the surprise interest rate decisions. Table 2 reports the coefficient on β using equation (9) for the daily change in sp_t. The stock price reacts significantly and as expected to the monetary policy announcements; falling by 5-6 percent for each percentage point increase in the interest rate.

[16] Similar results are also found using a VAR study that allows for contemporaneous interactions between monetary policy and the stock market in the U.S., see Bjørnland and Leitemo (2004).

Table 2. Coefficient estimates on response in the *OSEBX* from event study, (t- value in parenthesis).

	Announcement followed by a change in target rate	
	OLS	IV
β t-stat	-5.45 (-5.57)	-6.64 (-3.34)

Event studies, with their exclusive focus on the immediate response, cannot answer questions about transmission mechanisms. 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 results found using the VAR analysis is consistent with the findings from event studies.

5. Concluding remarks

Understanding the transmission mechanism of monetary policy is imperative for the implementation of an efficient monetary policy strategy in the many countries that have recently adopted inflation-targeting. For a small open economy, the exchange rate plays a core role in relation to monetary policy. It plays a significant part in the formulation of monetary policy (being an important influence on the overall level of prices), and is itself also influenced by monetary policy. Hence, identifying the appropriate monetary policy and exchange rate interactions may be essential when monetary policy is analysed.

The quantitative effects of monetary policy shocks have to a large extent been addressed in terms of vector autoregressive (VAR) models. Through the applications of Leeper et al. (1996) and Christiano et al. (1999, 2005), one has reached a consensus on how monetary policy affects the closed economy (like the U.S.). However, VAR studies of the open economy have provided less of a consensus with regard to the effects of monetary policy, and have along certain dimensions even provided some puzzling results. The exchange rate, in particular, has been a troublesome issue.

There is, however, one major obstacle when taking the closed economy VAR to the open economy. That is, how to properly address a possible simultaneity between monetary policy and the exchange rate. In particular, 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. However, recently Faust and Rogers (2003) have shown that the hump-shaped exchange rate behaviour which is a feature of the open economy VAR is very sensitive to this kind of restriction.

This paper analyses the effects of monetary policy in an open economy like Norway through structural VARs, paying particular attention to a possible interdependence between the monetary policy stance and exchange rate movements. I explicitly account for the interdependence between monetary policy and exchange rates by imposing a combination of short-run and long-run restrictions. In particular, I build on the traditional VAR literature in that I identify recursively a standard structure between macroeconomic variables and monetary policy, so that monetary policy can react to all shocks, but the macroeconomic variables react with a lag to the monetary policy shocks. However, this present approach differs from the traditional method in that I also allow monetary policy to respond to the contemporaneous exchange rate, which itself is allowed to react simultaneously to all shocks. To identify and orthogonalise all shocks, I assume instead that monetary policy shocks can have no long-run effects on real exchange rates. By using only one long-run restriction, the simultaneity problem is addressed without deviating extensively from the established literature of identifying a monetary policy shock as an exogenous shock to an interest rate reaction function (the systematic part of monetary policy).

Once allowing for full simultaneity between monetary policy and the exchange rate, I find that a monetary policy shock now implies a strong and immediate appreciation of the exchange rate. However, the qualitative properties of a monetary policy shock found in the established literature are still preserved. In particular, a contractionary monetary policy shock temporarily lowers output (and increases unemployment) and has a sluggish but negative effect on consumer price inflation. When compared to previous periods, the exchange rate volatility with respect to monetary policy has increased in the present inflation-targeting period, while the contribution of monetary policy shocks to interest rate variation has declined. The increased exchange rate volatility is not surprising given that Norway no longer has a (long run) anchor for the exchange rate. On the other hand, by making monetary policy more transparent, more of the interest rate variance is now explained by fundamental variables, and less by the unsystematic monetary policy.

Finally, by complementing the VAR analysis with an event study for the inflation target period, I find further support for the fact that exchange rates, as well as other asset prices (stock prices in particular), react immediately to news. In particular exchange rates and stock prices fall with approximately two and five percent respectively, for each one percentage point increase in the interest rate. However, event studies, with their exclusive focus on the immediate response, cannot answer questions about transmission mechanism. To do so, I need 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 results found using the VAR analysis are consistent with the findings from event studies.

References

Akram, Q.F., Bårdsen, G. and Ø. Eitrheim (2005), "Monetary policy and asset prices: To respond or not?" Norges Bank Working Paper 2005/09. Forthcoming in *International Journal of Finance and Economics*.

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

Bernanke, B.S. and K.N. Kuttner (2004), "What explains the Stock Market's Reaction to Federal Reserve Policy?", NBER Working Paper no. 10402.

Bjørnland, H.C. (2005), "Monetary Policy and the Illusionary Exchange Rate Puzzle", Working Paper 2005/11, Norges Bank.

Bjørnland, H.C. and H. Hungnes (2005), "The importance of interest rates for forecasting the exchange rate." Forthcoming in *Journal of Forecasting*.

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.

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

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.

Faust, J. (1998), “The robustness of identified VAR conclusions about money,” International Finance Discussion Papers 610, Board of Governors of the Federal Reserve System (U.S.).

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.

Gjedrem, S. (1999), “Challenges to economic policy”, address at the Annual Foreign Exchange Seminar, arranged by the Association of Norwegian Economists in Gausdal, Norway, 28 January 1999.

Haldane, A.G. (1997), “The Monetary Framework in Norway”, in A.B. Christiansen and J.F. Qvigstad (eds.), *Choosing a Monetary Policy Target*, Oslo: Scandinavian University Press, 67-108.

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

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.

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.

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, Chap. 1, pp 56-74.

Norges Bank (1999), "Norges Bank's submission on economic policy for 2000", Document submitted to the Ministry of Finance on 21 October 1999.

Norges Bank (2000), "Inflation Report" 3/2000.

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

Olsen, K. J.F. Qvigstad and Ø. Røisland (2002), "Monetary policy in real time: the role of simple rules," BIS Papers No 19.

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, Chap.2, pp 36-55.

Rigobon, R. and B. Sack (2004), "The Impact of Monetary Policy on Asset Prices," *Journal of Monetary Economics*, 51, 1553-1575.

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

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

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

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.

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.

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

(i*) The three months foreign effective interest rate calculated as a trade weighted sum of the interest rate of Norway's four largest trading partners (USA, EUR, SWE, GBR), (quarterly and monthly data). *Source Norges Bank*

(i) The three months domestic effective nominal interest rate (NIBOR), (quarterly, monthly and daily data). *Source Norges Bank.*

(y) Gross domestic product Mainland Norway, s.a. and trend adjusted, (quarterly data). *Source Norges Bank*

(p) Consumer price index domestic sources, s.a. The domestic consumer price index is adjusted for changes in energy prices and taxes, (quarterly and monthly data). *Source Norges Bank*

(e) Real exchange rate, (quarterly and monthly data). *Source Norges Bank*

(s) Euro exchange rate against the Norwegian krone; NOK, (daily data). *Source Norges Bank*

(nw) Wage costs per hour, mainland Norway, s.a., (quarterly data). *Source Norges Bank*

(op) Oil Price. Nominal oil price of Brent Blend in US $. Monthly average of daily spot prices, (quarterly data). *Source: Telerate.*

(u) Unemployment rate. Registered unemployment rate, s.a., (monthly data). *Source: Aetat, the Norwegian Public Employment Service.*

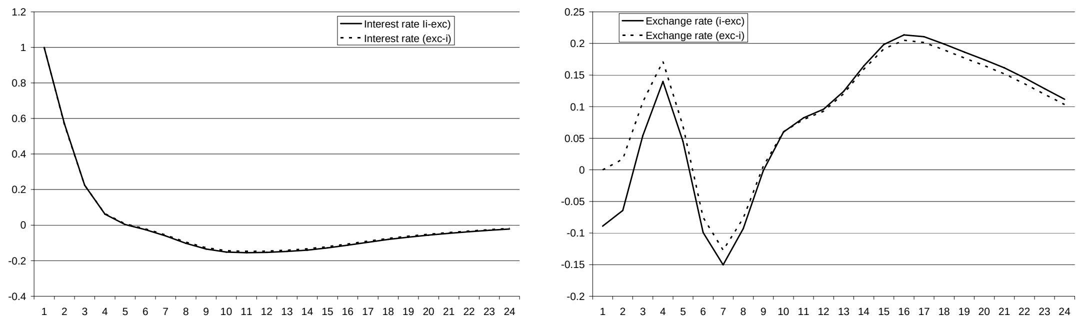
(sp) Oslo Børs share index (OSEBX) (daily data). *Source: Oslo Børs*

Appendix B Cholesky decomposition

If there is strong simultaneity between shocks to monetary policy and 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 investigated in Figure B.1, which displays the impulse responses for the interest rate and the exchange rate from a monetary policy shock, using two different Cholesky decompositions. The solid line corresponds to the (baseline) assumption that an exchange rate shock has no immediate effect on the interest rate, whereas the dotted line corresponds to an (alternative) ordering where the interest rate and the exchange rate swap places as the ultimate and penultimate variables, so that a monetary policy shock has no immediate effect on the real exchange rate.

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

A) Interest rate (percentage points) B) Exchange rate (percentage)



[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.

Using either of the Cholesky orderings, the contractionary monetary policy shock increases interest rates temporarily as expected. Following the baseline Cholesky ordering, the exchange rate appreciates marginally immediately, but then depreciates back to baseline for a few quarters, before it appreciates and reaches its maximum after 7 quarters. The effect thereafter dies out. Hence, there is evidence of "delayed overshooting", as well as puzzling behaviour the first four quarters. Figure B.1 also illustrates that using the alternative Cholesky ordering where the exchange rate is forced to zero initially, does not imply a lot of difference, as the initial exchange rate response is close to zero also in the baseline scenario.

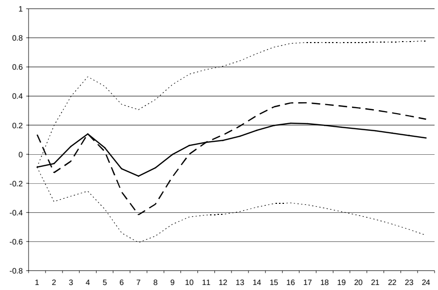
A natural question to ask is to whether the exchange rate puzzle is due to omitted variables. To shed some light on this issue, the VAR model is augmented in two dimensions. First, three additional domestic variables that are important to consider in the interest rate setting (real consumption, real mainland investment and the nominal wage) are added.[17] Thereafter, the VAR is expanded with three additional foreign variables to account for foreign spill over effects (foreign trade weighted output, foreign trade weighted prices and import

[17] The inclusion of additional domestic variables is motivated by the set up in Christiano et al. (2005), and the variables are ordered equivalently in the Cholesky decomposition. Note that the nominal wage is included instead of the real wage in the VAR, as it may be an important indicator for future inflation pressure.

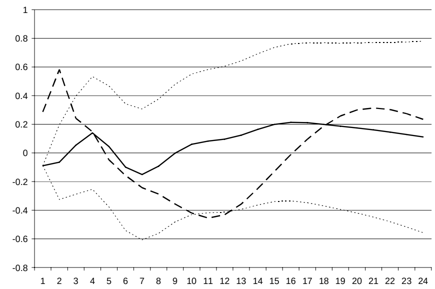
prices).[18] In no cases does the inclusion of additional (domestic or foreign) variables solve the exchange rate puzzle.

Figure B.2. Response in the exchange rate to a contractionary monetary policy shock using additional variables in the VAR. Cholesky decomposition.[1]

A) VAR with additional domestic variables



B) VAR with additional foreign variables



1) The solid lines correspond to the baseline VAR in figure B.1. The semi-dotted lines correspond to the 8-variabels VAR. The dotted lines are one standard error bands based on the baseline VAR

[18] The model resembles that of Lindé (2003), and the foreign variables are placed on top in the Cholesky ordering, reflecting a small country assumption.

WORKING PAPERS (ANO) FROM NORGES BANK 2002-2005

Working Papers were previously issued as Arbeidsnotater from Norges Bank, see Norges Bank's website http://www.norges-bank.no

2002/1 Bache, Ida Wolden
Empirical Modelling of Norwegian Import Prices Research Department, 44 p

2002/2 Bårdsen, Gunnar og Ragnar Nymoen
Rente og inflasjon Forskningsavdelingen, 24 s

2002/3 Rakkestad, Ketil Johan
Estimering av indikatorer for volatilitet Avd. for verdipapirer og internasjonal finans, 33 s

2002/4 Akram, Qaisar Farooq
PPP in the medium run despite oil shocks: The case of Norway Research Department, 34 p

2002/5 Bårdsen, Gunnar, Eilev S. Jansen and Ragnar Nymoen
Testing the New Keynesian Phillips curve Research Department, 38 p

2002/6 Lindquist, Kjersti-Gro
The Effect of New Technology in Payment Services on Banks' Intermediation
Research Department, 28 p

2002/7 Sparrman, Victoria
Kan pengepolitikken påvirke koordineringsgraden i lønnsdannelsen? En empirisk analyse
Forskningsavdelingen, 44 s

2002/8 Holden, Steinar
The costs of price stability - downward nominal wage rigidity in Europe
Research Department, 43 p

2002/9 Leitemo, Kai and Ingunn Lønning
Simple Monetary Policymaking without the Output Gap Research Department, 29 p

2002/10 Leitemo, Kai
Inflation Targeting Rules: History-Dependent or Forward-Looking? Research Department, 12 p

2002/11 Claussen, Carl Andreas
Persistent inefficient redistribution International Department, 19 p

2002/12 Næs, Randi and Johannes A. Skjeltorp
Equity Trading by Institutional Investors: Evidence on Order Submission Strategies
Research Department, 51 p

2002/13 Syrdal, Stig Arild
A Study of Implied Risk-Neutral Density Functions in the Norwegian Option Market
Securities Markets and International Finance Department, 104 p

2002/14 Holden, Steinar and John C. Driscoll
A Note on Inflation Persistence Research Department, 12 p

2002/15 Driscoll, John C. and Steinar Holden
Coordination, Fair Treatment and Inflation Persistence Research Department, 40 p

2003/1 Solveig Erlandsen
Age structure effects and consumption in Norway, 1968(3) – 1998(4) Research Department, 27 p

2003/2 Bjørn Bakke og Asbjørn Enge
Risiko i det norske betalingssystemet
Avdeling for finansiell infrastruktur og betalingssystemer, 15 s

2003/3 Egil Matsen and Ragnar Torvik
Optimal Dutch Disease Research Department, 26 p

2003/4 Ida Wolden Bache
Critical Realism and Econometrics Research Department, 18 p

2003/5 David B. Humphrey and Bent Vale
Scale economies, bank mergers, and electronic payments: A spline function approach
Research Department, 34 p

2003/6 Harald Moen
Nåverdien av statens investeringer i og støtte til norske banker
Avdeling for finansiell analyse og struktur, 24 s

2003/7 Geir H.Bjønnes, Dagfinn Rime and Haakon O.Aa. Solheim
Volume and volatility in the FX market: Does it matter who you are? Research Department, 24 p

2003/8 Olaf Gresvik and Grete Øwre
Costs and Income in the Norwegian Payment System 2001. An application of the Activity Based Costing framework Financial Infrastructure and Payment Systems Department, 51 p

2003/9 Randi Næs and Johannes A.Skjeltorp
Volume Strategic Investor Behaviour and the Volume-Volatility Relation in Equity Markets
Research Department, 43 p

2003/10 Geir Høidal Bjønnes and Dagfinn Rime
Dealer Behavior and Trading Systems in Foreign Exchange Markets Research Department, 32 p

2003/11 Kjersti-Gro Lindquist
Banks' buffer capital: How important is risk Research Department, 31 p

2004/1 Tommy Sveen and Lutz Weinke
Pitfalls in the Modelling of Forward-Looking Price Setting and Investment Decisions
Research Department, 27 p

2004/2 Olga Andreeva
Aggregate bankruptcy probabilities and their role in explaining banks' loan losses
Research Department, 44 p

2004/3 Tommy Sveen and Lutz Weinke
New Perspectives on Capital and Sticky Prices Research Department, 23 p

2004/4 Gunnar Bårdsen, Jurgen Doornik and Jan Tore Klovland
A European-type wage equation from an American-style labor market: Evidence from a panel of Norwegian manufacturing industries in the 1930s Research Department, 22 p

2004/5 Steinar Holden and Fredrik Wulfsberg
Downward Nominal Wage Rigidity in Europe Research Department, 33 p

2004/6 Randi Næs
Ownership Structure and Stock Market Liquidity Research Department, 50 p

2004/7 Johannes A. Skjeltorp and Bernt-Arne Ødegaard
The ownership structure of repurchasing firms Research Department, 54 p

2004/8 Johannes A. Skjeltorp
The market impact and timing of open market share repurchases in Norway
Research Department, 51 p

2004/9 Christopher Bowdler and Eilev S. Jansen
Testing for a time-varying price-cost markup in the Euro area inflation process
Research Department, 19 p

2004/10 Eilev S. Jansen
Modelling inflation in the Euro Area Research Department, 49 p

2004/11 Claudia M. Buch, John C. Driscoll, and Charlotte Østergaard
Cross-Border Diversification in Bank Asset Portfolios Research Department, 39 p

2004/12 Tommy Sveen and Lutz Weinke
Firm-Specific Investment, Sticky Prices, and the Taylor Principle Research Department, 23 p

2004/13 Geir Høidal Bjønnes, Dagfinn Rime and Haakon O.Aa. Solheim
Liquidity provision in the overnight foreign exchange market Research Department, 33 p

2004/14 Steinar Holden
Wage formation under low inflation Research Department, 25 p

2004/15 Roger Hammersland
Large T and small N: A three-step approach to the identification of cointegrating relationships in time series models with a small cross-sectional dimension Research Department, 66 p

2004/16 Q. Farooq Akram
Oil wealth and real exchange rates: The FEER for Norway Research Department, 31 p

2004/17 Q. Farooq Akram
En effisient handlingsregel for bruk av petroleumsinntekter Forskningsavdelingen, 40 s

2004/18 Egil Matsen,Tommy Sveen and Ragnar Torvik
Savers, Spenders and Fiscal Policy in a Small Open Economy Research Department, 31 p

2004/19 Roger Hammersland
The degree of independence in European goods markets: An I(2) analysis of German and Norwegian trade data Research Department, 45 p

2004/20 Roger Hammersland
Who was in the driving seat in Europe during the nineties, International financial markets or the BUBA? Research Department, 35 p

2004/21 Øyvind Eitrheim and Solveig K. Erlandsen
House prices in Norway 1819–1989 Research Department, 35 p

2004/22 Solveig Erlandsen and Ragnar Nymoen
Consumption and population age structure Research Department, 22 p

2005/1 Q. Farooq Akram
Efficient consumption of revenues from natural resources – An application to Norwegian petroleum revenues Research Department, 33 p

2005/2 Q. Farooq Akram, Øyvind Eitrheim and Lucio Sarno
Non-linear dynamics in output, real exchange rates and real money balances: Norway, 1830-2003 Research Department, 53 p

2005/3 Carl Andreas Claussen and Øistein Røisland
Collective economic decisions and the discursive dilemma Monetary Policy Department, 21 p

2005/4 Øistein Røisland
Inflation inertia and the optimal hybrid inflation/price level target
Monetary Policy Department, 8 p

2005/5 Ragna Alstadheim
Is the price level in Norway determined by fiscal policy? Research Department, 21 p

2005/6 Tommy Sveen and Lutz Weinke
Is lumpy investment really irrelevant for the business cycle? Research Department, 26 p

2005/7 Bjørn-Roger Wilhelmsen and Andrea Zaghini
Monetary policy predictability in the euro area: An international comparison
Economics Department, 28 p

2005/8 Moshe Kim, Eirik Gaard Kristiansen and Bent Vale
What determines banks' market power? Akerlof versus Herfindahl Research Department, 38 p

2005/9 Q. Farooq Akram, Gunnar Bårdsen and Øyvind Eitrheim
Monetary policy and asset prices: To respond or not? Research Department, 28 p

2005/10 Eirik Gard Kristiansen
Strategic bank monitoring and firms' debt structure Research Department, 35 p

2005/11 Hilde C. Bjørnland
Monetary policy and the illusionary exchange rate puzzle Research Department, 30 p

2005/12 Q. Farooq Akram, Dagfinn Rime and Lucio Sarno
Arbitrage in the foreign exchange market: Turning on the microscope
Research Department, 43 p

2005/13 Geir H. Bjønnes, Steinar Holden, Dagfinn Rime and Haakon O.Aa. Solheim
"Large" vs. "small" players: A closer look at the dynamics of speculative attacks
Research Department, 31 p

2005/14 Julien Garnier and Bjørn-Roger Wilhelmsen
The natural real interest rate and the output gap in the euro area: A joint estimation
Economics Department, 27 p

2005/15 Egil Matsen
Portfolio choice when managers control returns Research Department, 31 p

2005/16 Hilde C. Bjørnland
Monetary policy and exchange rate interactions in a small open economy
Research Department, 28 p

Hilde C. Bjørnland: Monetary policy and exchange rate interactions in a small open economy

KEYWORDS:

VAR
Monetary policy
Open economy
Identification
Event study

Working Paper 2005/16

Lobo Media - 34853