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The role of house prices in the monetary policy transmission mechanism in small open economies

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The role of house prices in the monetary policy transmission mechanism in small open economies

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Abstract

We analyse the role of house prices in the monetary policy transmission mechanism in Norway, Sweden and the UK using structural VARs. A solution is proposed to the endogeneity problem of identifying shocks to interest rates and house prices by using a combination of short-run and long-run (neutrality) restrictions. By allowing the interest rate and house prices to react simultaneously to news, we find the role of house prices in the monetary transmission mechanism to increase considerably. In particular, house prices react immediately and strongly to a monetary policy shock. Furthermore, the fall in house prices seem to enhance the negative response in output and consumer price inflation that has traditionally been found in the conventional literature. Moreover, we find that the interest rate respond systematically to a change in house prices.

Keywords: VAR, monetary policy, house prices, identification.

JEL-codes: C32, E52, F31, F41

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1 Introduction

The recent US subprime crisis and the subsequent financial crisis has increased the focus on asset price developments, especially by central banks. This is primarily due to the central collateral role of asset prices such as prices of dwellings. Hence, asset prices can be an important *source* of macroeconomic fluctuations that an inflation targeting central bank may want to respond to, see e.g. Bernanke et al. (2000) and Bernanke and Gertler (1989).

However, asset prices are not only considered as sources of disturbances. Due to their role as stores of wealth, they could also be important *transmitters* of shocks since they react quickly to news (incl. monetary policy announcements), as emphasized in Zettelmeyer (2004), Rigobon and Sack (2004) and Bernanke and Kuttner (2005) among others. Hence, with their timely response to economic shocks, asset prices may be important indicators of the monetary policy stance. Understanding the role of asset prices in the transmission mechanism of monetary policy may therefore be a useful prerequisite for the implementation of an efficient monetary policy strategy.

In this paper, we investigate the role of house prices in the monetary transmission mechanism in three open economies, Norway, Sweden and the UK, using a structural vector autoregressive (VAR) model. We focus on housing as it is the most important asset for households in industrialized countries. Unlike other assets, housing has a dual role of being both a store of wealth and a durable consumption good. Consequently, a shock to house prices may therefore affect the wealth of homeowners. As the value of collateral rises, this will also increase the availability of credit for borrowing-constrained agents. Finally, increased house prices may have a stimulating effect on housing construction (due to the Tobin's *q* effect). In total, a shock to house prices may therefore affect real growth and ultimately consumer prices, making house prices an important forward looking variable that the monetary policymaker may want to monitor.[1]

The common procedure for analysing the effect of monetary policy on economic variables has usually been the structural VAR approach. A major challenge when incorporating asset prices like house prices into a VAR model, though, is how to identify the system, as both the interest rate and asset prices may respond simultaneously (within the quarter) to news. Most of the VAR studies that incorporate house prices, do this by placing recursive, contemporaneous restrictions on the interaction between monetary policy and house prices (see e.g. Goodhart and Hofmann (2001), Iacoviello (2005) and Giuliodori (2005)). In particular, they either assume that house prices are restricted from responding immediately to monetary policy shocks (Goodhart and Hofmann, 2001, and Giuliodori, 2005), or that monetary policy is restricted from reacting immediately to innovations in house prices (Iacoviello, 2005). Yet, both restrictions seem to be undue, the first as theory predicts that asset prices such as housing are forward looking and will respond quickly to monetary

[1] Greenspan (2001) also spurred interest in this topic, by suggesting that house prices have gained attention in the formulation of the monetary policy strategy.

policy news[2] and the second because it restricts the policy maker from using all the current information when designing monetary policy. The issue as to whether the Central Bank would actually gain from responding to house price movements remains an unresolved issue. However, ruling out the possibility that they in fact have responded, may imply that these studies have produced a numerically important bias in the estimate of the degree of interdependence between monetary policy and house prices.

Another issue to be considered is to what extent one should allow for other asset prices when analysing the role of house prices in the monetary transmission mechanism. For the open economy, the exchange rate may be a relevant candidate. 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, each reacting to news in the other, as emphasized recently by Faust and Rogers (2003), Bjørnland (2008) and Bjørnland and Halvorsen (2008).

Hence, we analyse the effects of monetary policy shocks on house prices while also including the exchange rate into the model. By incorporating additional asset prices such as the exchange rate, the role of house prices will be set in a wider context. However, including additional asset prices also comes at a cost, as the problem of simultaneity will now also relate to the new variables. Previous studies analysing the role of house prices, have therefore either ignored additional asset prices (Iacoviello, 2005), assumed the exchange rate to be exogenous (Giuliodori, 2005) or assumed a recursive order among the asset prices, so that all asset prices respond with a lag to monetary policy shocks (Goodhart and Hofmann, 2001).

In contrast, we will allow for full simultaneity between asset prices and monetary policy.[3] To identify all shocks, we will use an identification that restricts the long run multipliers of shocks, but leaves the contemporaneous relationship between the interest rate and asset prices intact. Identification is achieved by assuming that monetary policy shocks can have no long run effect on the level of the real exchange rate or on real gross domestic output (GDP). These are standard neutrality assumptions that hold for large classes of models in the monetary policy literature (see Obstfeld, 1985, Blanchard and Quah, 1989, and Clarida and Gali, 1994). Similar restrictions have also recently been found to be highly successful in alleviating the exchange rate puzzle in several small open economies, see Bjørnland (2008). Identified in this way, house prices and exchange rates can now respond immediately to all shocks, while the monetary policymaker can consider news in all asset prices, when designing an optimal monetary policy response. Note that we have not restricted the long run effects of monetary policy shocks on house prices, as we believe this to be much more of a controversial issue that we would like to examine rather than impose at the outset.

Once allowing for a contemporaneous relationship between the interest rate and asset prices, the remaining VAR can be identified using standard recursive zero restrictions on the

[2] Iacoviello (2005) develops and estimates a monetary business cycle model with nominal loans and collateral constraints tied to housing values. The monetary business cycle model clearly implies an instant response in house prices to a monetary policy shock.

[3] See Bjørnland and Jacobsen (2008) for a more detailed discussion and application to the U.S.

impact matrix of shocks. That is, we 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 variables such as output and inflation do not react contemporaneously to monetary shocks, whereas the monetary policymaker might respond immediately to macroeconomic news. 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). These restrictions are therefore less controversial and studies identifying monetary policy without these restrictions have found qualitatively similar results, see for example Faust et al. (2004). Furthermore, by using a combination of restrictions, we will allow for a contemporaneous interaction between monetary policy and asset price dynamics, without having to resort to methods that deviate extensively from the established view of how one identifies monetary policy shocks in the literature (Christiano et al. 1999, 2005).

Our findings suggest that, following a contractionary monetary policy shock, house prices fall immediately. Yet, we find the impact of monetary policy shocks on housing to be small in comparison to the magnitude of fluctuations in house prices. Furthermore, we find the interest rate to respond systematically to a change house prices. However, the strength and timing of the response varies from one country to another, indicating that housing may play a different role in the monetary policy setting.

The paper is organised as follows. In Section 2, the VAR methodology is explained, whereas in Section 3 we discuss the empirical results. Section 4 concludes.

2 The identified VAR model

The choice of variables included in our VAR model 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 annual changes of the log of 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*), the log of the real exchange rate against a basket of trading partners (e_t) and the log of real house prices (ph_t).

In all cases, the nominal interest rate is chosen to capture monetary policy shocks; consistent with the fact that the central bank uses interest rate instruments in the monetary policy setting. This is in line with Rotemberg and Woodford (1997), which find central bank behaviour to be well modelled by a policy rule that sets the interest rate as a function of variables such as output and inflation. This is explained in more detail below.

2.1 Identification

We first define Z_t as the (6x1) vector of the macroeconomic variables discussed above, where y_t, e_t and ph_t are non-stationary and differenced to stationary: $Z_t = \left[i^*, \Delta y, \pi, \Delta ph, \Delta e, i\right]_t'$.

Assuming Z_t to be invertible, it can be written in terms of its moving average (ignoring any deterministic terms)

$$Z_t = B(L)v_t , \tag{1}$$

where v_t is a (6x1) 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 (6x6) convergent matrix polynomial in the lag operator L, $B(L) = \sum_{j=0}^{\infty} B_j L^j$. Following the literature, the innovations, (v_t), are assumed to be written as linear combinations of the underlying orthogonal structural disturbances (ε_t), i.e., $v_t = S\varepsilon_t$. The VAR can then be written in terms of the structural shocks as

$$Z_t = C(L)\varepsilon_t , \tag{2}$$

where $B(L)S = C(L)$. If S is identified, we can derive the MA representation in (2) as $B(L)$ is calculated from a reduced form estimation. To identify S, the ε_t's are normalised so they all have unit variance. The normalisation of cov(ε_t) implies that $SS' = \Omega$. With a six variable system, this imposes 21 restrictions on the elements in S. However, as the S matrix contains 36 elements, to orthogonalise the different innovations, we need fifteen additional restrictions to uniquely identify the system.

With a six variables VAR, we can identify six structural shocks. The three shocks that are of primary interest here are the shocks to monetary policy (ε_t^{MP}), shocks to house prices (ε_t^{PH}) and exchange rate shocks (ε_t^{ER}). We follow standard practice in the VAR literature and only loosely identify the other three shocks as inflation (or cost push) shocks (moving prices before output) (ε_t^{CP}), output shocks (ε_t^{Y}) and foreign interest rate shocks (ε_t^{i*}). We then order the vector of structural shocks as $\varepsilon_t = \left[\varepsilon_t^{i*}, \varepsilon_t^{Y}, \varepsilon_t^{CP}, \varepsilon_t^{PH}, \varepsilon_t^{ER}, \varepsilon_t^{MP} \right]'$.

Regarding the order of the variables, 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. Furthermore, the standard restrictions in the closed economy (namely that macroeconomic variables do not simultaneously react to policy variables, while the simultaneous reaction from the macroeconomic environment to policy variables is allowed for), is taken care of by placing output and inflation above the interest rate in the ordering, and by assuming zero restrictions on the relevant coefficients in the S matrix as described in (3). We also assume that house prices do not react simultaneously to an exchange rate shock.

.

$$\begin{bmatrix} i^* \\ \Delta y \\ \pi \\ \Delta ph \\ \Delta e \\ i \end{bmatrix}_t = B(L)\begin{bmatrix} S_{11} & 0 & 0 & 0 & 0 & 0 \\ S_{21} & S_{22} & 0 & 0 & 0 & 0 \\ S_{31} & S_{32} & S_{33} & 0 & 0 & 0 \\ S_{41} & S_{42} & S_{43} & S_{44} & 0 & S_{46} \\ S_{51} & S_{52} & S_{53} & S_{54} & S_{55} & S_{56} \\ S_{61} & S_{62} & S_{63} & S_{64} & S_{65} & S_{66} \end{bmatrix}\begin{bmatrix} \varepsilon^{i^*} \\ \varepsilon^{Y} \\ \varepsilon^{CP} \\ \varepsilon^{PH} \\ \varepsilon^{ER} \\ \varepsilon^{MP} \end{bmatrix}_t \tag{3}$$

This provides us with thirteen contemporaneous restrictions directly on the S matrix. The matrix is, however, still two restrictions short of identification. We do not want to restrict monetary policy from responding contemporaneously to shocks in house prices and the exchange rate (i.e. S_{64} and $S_{65} \neq 0$), or house prices and exchange rates from responding contemporaneously to monetary policy shocks (i.e. S_{46} and $S_{56} \neq 0$). We therefore suggest to impose restrictions that i) a monetary policy shock can have no long-run effects on the level of the real exchange rate ii) a monetary policy shock can have no long-term effects on the level of the real output. The restrictions can be found by setting the values of the infinite number of relevant lag coefficients in (2), $\sum_{j=0}^{\infty} C_{26,j}$ and $\sum_{j=0}^{\infty} C_{56,j}$, equal to zero, (see Blanchard and Quah, 1989). There are now enough restrictions to identify and orthogonalise all shocks. Writing the long run expression of $B(L)S = C(L)$ as $B(1)S = C(1)$, where $B(1) = \sum_{j=0}^{\infty} B_j$ and $C(1) = \sum_{j=0}^{\infty} C_j$ indicate the (6x6) long-run matrix of $B(L)$ and $C(L)$ respectively. The long-run restrictions $C_{26}(1) = 0$ and $C_{56}(1) = 0$ implies respectively

$$\begin{aligned} B_{21}(1)S_{16} + B_{22}(1)S_{26} + B_{23}(1)S_{36} + B_{24}(1)S_{46} + B_{25}(1)S_{56} + B_{26}(1)S_{66} &= 0 \\ B_{51}(1)S_{16} + B_{52}(1)S_{26} + B_{53}(1)S_{36} + B_{54}(1)S_{46} + B_{55}(1)S_{56} + B_{56}(1)S_{66} &= 0. \end{aligned} \tag{4}$$

The system is now just identifiable. The zero contemporaneous restrictions identify the non-zero parameters above the interest rate equation, while the remaining parameters can be uniquely identified using the long run restriction (4), where $B(1)$ is calculated from the reduced form estimation of the reduced form of (1). Note that (4) reduces to: $B_{24}(1)S_{46} + B_{25}(1)S_{56} + B_{26}(1)S_{66} = 0$ and $B_{54}(1)S_{46} + B_{55}(1)S_{56} + B_{56}(1)S_{66} = 0$, given the zero contemporaneous restrictions.

3 Empirical results

The model is estimated for Norway, Sweden and the UK, using quarterly data from 1983Q1 to 2006Q4. Using an earlier starting period 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 (see Bagliano and Favero, 1998, and Clarida et al., 2000). Data and sources are described in the appendix.

The VAR comprises the domestic and foreign interest rates, inflation, and quarterly growth rates of the following: GDP, real house prices and real exchange rates. Inflation is measured as the annual growth rate of CPI for all countries. Alternatively, we could have included the quarterly growth rate of CPI in the VAR. However, annual inflation is a more direct measure of the target rate of importance to the policymakers. Moreover, using quarterly inflation may produce misleading results about the dynamic effects of monetary policy, if there are time-varying seasonal variations in the inflation rate (Lindé, 2003).

For all countries, the VAR is now invertible. Yet, some of the variables may be in the borderline of being (trend) stationary and non-stationary. This could be due to the low power of the tests in distinguishing between a unit root and a (trend) stationary variable. For UK, where the problem may be most pronounced, we therefore also include a trend in the VAR.

The lag order of the model is determined using Schwarz and Hannan-Quinn information criteria and the F-forms of likelihood ratio tests for model reductions. The tests suggested that four lags were acceptable for all countries. With a relatively short sample, we use four lags in the estimation and check for robustness using alternative lag lengths. With four lags, the hypothesis of autocorrelation and heteroscedasticity is rejected at the five-percent level for all countries. Some non-normality remained in the system, but essentially due to non-normality in the foreign interest rate equation. Some impulse dummies (that take the value 1 in one quarter and 0 otherwise) were also included in the models, to take account of outliers (see the appendix).

3.1 Impulse responses using structural decomposition

Figures 1-12 plot the response following a contractionary monetary policy shock in the interest rate, GDP, inflation and real house prices in Norway, Sweden and the UK respectively.[4] The responses are graphed with probability bands represented as .16 and .84 fractiles (as suggested by Doan, 2004).[5] In all cases, the monetary policy shock is normalized to increase the interest rate with one percentage point in the first quarter.

The figures imply that a contractionary monetary policy shock has the usual effects on interest rates, output and inflation identified in other international studies: temporarily increasing the interest rate and lowering output and inflation gradually. There is a high degree of interest-rate inertia in the model, as a monetary policy shock is only offset by a gradual reduction in the interest rate. The monetary policy reversal combined with the interest-rate inertia is consistent with what has become known as good monetary policy conduct (see Woodford, 2003). In particular, interest-rate inertia is known to let the policymaker smooth out the effects of policy over time by affecting private-sector expectations. Moreover, the reversal of the interest rate stance is consistent with the policymaker trying to offset the adverse effects of the initial policy deviation from the systematic part of policy.

[4] The responses for the other variables can be obtained at request.

[5] This is the Bayesian simulated distribution obtained by Monte Carlo integration with 2500 replications, using the approach for just-identified systems. The draws are made directly from the posterior distribution of the VAR coefficients (see Doan, 2004).

Figure 1 Response to a monetary policy shock.
Norway: Interest rate (percentage points)

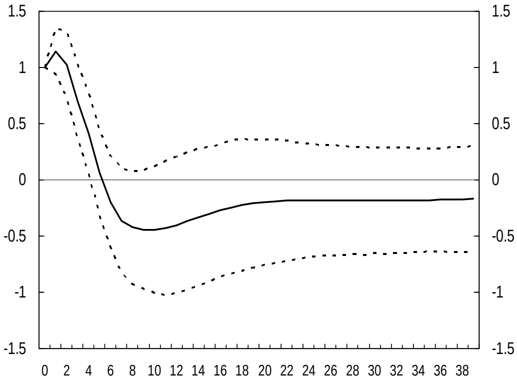


Figure 2 Response to a monetary policy shock.
Norway: GDP (per cent)

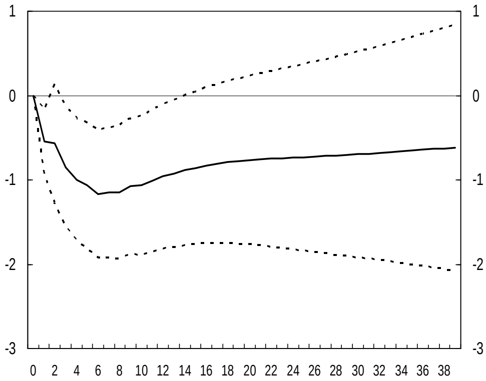


Figure 3 Response to a monetary policy shock.
Norway: Inflation (percentage points)

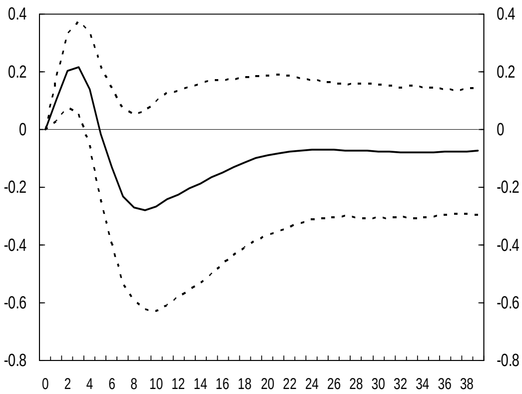
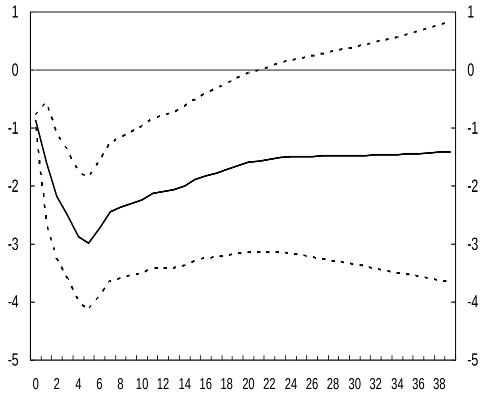


Figure 4 Response to a monetary policy shock.
Norway: Real house prices (per cent)



Regarding the other variables, output falls by 0.5-1.2 per cent for close to two years, before the effects essentially dies out. The effect on inflation is also eventually negative as expected. However, with the exception of Sweden, there is some evidence that consumer prices increase initially, also referred to as price puzzle (see Sims, 1992). The puzzle may be explained by a cost channel of the interest rate, where (at least part of) the increase in firms borrowing costs is offset by an increase in prices (Ravenna and Walsh, 2006; Chowdhury et al., 2006). Eventually, though, prices start to fall, until after 3-4 years, inflation has fallen by 20-70 basis points. The effect thereafter dies out. House prices fall contemporaneously in all three economies by 1-2 per cent. Hence, the initial effect (within the quarter) is non-trivial. Following the immediate effect, house prices fall even further, until after 1.5-2.5 years, real house prices have fallen with 3 to 5 percentages. However, the probability bands are at this point wide, emphasizing the uncertainty in the responses.

Figure 5 Response to a monetary policy shock.
Sweden: Interest rate (percentage points)

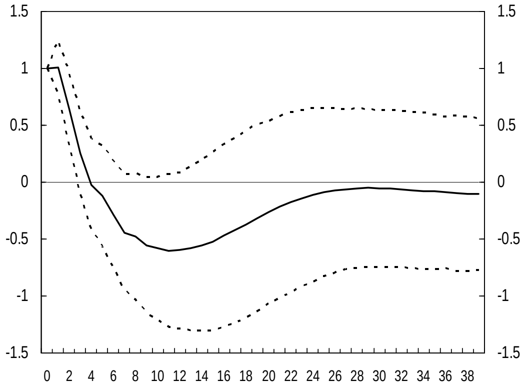


Figure 6 Response to a monetary policy shock.
Sweden: GDP (per cent)

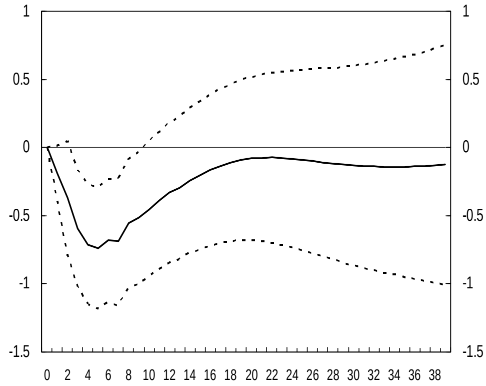


Figure 7 Response to a monetary policy shock.
Sweden: Inflation (percentage points)

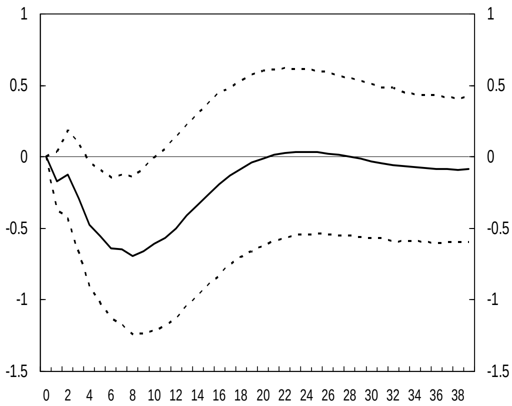
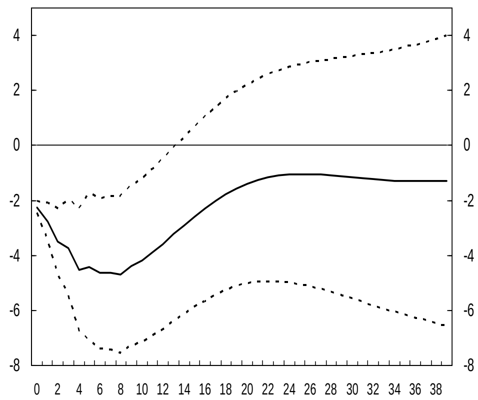


Figure 8 Response to a monetary policy shock.
Sweden: Real house prices (per cent)



Thus, monetary policy has a strong and prolonged effect on house prices, emphasising the role of house prices in the monetary policy transmission mechanism. The results are consistent with the fact that a contractionary monetary policy shock also lowers output and will accordingly have an expected negative effect on employment and wages. In addition, higher interest rates will raise household's interest payments. Thus, household's debt servicing capacity will decline when interest payments increase and income is curbed. This can explain the strong effect of monetary policy shocks on house prices.

These results are quantitatively different from those that were found in for instance Goodhart and Hofmann (2001) and Giuliodori, (2005) analysing several European countries. However, in both of these studies, housing is restricted from responding immediately to monetary policy shocks. But even after a year, monetary policy has a much smaller impact on house prices than we find here. Similar findings are also found for the US in Iacoviello (2005), although there the impact effect is larger initially (as they allow for an instantaneous response in housing to monetary policy shocks, but restrict instead monetary policy from reacting contemporaneously to shocks in house prices). In contrast, Del Negro and Otrok (2007) find in a recent study for the US, results that are more in line with what we find here (or even stronger). To obtain these results, they refrain from the Cholesky recursive decomposition. Instead they use sign restrictions, where they search among all possible reasonable identification procedures and VAR specifications, for the one that deliver the largest impact on house prices (that is, the upper bound). Doing so, they find much stronger effects on house prices of a monetary policy shock than Goodhart and Hofmann (2001), Giuliodori, (2005) and Iacoviello (2005).

Figure 9 Response to a monetary policy shock.
UK: Interest rate (percentage points)

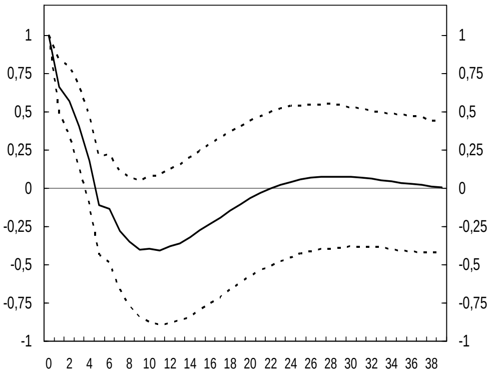


Figure 10 Response to a monetary policy shock.
UK: GDP (per cent)

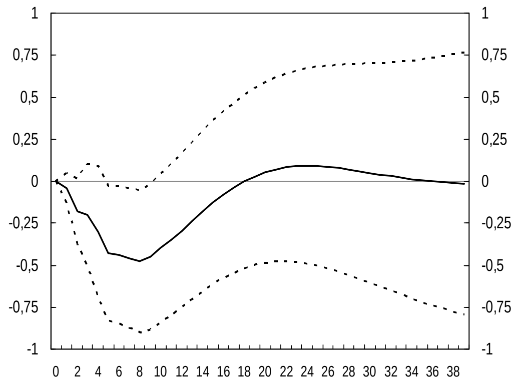


Figure 11 Response to a monetary policy shock.
UK: Inflation (percentage points)

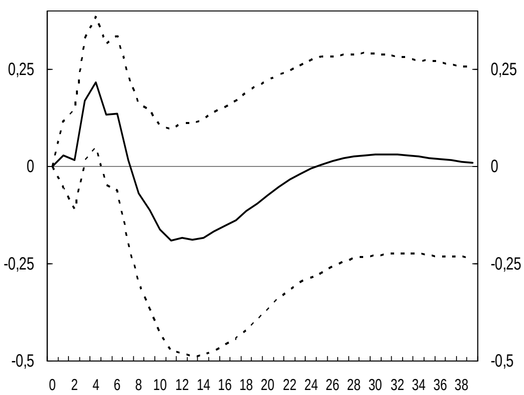
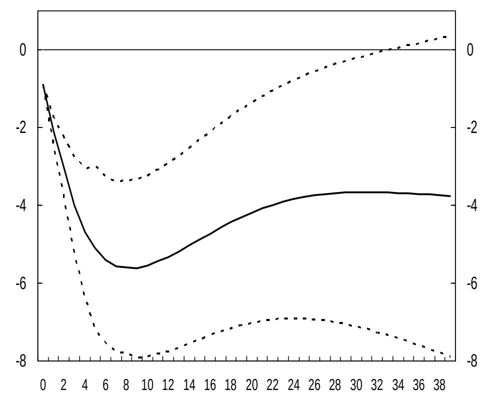


Figure 12 Response to a monetary policy shock.
UK: Real house prices (per cent)



Having examined the response in all variables to a monetary policy shock, we finally turn to investigate the reverse causation, namely the (systematic) response in monetary policy to a house price shock. Figures 13-15 plot the effect of a house price shock (normalized to increase house prices with one percent the first quarter) on both interest rates (*frame a*) and on inflation (*frame b*) in Norway, Sweden and the UK respectively.

Figure 13a Response to a house price shock.
Norway: Interest rate (percentage points)

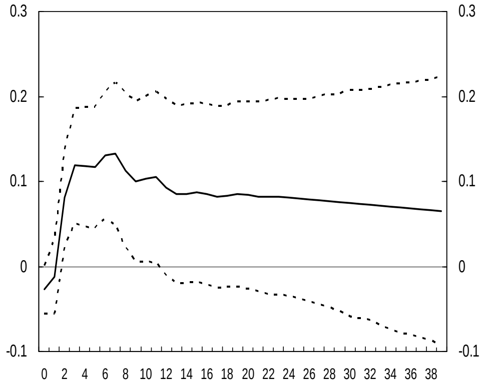


Figure 13b Response to a house price shock.
Norway: Inflation (percentage points)

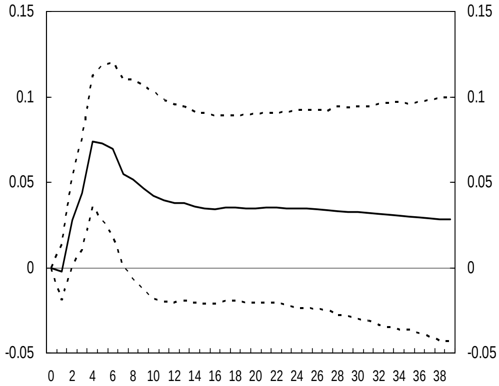


Figure 14a Response to a house price shock.
Sweden: Interest rate (percentage points)

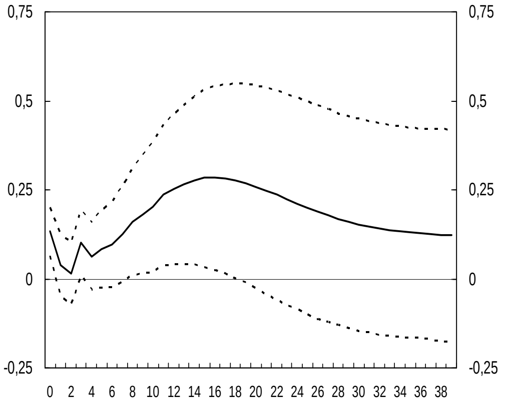


Figure 14b Response to a house price shock.
Sweden: Inflation (percentage points)

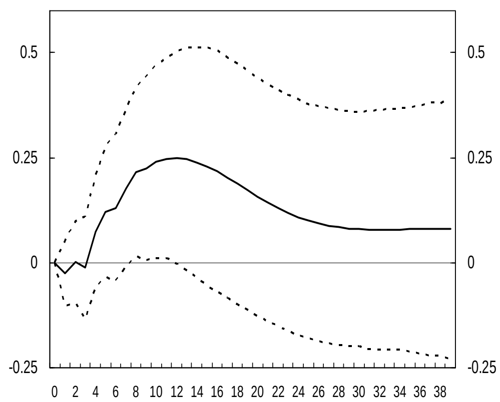


Figure 15a Response to a house price shock.
UK: Interest rate (percentage points)

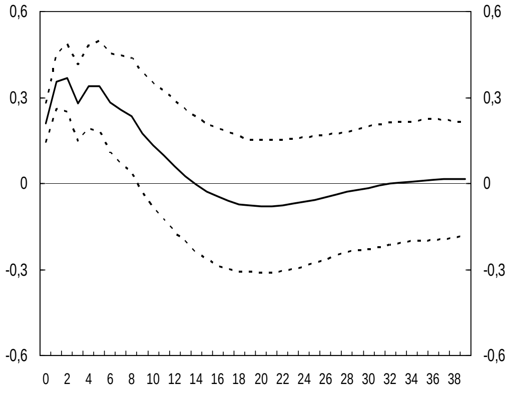
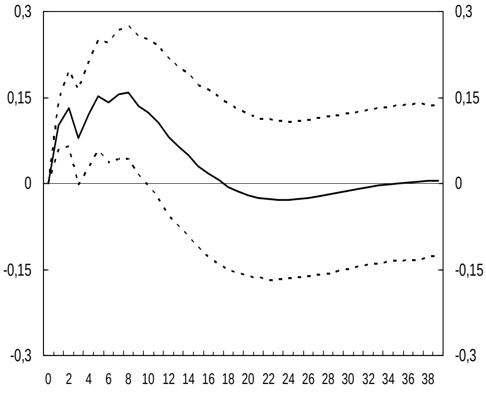


Figure 15b Response to a house price shock.
UK: Inflation (percentage points)



The figures emphasize that in Sweden and the UK, there is a simultaneous response in interest rates following the house price shock. In particular, following a one percent increase in house prices, interest rates increase with 15-20 basis points. For Norway, the initial response is insignificant, but after two quarters, increases with 10 basis points. The strength and timing of the response thereafter varies from one country to another, perhaps indicating that housing may play a different role in the monetary policy setting. The response in interest rates could be (indirectly) related to the effect of housing on inflation: The effect of a positive innovation to house prices on inflation is positive and significant, although sluggish and transitory as expected.

Hence, an unpredicted shock to house prices, influence the interest rate setting, at least within a year. Note however, that what we are measuring is the systematic response to unpredicted changes in house prices. Furthermore, the fact that innovations in house prices also increase inflation, imply that we can not exclude the possibility that the systematic monetary policy response to innovations in house prices could just reflect that house prices have an impact on less controversial objectives such as inflation. In the words of the Monetary Policy Committee at the Bank of England in May 2004:

"In presenting a decision to raise the repo rate, it would be important for the Committee to make clear that it was not targeting house prices inflation, or any other asset price. The significance of the unexpected acceleration in house prices was that it supported a stronger short-term outlook for consumption and output growth, and hence a steeper projected rise in inflation"

Sveriges Riksbank has also been fairly transparent as to how it takes into consideration developments in asset prices, including house prices. As Sveriges Riksbank (2007) puts it:

"…the paths of asset prices and indebtedness can at times be either difficult to rationalize or unsustainable in the long term. This means that there are risks of sharp corrections in the future which in turn affect the real economy and inflation. ... In practice, taking risks of this kind into consideration can mean that interest rate changes are made somewhat earlier or later, in relation to what would have been the most suitable according to the forecasts for inflation and the real economy."

To sum up, we have documented that there could be a great deal of simultaneity between monetary policy and asset prices. In particular, a contractionary monetary policy shock that increases the interest rate with 1 percentage point, reduces real house prices by a total of 3-5 percent. Furthermore, monetary policy responds by increasing interest rates by 10-40 basis points, following a shock that increases house prices by 1 percent.

3.2 Impulse responses using Cholesky decomposition

What have we gained using our preferred specification rather than the Cholesky decomposition? An exercise that allows us to test the implications of our own suggested decomposition would be to impose a recursive contemporaneous Cholesky ordering of *all* shocks, thereby restricting asset prices and monetary policy from responding simultaneously to news. Given the same ordering of the variables as in the baseline case above (where house prices are ordered above the interest rate), such a decomposition will imply that house prices will be restricted from responding contemporaneously to monetary policy shocks. In Figures 16-18 below, we compare our results with the findings from the Cholesky decomposition.

Figure 16a Response to a monetary policy shock.
Norway: Real house prices (per cent)

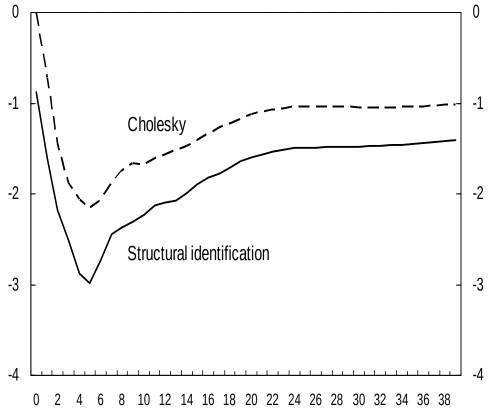


Figure 16b Response to a monetary policy shock.
Norway: Inflation (percentage points)

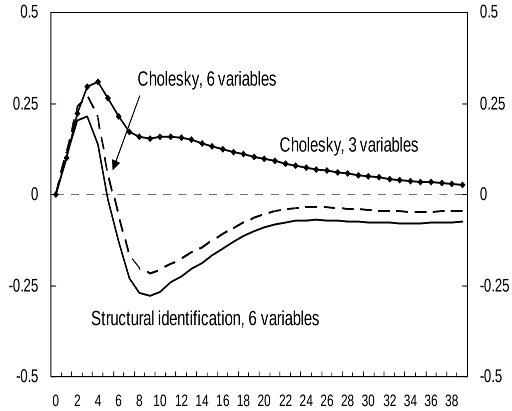


Figure 17a Response to a monetary policy shock.
Sweden: Real house prices (per cent)

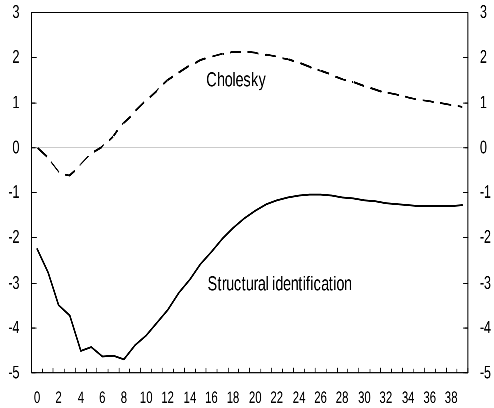


Figure 17b Response to a monetary policy shock.
Sweden: Inflation (percentage points)

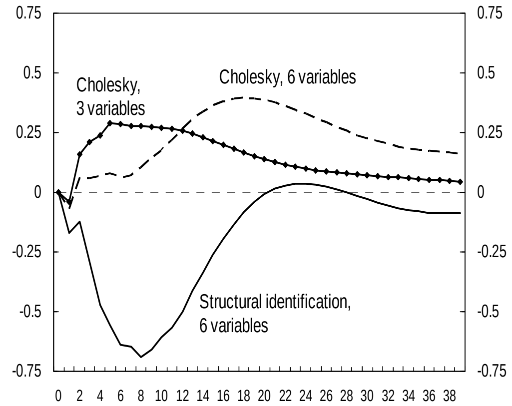


Figure 18a Response to a monetary policy shock.
UK: Real house prices (per cent)

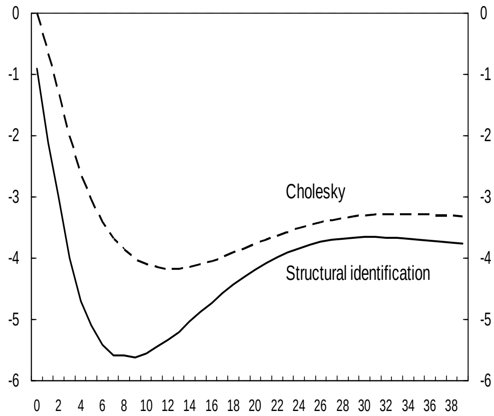
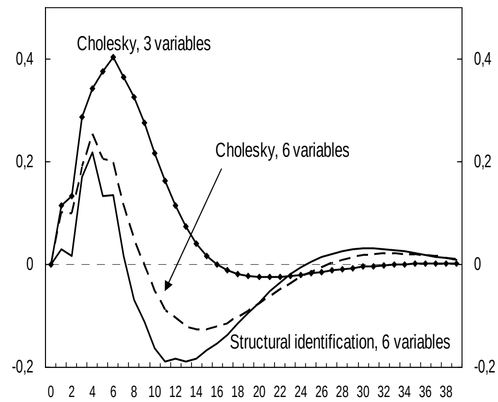


Figure 18b Response to a monetary policy shock.
UK: Inflation (percentage points)



Frame A shows the results for house prices. We also investigate the implication for inflation by using the same Cholesky decomposition. In addition, we perform an exercise where we leave out all the asset prices, and ask to what extent the responses in inflation will depend on the inclusion of the asset price variables. Hence, in frame B of the figures we compare our baseline results with two alternative models: (i) a closed economy VAR model with only three domestic variables, identified using the Cholesky decomposition with the ordering:

output, inflation and the interest rate and (ii) our original VAR, but now identified using the Cholesky decomposition (where house prices respond with a lag to monetary policy shocks).

The results emphasize that the effects of monetary policy on housing will be much smaller using the Cholesky decompositions than our suggested identification. In fact, for Sweden, the effects of a monetary policy shock are not only negligible, but also turn out with the wrong sign. Hence, accounting for interdependence between monetary policy and housing seems important.

Using the closed economy VAR with the Cholesky decomposition, there is a substantial prize puzzle in all countries. Following a contractionary monetary policy shock, the effect on inflation never turns negative. However, including all asset prices in the VAR, while maintaining Cholesky restrictions, seems to reduce the price puzzle in Norway and UK. However, for Sweden, inflation is still always positive. Only when we use our structural identification scheme instead of the Cholesky decomposition, is the price puzzle clearly curbed also in Sweden: In fact, the puzzle is completely eliminated.

Hence, we have shown that by adding just a few series of relevant forward looking asset prices and using an identification that allow for contemporaneous interaction between monetary policy and these asset prices, will reduce the price puzzle (and in the case of Sweden, remove the puzzle). This approach is in some sense consistent with Bernanke, Boivin and Eliasz (2005), who show that by using a data-rich factor augmented VAR, they are able to reduce the price puzzle substantially. Similar conclusion can also be drawn from Brissimis and Magginas (2006), who find that by incorporating forward-looking variables (leading indicators) into the VAR, they are able to reduce the price puzzle substantially.

4 Concluding remarks

Understanding the main features of the transmission mechanism of monetary policy is crucial for the implementation of an efficient monetary policy strategy. So far the implementation of inflation targeting seems to be successful, as it has brought consumer price inflation to a low and fairly stable level in an increasing number of countries. However, asset price fluctuations still appear to be substantial, and the UK and US housing market stand as recent examples. Asset prices are affected by monetary policy shocks, and the volatility of asset prices may in turn have considerable effects on aggregate output and consumer price inflation. Hence, identifying the appropriate monetary policy and asset price interactions may be essential when analyzing monetary policy.

In this paper we analyze the role of house prices in the monetary transmission mechanism in three different economies, Norway, Sweden and the UK. The quantitative effects of monetary policy shocks are studied through structural VARs.

We obtain identification by imposing a combination of short-run and long-run restrictions which allow interdependence between the monetary policy stance and asset price movements. By allowing for simultaneity between monetary policy and house prices, we find that there are simultaneous responses. Unexpected changes in interest rates have an immediate effect on house prices in most countries, and house prices can contemporaneously convey important information for the conduct of monetary policy. We find that overall, house prices fall by 3-5 percent following a monetary policy shock that raises the interest rate by one percentage point. Interest rates also respond systematically to house price shocks, however, the strength and timing of the response varies across countries. This indicates that house prices play a different role in the monetary policy setting in the three economies.

Finally, the restrictions we impose preserve the qualitative impact on domestic variables of a monetary policy shock that has been found in the established VAR literature. A contractionary monetary policy shock raises interest rates temporarily, lowers output and has a sluggish and negative effect on consumer price inflation. Moreover, our results show that by including a few asset price series in the VAR, the "price puzzle" is curbed. Further reductions are found when we allow for simultaneous responses using our structural decomposition instead of the Cholesky decomposition. As argued in the literature, evidence of a price puzzle could be due to VAR misspecification. Thus, by using more information in terms of asset prices in the VAR estimation, the risk of misspecification is reduced.

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Appendix. Data

The following data series are used:

(i_t*) Trade-weighted foreign money market rate (in the models for Norway, Sweden and UK). For 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. For Norway and Sweden, the foreign interest rate is a weighted average of the interest rate in the major trading partners. *Sources*: *EcoWin, Norges Bank and Sveriges Riksbank*

(y_t) Log of real GDP, s.a. For Norway, GDP Mainland Norway is used. *Sources*: *OECD and Statistics Norway*

(π_t) Inflation, measured as annual change in the log of the consumer price index (CPI). For UK, the harmonized CPI is used, and for Norway, the consumer price index is adjusted for taxes and energy prices. *Sources*: *OECD and Statistics Norway*

(ph_t) Log of real house prices, s.a. *Sources*: *EcoWin, Norwegian Association of Real Estate Agents, Association of Real Estate Agency Firms, FINN.no, ECON Pöyry and Norges Bank*

(e_t) 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. *Sources*: *OECD and Norges Bank*

(i_t) Three months money market rate. *Sources*: *OECD, EcoWin and Norges Bank*

Dummies

For *Sweden*, three dummies were included; 1992Q3, 1993Q1 and 1995Q4. The first captures an exceptionally high interest rate that reflects defense of the Swedish exchange rate, the second captures the subsequent floating of the Swedish krona and the third reflects additional turbulence in the exchange rate.

For *Norway*, we had to include more dummies in order to identify a fairly stable monetary policy regime, as various, and partly idiosyncratic circumstances characterize Norwegian monetary policy in this period. Seven impulse dummies were included; 1986Q2, 1986Q3, 1992Q3, 1992Q4, 1993Q1, 1998Q3 and 2002Q4. The dummy for 1986Q2 reflects a devaluation of the Norwegian krone by 9 per cent, and the 1986Q3-dummy accounts for a subsequent sharp rise in inflation. The dummies for 1992Q3, 1992Q4 and 1993Q1, all adjust for the interest rate and exchange rate turbulence that resulted in the breakdown of the fixed exchange rate regime in December 1992. The dummy for 1998Q3 captures a very high interest rate in order to defend the Norwegian krone, and the 2002Q4-dummy reflects a severe appreciation of the Norwegian krone in excess of its fundamentals, see Bjørnland (2008). Olsen et al. (2002) compute interest rates in accordance to Taylor rules using Norwegian data for the period 1995 till 2002, and 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 in this period. Sveen (2000) shows similar comparisons of Taylor-interest rates and actual short term interest rates for the period 1981 to 1998. The analysis confirms the deviation from the Taylor rule in the brief period 1996/7-1998, and also identifies a more prolonged Taylor rule deviation from around 1989 till about 1994. We therefore include two dummies that take the value 1 in the respective period 1989Q2-1994Q1 and 1996Q4-1998Q2, and 0 otherwise. Their coefficients have the expected sign, and imply that the interest rate should have been kept lower from 1989 to 1994 and higher from 1996 to 1998, had the Taylor rule been followed.