

The role of house prices in the monetary policy transmission mechanism in the U.S.*

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Abstract

We analyze the role of house prices in the monetary policy transmission mechanism in the U.S. using structural VARs. The VAR is identified using a combination of short-run and long-run (neutrality) restrictions, allowing for a contemporaneous interaction between monetary policy and various asset prices. By allowing the interest rate and asset prices to react simultaneously to news, we find the role of house prices in the monetary transmission mechanism to increase considerably. In particular, following a monetary policy shock that raises the interest rate by one percentage point, house prices fall immediately by 1 percent, for then to decline by a total of 4-5 percent after three years. Furthermore, the fall in house prices enhances the negative response in output and consumer price inflation that has traditionally been found in the conventional literature.

JEL-codes: C32, E52, F31, F41.

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1 Introduction

The widespread liberalization of financial markets in the 1980s has increased the interest in asset price developments, in particular among central banks. This is primarily due to the fact that asset prices, such as housing and stock prices, have a central collateral role in the lending sector, making them important sources of macroeconomic fluctuations that an inflation targeting central bank may want to respond to, see e.g. Bernanke, Gertler, and Gilchrist (1999) and Bernanke and Gertler (1989).

However, asset prices are not only considered as sources of shocks. Due to their role as stores of wealth, they may also be important transmitters of shocks since asset prices react quickly to news (incl. monetary policy announcements), as emphasized in 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 stance of monetary policy. Understanding the role of asset prices in the transmission mechanism of monetary policy may therefore be imperative for the implementation of an efficient monetary policy strategy.

In this paper, we analyse the role of house prices among other asset prices in the monetary transmission mechanism in the US, 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 an important durable consumption good. A shock to house prices may therefore affect the wealth of homeowners who may want to extract some of the gain to consumption or investment. 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). A shock to house prices may affect real growth and ultimately consumer

prices, making house prices an important forward looking variable that the monetary policymaker may want to monitor.¹

A common approach for establishing the quantitative effects of monetary policy has been the structural VAR approach. However, compared to the vast number of studies analyzing the effects of monetary policy shocks on macroeconomic variables such as output and inflation, (see e.g. Christiano, Eichenbaum, and Evans (1999) and the references therein), the role of housing in the monetary policy transmission mechanism has largely been ignored; with the recent exceptions of Goodhart and Hofmann (2001), Iacoviello (2005) and Giuliadori (2005). A major challenge when incorporating asset prices like housing into the VAR model, though, is how to identify the system, as there is a simultaneity problem when identifying the response of interest rates and housing to news. Most of the VAR studies that incorporate housing, including those cited above, largely ignore this simultaneity by placing recursive, contemporaneous restrictions on the interaction between monetary policy and house prices, assuming either that house prices are restricted from responding immediately to monetary policy shocks (Goodhart and Hofmann (2001), and Giuliadori (2005)), or that monetary policy is restricted from reacting immediately to innovations in house prices (Iacoviello (2005)). Yet, both restrictions are potentially wrong, the first as theory predicts that asset prices such as housing are forward looking and will respond quickly to monetary policy news (at least within the quarter)² and the second because it restricts the policy maker from using all the current information when designing monetary policy.

In this study we will allow for full simultaneity between monetary policy and house prices. In addition, we will include stock prices into the VAR, that can also respond si-

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

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

multaneously to all shocks. Previous studies analyzing the role of house prices, have usually ignored the role of other asset prices, or if included, assumed a recursive order for the VAR, so that stock prices respond with a lag to monetary policy shocks, see e.g. Goodhart and Hofmann (2001). However, there is reason to expect that stock market wealth may affect household behavior quite analogous to housing wealth, although the marginal propensity to consume out of stock market wealth may be smaller than out of housing wealth, (see e.g. Case et al. (2005) and Carroll, Otsuka, and Slacalek (2006) for empirical evidence). Furthermore, stock prices have been found to play a notable role in the US monetary policy transmission mechanism once one allows for interdependence between monetary policy and stock price fluctuations, see Rigobon and Sack (2003), and Bjørnland and Leitemo (2008). Hence, we will examine the potential role for both house prices and stock prices in the VAR.

To identify all shocks, we will leave the contemporaneous relationship between the interest rate and asset prices intact, and restrict instead the long run multipliers of the monetary policy shock. In particular, we follow Bjørnland and Leitemo (2008) and assume that monetary policy shocks can have no long run effect on the level of the real stock price or on real GDP. Identified in this way, house prices and stock prices 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. This maintains the high degree of interdependence commonly observed in the market between monetary policy and various asset prices. 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 restric-

tions on the impact matrix of shocks. That is, we build on the traditional closed economy VAR literature (Sims (1980); Christiano, Eichenbaum, and Evans (1999); Christiano, Eichenbaum, and Evans (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 emphasized 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, Swanson, and Wright (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, Eichenbaum, and Evans (1999) and Christiano, Eichenbaum, and Evans (2005)).

Our findings suggest that, following a contractionary monetary policy shock, house prices fall immediately. Furthermore, we find the interest rate to increase systematically in response to a shock that increases house prices.

The rest of the paper is organized as follows. In Section 2, the VAR methodology is explained, whereas in Section 3 we discuss the empirical results for the baseline model. Section 4 discusses robustness of results and Section 5 concludes.

2 Identification

The choice of variables in the VAR model reflects the theoretical set up of a New-Keynesian model, such as that described in Svensson (1997). 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 log of real house prices (ph_t) and the log of real share prices (s_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 behavior to be well modeled by a policy rule that sets the interest rate as a function of variables such as output and inflation.

We first define Z_t as the (5x1) vector of the macroeconomic variables discussed above, where y_t , ph_t and s_t are differenced to be stationary: $Z_t = [\Delta y_t, \pi_t, \Delta ph_t, \Delta s_t, i_t]'$. 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 vector of reduced form residuals assumed to be identically and independently distributed with a positive semidefinite covariance matrix Ω . $B(L)$ is the (5x5) convergent matrix polynomial in the lag operator L . 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

$$Z_t = C(L)\varepsilon_t, \quad (2)$$

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 elements in ε_t are normalized so they all have unit variance. The normalization of $cov(\varepsilon_t, \varepsilon_t)$ implies $SS' = \Omega$. 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, we need ten additional restrictions.

With a five variables VAR, we can identify five 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 stock price shocks (ε_t^s). We follow standard practice in the VAR literature and only loosely identify the last two shocks as inflation (or cost push) shocks (moving prices before output) (ε_t^π) and output shocks (ε_t^y).

Ordering the vector of structural shocks as: $\varepsilon_t = [\varepsilon_t^y, \varepsilon_t^\pi, \varepsilon_t^{ph}, \varepsilon_t^s, \varepsilon_t^{MP}]'$, we assume zero restrictions on the relevant coefficients in the S matrix as described below:

$$\begin{pmatrix} \Delta y_t \\ \pi_t \\ \Delta hp_t \\ \Delta s_t \\ i_t \end{pmatrix} = B(L) \begin{pmatrix} S_{11} & 0 & 0 & 0 & 0 \\ S_{21} & S_{22} & 0 & 0 & 0 \\ S_{31} & S_{32} & S_{32} & 0 & S_{35} \\ S_{41} & S_{42} & S_{43} & S_{44} & S_{45} \\ S_{51} & S_{52} & S_{53} & S_{54} & S_{55} \end{pmatrix} \begin{pmatrix} \varepsilon_t^y \\ \varepsilon_t^\pi \\ \varepsilon_t^{ph} \\ \varepsilon_t^s \\ \varepsilon_t^{MP} \end{pmatrix}$$

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. The idea is that due to nominal rigidities, there is a slow process of pass through to macroeconomic variables. We further assume a lag in the effect of stock price shocks and house price shocks on inflation and output.³ Regarding the ordering of the first two variables, we will show that the effects of the monetary policy shocks (or shocks to either of the asset prices) will be invariant to how these variables are ordered. This follows from a generalization of proposition 4.1 in Christiano, Eichenbaum, and Evans (1999), and is discussed further in the robustness section below.

This provides us with eight contemporaneous restrictions directly on the first three rows in the S matrix. The matrix is, however, still two restrictions short of identification. Since we do not want to restrict monetary policy from responding contemporaneously to shocks in either house prices or stock prices (i.e. S_{53} and S_{54} should be different from zero), or house prices and stock prices from responding contemporaneously to monetary policy shocks (i.e. S_{35} and S_{45} should be different from zero), we therefore suggest imposing the restrictions that i) a monetary policy shock can have no long-run effects on the level of the real stock prices, and ii) a monetary policy shock can have no long-run effects on the level of the real output, which as discussed above, are plausible neutrality assumptions. The restrictions can be found by setting the values of the infinite number of relevant lag coefficients in (2), $\sum_{j=0}^{\infty} C_{15,j}$ and $\sum_{j=0}^{\infty} C_{45,j}$, 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 (5x5) long-run matrix of $B(L)$ and $C(L)$ respectively. The long-run restrictions imply respectively

³We also assume that house prices do not react simultaneously to a stock price shock.

$$B(1)_{11}S_{15} + B(1)_{12}S_{25} + B(1)_{13}S_{35} + B(1)_{14}S_{45} + B(1)_{15}S_{55} = 0, \quad (3)$$

$$B(1)_{41}S_{15} + B(1)_{42}S_{25} + B(1)_{43}S_{35} + B(1)_{44}S_{45} + B(1)_{45}S_{55} = 0, \quad (4)$$

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 restrictions, where $B(1)$ is calculated from the reduced form estimation. Note that (3 and 4) reduce to $B_{13}S_{35} + B_{14}S_{45} + B_{15}S_{55} = 0$ and $B_{43}S_{35} + B_{44}S_{45} + B_{45}S_{55} = 0$ respectively, given the zero contemporaneous restrictions.

3 Empirical results

The model is estimated for United States using quarterly data from 1983Q1 to 2007Q4. 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, Gali, and Gertler (2000)).

The VAR comprises the domestic interest rate, annual inflation rates, and quarterly growth rates of the following: GDP, real house prices and real stock prices. Note that inflation is measured as the annual growth rate of CPI. 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.

The estimated VAR is stable and thus invertible. 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. With a relatively short sample, we use four lags in the estimation and check for robustness using alternative lag lengths. With four lags, the estimated VAR is stable and thus invertible. Furthermore, the hypothesis of autocorrelation and heteroscedasticity is rejected at the one-percent level. Some non-normality remained in the system, essentially due to non-normality in the equation for share prices.⁴

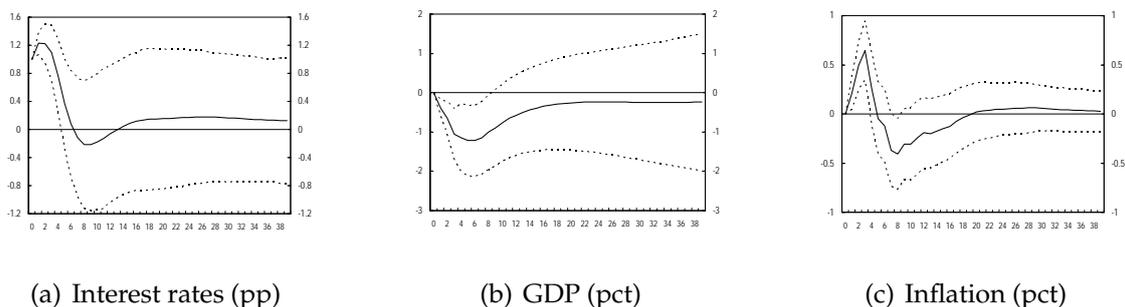
3.1 Impulse responses using structural decomposition

Figures 1 (a-c) plot respectively, the response in the interest rate, GDP and inflation to a contractionary monetary policy shock, while Figure 2 (a-b) plot the responses in house prices and stock prices to the same shock. The responses are graphed with probability bands represented as .16 and .84 fractiles (as suggested by Doan (2004)). In all cases, the monetary policy shock is normalized to increase the interest rate with one percentage point the first quarter.

The figures imply that a contractionary monetary policy shock has the usual effects 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 Wood-

⁴Two impulse dummies (that take the value 1 in one quarter and 0 otherwise) were also included in the models for the period 1984Q4 and 1986Q2. The first dummy represents a very high interest rate while the second account for a large residual in the equations for consumer price inflation and the Fed Funds rate. Robustness to the inclusion of these dummies is reported below.

Figure 1: *Response to a monetary policy shock*

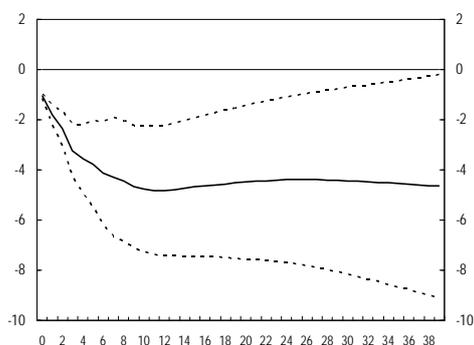


ford (2003)). In particular, interest-rate inertia is known to let the policymaker smooth out the effects of policy over time by affecting private-sector expectations. Moreover, the reversal of the interest rate stance is consistent with the policymaker trying to offset the adverse effects of the initial policy deviation from the systematic part of policy.

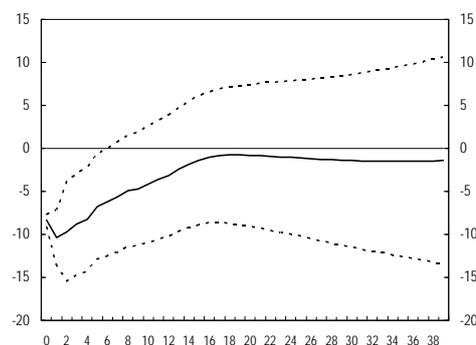
Regarding the other variables, output falls by 1 per cent for close to two years, before the effect essentially dies out. The effect on inflation is also eventually negative as expected. However, there is some evidence that consumer prices increase initially, also referred to as price puzzle (see Sims (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, Hoffmann, and Schabert (2006)). Eventually, though, prices start to fall, until after 3-4 years, inflation has fallen by 0.5 per cent. The effect thereafter dies out.

Turning to real house prices, Figure 2a suggests that monetary policy has a strong and prolonged effect on real house prices. In particular, following a contractionary monetary policy shock, house prices fall immediately by one per cent. There is evidence of delayed response, as house prices continue to fall for close to 3 years, when they have fallen with 4 percent. In the long run, though, the effect is insignificant. The persistent effect suggests that is reasonable not to impose the restriction that monetary policy can have no long-run effects on the level of real house prices from the outset.

Figure 2: *Response to a monetary policy shock*



(a) Real house price (per cent)



(b) Real stock price (per cent)

Are the results plausible? Since a contractionary monetary policy shock also lowers output, one can expect there to eventually be negative effects on employment and wages. Higher interest rates also raise household's interest payments. Thus, household's debt servicing capacity will decline when interest payments increase and income is curbed. This can explain both the the strong initial and prolonged effect of monetary policy shocks on house prices.

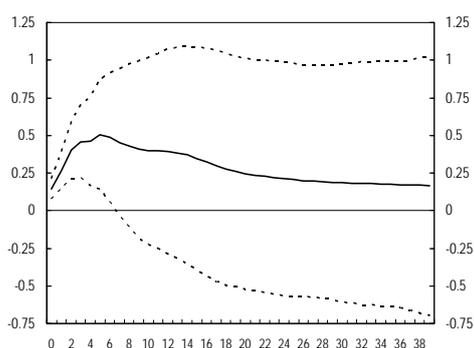
These results are different from those that were found for the U.S. in Iacoviello (2005).⁵ Although he also finds house prices to fall immediately, the effect found there is much smaller. The relatively weaker results may be due to the fact that Iacoviello restricts monetary policy from reacting contemporaneously to shocks in house prices. In contrast, Del Negro and Otrok (2007) use sign restrictions to test, among all possible reasonable identification procedures and VAR specifications, for the combination that deliver the largest impact on house prices (that is, the upper bound). Doing so, they find much stronger results than Iacoviello (2005), suggesting that our results may be plausible.

⁵The results are of course also different from Goodhart and Hofmann (2001) and Giuliadori (2005), which use an identification that restricts house prices from responding contemporaneously to a monetary policy shock.

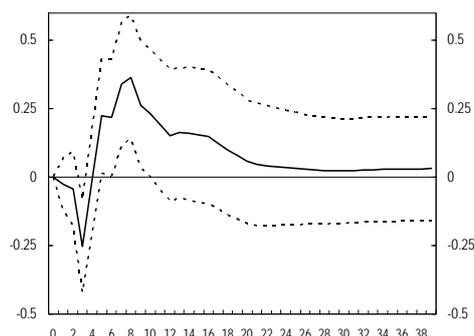
Regarding the other asset prices, Figure 2b shows that the monetary policy shock has an immediate and negative effect on the real stock price as expected. This is consistent with results found in Bjørnland and Leitemo (2008), using monthly data for the U.S. covering the period from 1983 to 2002.

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 3a and 3b plot the effect of a house price shock (normalized to increase house prices with one percent the first quarter) on interest rates and inflation respectively. We graph the response in inflation, so as to investigate to what extent the response in interest rate also relates to that in inflation.

Figure 3: *Response to a house price shock*



(a) Interest rates (percentage points)



(b) Inflation per cent

The figures emphasize that 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 immediately with 15 basis points, increasing to 50 basis points after one and a half year. The response in interest rates seems to be (indirectly) related to the effect of housing on inflation, with the latter increasing temporarily following the house price shock.

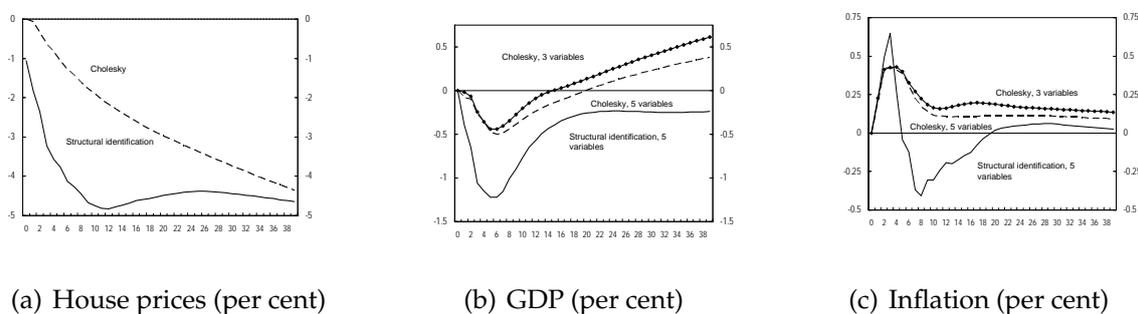
Hence, an unpredicted shock to house prices, influence the interest rate setting, at

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.

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. Using 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 cannot respond contemporaneously to a monetary policy shock. Similar restrictions were used in both Goodhart and Hofmann (2001) and Giuliadori (2005)).

Figure 4: *Response to a monetary policy shock: Cholesky versus structural VAR*



In Figure 4a we compare the results for house prices with the findings from the Cholesky decomposition. The solid line is our baseline structural impulse response

while the dotted line is the impulse response from the Cholesky decomposition. The results emphasize that the effects of monetary policy on housing would be much smaller using the Cholesky decompositions than our suggested identification. Hence, accounting for interdependence between monetary policy and housing seems important.

Figures 4b and 4c investigate the implication for GDP and inflation by using the same Cholesky decomposition. In addition, we also perform an exercise where we exclude the asset prices from the VAR, and ask to what extent the responses in GDP and inflation will depend on the inclusion of these financial variables. Hence, the figures compare our baseline results with (i) a 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).

Figure 4b emphasize that using either the three or the five variable VAR with the Cholesky decomposition, output respond very little following a contractionary monetary policy shock. Only when we include all asset prices and use our structural identification scheme does GDP respond significantly negative for a prolonged period.

Similar puzzling results are also found with regard to inflation. Using the three variable VAR with the Cholesky decomposition, there is a substantial price puzzle in the U.S. Following a contractionary monetary policy shock, the effect on inflation never turns negative. Including all asset prices in the VAR, while maintaining Cholesky restrictions, does not seem to reduce the price puzzle any further as the effect on inflation remains positive. Only when we use our structural identification scheme instead of the Cholesky decomposition, is the price puzzle clearly curbed.

Hence, we have shown that by adding just a few series of relevant financial variables and using an identification that allows for contemporaneous interaction between monetary policy and asset prices, will reduce the price puzzle. These results are in

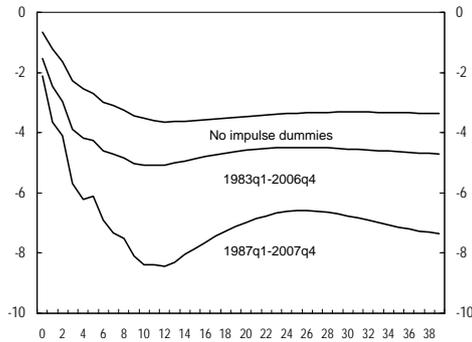
some sense consistent with the findings in Bernanke, Boivin, and Elias (2005), who show that by using a data-rich factor augmented VAR, they are able to reduce the price puzzle substantially. Similar conclusion can also be drawn from Brissimis and Magginas (2006), who find that by incorporating forward-looking variables (leading indicators) into the VAR, they are able to reduce the price puzzle substantially.

4 Robustness

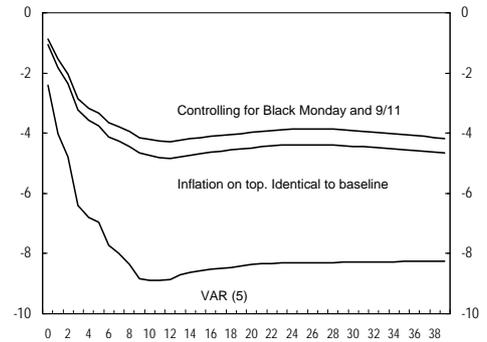
We now turn to tests of robustness of our preferred models by doing the following step-wise changes: First, we let the estimation period start in 1987 (when Alan Greenspan took office), so as to analyze the responses in a more stable monetary policy regime (1987-2007). Second, we cut of a year from the original sample (1983-2006), to control for the possibility that the estimated simultaneous response between monetary policy and house prices is greatly affected by the recent subprime crisis and the related housing market turnaround. Third, we remove the two impulse dummies used in the VAR (1984Q4 and 1986Q2). Fourth, we test robustness by adding two impulse dummies; 1987Q4 and 2001Q3, to control for the stock market crash in October 1987 and the stock market turmoil corresponding to 9/11. Fifth, we use five lags in the VAR instead of our preferred four lags. Finally, we test robustness by altering the ordering of the variables in the model. More precisely, we interchange the ordering of GDP and consumer price inflation. According to Christiano et al (1999; Proposition 4.1), the ordering of variables above the interest rate equation does not matter for the impulse responses following a monetary policy shock, when using Cholesky restrictions.

The results to these robustness tests are graphed in Figure 5a and 5b. We focus on the responses in house prices, but the results for the other variables can be obtained at request. The tests are supportive of our main conclusion that house prices react

Figure 5: Response to a monetary policy shock. Robustness tests.



(a) House prices (per cent)



(b) House prices (per cent)

simultaneously to monetary policy shocks. In fact, most tests suggest that the results are magnified somewhat compared to the baseline results. One exception is when we include the two dummies for the stock market crashes, as the response in house prices now become marginally smaller. Finally, the test of the alternative order of the VAR illuminates that our findings are fully consistent with the proposition in Christiano, Eichenbaum, and Evans (1999), although we use a combination of short-run and long-run restrictions.

5 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 US housing market stands as a recent and clear example. 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 the U.S, paying attention also to other asset prices, stock price in particular. The quantitative effects of monetary policy shocks are studied through structural VARs. Contrary to recent studies, we allow for full interdependence between monetary policy and asset prices, including both housing and stock prices. Identification is achieved by imposing a combination of short-run and long-run restrictions.

By allowing for simultaneity between monetary policy and house prices, we find that real house prices fall immediately by 1-2 per cent following a monetary policy shock that raises the interest rate by one percentage point. Hence, house prices can contemporaneously convey important information for the conduct of monetary policy. Furthermore, interest rates respond systematically to house price shocks. The systematic response of monetary policy to house prices could reflect that shocks to house prices ultimately influence output and inflation.

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, lowers output temporarily 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" that has been found in many studies 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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