

House Prices and Stock Prices: Different Roles in the US Monetary Transmission Mechanism*

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Abstract

We analyze the role of house prices and stock prices in the monetary-policy transmission mechanism in the US, using a structural vector autoregressive model. If we allow the interest rate and asset prices to react simultaneously to news, we find different roles for house prices and stock prices in the monetary transmission mechanism. Following a contractionary monetary-policy shock, stock prices fall immediately, while the response in house prices is more gradual. Regarding the systematic response in monetary policy, stock prices play a more important role than house prices. As a consequence, house prices contribute more than stock prices to fluctuations in gross domestic product and inflation.

Keywords: House prices; identification; monetary policy; vector autoregressive model

JEL classification: C32; E44; E52

I. Introduction

The widespread liberalization of financial markets in the 1980s increased interest in asset-price developments, in particular among central banks, as a result of several factors. First, asset prices, such as housing and stock prices, have a central collateral role in the lending sector, making them important sources of macroeconomic fluctuations, to which an inflation-targeting

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central bank might respond (e.g., Bernanke and Gertler, 1989; Bernanke *et al.*, 1999).¹

Second, asset prices are forward-looking variables, reflecting the expected future return on the asset, which is determined by fundamental variables. If the policy-maker is at an informational disadvantage regarding the private sector, or if the fundamentals are not fully observable to the policy-maker, asset prices can be helpful as indicator variables because they reflect private-sector expectations about the state of the economy.

Finally, asset prices not only reflect fundamentals, but also frequently include bubble components. Because of the presence of such bubbles, asset prices can influence target variables more than is reflected by the fundamental part of the asset price. Hence, asset prices can also become distinct indicators of monetary policy (e.g., Cecchetti *et al.*, 2000). However, given the incomplete understanding of the determination of asset prices (i.e., the underlying model), it might be difficult to identify possible bubble components, and thus to provide adequate monetary-policy responses.

In this paper, we analyze the role of two asset prices – house prices and stock prices – in the monetary transmission mechanism in the US, using a structural vector autoregressive (VAR) model. The motivation for including house prices in the model is that it is the most important asset for households in industrialized countries. Unlike other assets, housing has the dual role of being both a store of wealth and an important durable consumption good. Therefore, a shift in house prices will affect the wealth of homeowners, which might have a bearing on consumption and investment. As the value of collateral changes, this will also affect the availability of credit for borrowing-constrained agents. Finally, increased house prices can have a stimulating effect on housing construction (because of the effect of Tobin's q). Hence, a shock to house prices might affect real growth and ultimately consumer prices, making house prices an important forward-looking variable that the monetary policy-maker might want to monitor.²

Furthermore, we also include stock prices in the VAR model. We believe stock market wealth can affect household behavior quite analogous to housing wealth, although the marginal propensity to consume out of stock market wealth might be somewhat smaller than the marginal propensity to consume out of housing wealth (e.g., Case *et al.*, 2005; Carroll *et al.*, 2011).

¹ The recent financial crisis is a case in point. Arguably, the crisis began with the collapse of the US housing bubble in 2007/2008, which consequently caused the values of securities tied to real-estate pricing to plummet worldwide. This led to a liquidity crisis in the banking system, stress and collapse in many large financial institutions, and eventually a global recession as credit tightened and international trade declined.

² Greenspan (2001) has also spurred interest in this topic, by suggesting that house prices have gained attention in the formulation of the monetary-policy strategy.

However, a major challenge when incorporating asset prices into the VAR model is how to identify the system. The reason for this is that there is a simultaneity problem when identifying shocks to interest rates and asset prices, because all these might respond simultaneously to news. So far, most of the VAR studies that have analyzed the importance of housing (Goodhart and Hofmann, 2001; Giuliadori, 2005; Iacoviello, 2005) have largely ignored this simultaneity by placing recursive, contemporaneous exclusion restrictions on the interaction between monetary policy and house prices.³

The studies mentioned above have either ignored stock prices or, if included, have maintained the recursive order for the VAR, so that stock prices respond with a lag to monetary-policy shocks (e.g., Goodhart and Hofmann, 2001). This is equally implausible, and recent studies have found that stock prices play a notable role in the US monetary-policy transmission mechanism, once allowing for interdependence between monetary policy and stock price fluctuations (see Rigobon and Sack, 2003; Bjørnland and Leitemo, 2009).

Here, we include both house prices and stock prices into the VAR model, while allowing for full simultaneity between monetary policy and these asset prices. Identification is instead achieved by restricting the long-term multipliers of the monetary-policy shock. In particular, we assume that monetary-policy shocks can have no long-term effect on either the level of real stock prices or on real gross domestic product (GDP). These are uncontroversial restrictions, well founded in economic theory (e.g., Blanchard and Quah, 1989; Bjørnland and Leitemo, 2009).⁴ Identified in this way, house prices and stock prices can now respond immediately to all shocks, while the monetary policy-maker can consider news in all asset prices, when designing a 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-term effects of monetary-policy shocks on house prices, because we believe this to be a somewhat more controversial issue that we would like to examine rather than to impose at the outset.

Our findings suggest different roles for asset prices in the monetary transmission mechanism. In particular, following a contractionary monetary-policy shock (which increases the interest rate), stock prices fall

³ Typically, traditional structural VAR studies have assumed either that house prices are restricted from responding immediately to monetary-policy shocks (Goodhart and Hofmann, 2001; Giuliadori, 2005), or that monetary policy is restricted from reacting immediately to innovations in house prices (Iacoviello, 2005).

⁴ However, we see that our results do not hinge on these specific restrictions, because they can be obtained using sign restrictions instead.

immediately, while the response in house prices is more gradual. However, the fall in both house prices and stock prices enhances the negative response in output and inflation that has traditionally been found in the structural VAR body of literature.

Regarding the systematic response in the interest rate, monetary policy responds less to shocks in house prices than to shocks in stock prices in the short term, but the relationship is reversed in the long term. In part because of the delayed monetary-policy response to shocks in house prices, these shocks have a much larger impact on both GDP and inflation than shocks in stock prices.

The rest of the paper is organized as follows. In Section II, we explain our structural identification scheme, which provides an exact identification. In Section III, we present the empirical results from our structural model. In Section IV, we analyze the robustness to our identification strategy and model specification. We conclude in Section V.

II. Motivation and Identification

The choice of variables in the VAR model reflects the theoretical set-up of a New Keynesian model (e.g., Svensson, 1997). In particular, the VAR model comprises the annual change of the log of the GDP deflator (π_t ; referred to hereafter as inflation), the log of real GDP (y_t), the federal funds rate (i_t), the log of real house prices (ph_t), and the log of real stock prices (s_t).⁵ In all cases, the federal funds rate is chosen to capture monetary-policy shocks (consistent with the fact that the central bank uses interest rate instruments in setting monetary policy). This is in line with Rotemberg and Woodford (1997), who find that the behavior of the central bank is well modeled by a policy rule that sets the interest rate as a function of variables, such as output and inflation.

Identification

First, we define Z_t as the (5×1) vector of the macroeconomic variables discussed above, where y_t , ph_t , and s_t are now differenced to be stationary: $Z_t = [\Delta y_t, \pi_t, \Delta ph_t, \Delta s_t, i_t]'$. We model Z_t as an autoregressive process, which, when invertible, can be written in terms of its moving average (ignoring any deterministic terms):⁶

$$Z_t = B(L)v_t. \quad (1)$$

⁵ Further details on the data and sources are given in the Appendix.

⁶ This is discussed further and verified in Section III.

Here, v_t is a vector of reduced-form residuals, assumed to be identically and independently distributed with a positive semidefinite covariance matrix Ω , and $B(L)$ is the (5×5) 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 model 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 moving average representation in equation (2) because $B(L)$ is calculated from a reduced-form estimation of Z_t . To identify S , the elements in ε_t are normalized so that they all have unit variance. With a five-variable VAR model, we can identify five structural shocks. The three shocks that are of primary interest here are the monetary-policy shocks ($\varepsilon_t^{\text{MP}}$), house-price shocks ($\varepsilon_t^{\text{PH}}$), and stock-price shocks ($\varepsilon_t^{\text{SP}}$). We follow standard practice in the VAR body of literature and only loosely identify the other 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 $\varepsilon_t = [\varepsilon_t^y, \varepsilon_t^\pi, \varepsilon_t^{\text{PH}}, \varepsilon_t^{\text{SP}}, \varepsilon_t^{\text{MP}}]'$, we assume zero restrictions on the relevant coefficients in the S matrix, described as follows:

$$\begin{pmatrix} \Delta y_t \\ \pi_t \\ \Delta ph_t \\ \Delta s_t \\ i_t \end{pmatrix} = B(L) \begin{pmatrix} S_{11} & 0 & 0 & 0 & 0 \\ S_{21} & S_{22} & 0 & 0 & 0 \\ S_{31} & S_{32} & S_{33} & 0 & S_{35} \\ S_{41} & S_{42} & S_{43} & S_{44} & S_{45} \\ S_{51} & S_{52} & S_{53} & S_{54} & S_{55} \end{pmatrix} \begin{pmatrix} \varepsilon_t^y \\ \varepsilon_t^\pi \\ \varepsilon_t^{\text{PH}} \\ \varepsilon_t^{\text{SP}} \\ \varepsilon_t^{\text{MP}} \end{pmatrix}$$

We assume standard recursive zero restrictions on the impact matrix of shocks for the traditional macroeconomic variables (see Sims, 1980; Christiano *et al.*, 1999, 2005; among many others). That is, output and inflation react with a lag to monetary-policy shocks, whereas the monetary policy-maker might respond immediately to shocks to output and inflation. This is consistent with the theoretical set-up of Svensson (1997).⁷ We further assume a lag in the effect of stock-price and house-price shocks on inflation and output.⁸

⁷ Note that the effects of the monetary-policy shocks will be invariant to how output and inflation are ordered. This follows from a generalization of proposition 4.1 in Christiano *et al.* (1999), which entails that with a recursive contemporaneous matrix, the impulse responses to a specific shock are invariant to the ordering of variables above the specific shock.

⁸ We also assume that house prices do not react simultaneously to a stock-price shock.

However, the matrix is two restrictions short of identification because 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, alternatively, house prices and stock prices from responding contemporaneously to monetary-policy shocks (i.e., S_{35} and S_{45} should be different from zero). Instead, we impose the restrictions that (i) a monetary-policy shock can have no long-term effects on the level of real stock prices, and (ii) a monetary-policy shock has no long-term effect on the level of real output; these are plausible neutrality assumptions. The restrictions can be found by setting the values of the infinite number of relevant lag coefficients in equation (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 orthogonalize all shocks. We write the long-term 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 (5×5) long-term matrices of $B(L)$ and $C(L)$, respectively. The long-term restrictions imply

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

and

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

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-term restrictions, where $B(1)$ is calculated from the reduced-form estimation. Note that equations (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.

III. Empirical Results

The VAR model is estimated for the US using quarterly data from 1983 Q1 to 2010 Q1. The use of an earlier starting period would make it hard to identify a stable monetary-policy regime, because monetary policy prior to 1983 experienced important structural changes and unusual operating procedures (see Bagliano and Favero, 1998; Clarida *et al.*, 2000).

To recall, the VAR model comprises the federal funds rate, the annual inflation rate, and the quarterly growth rates of real GDP, real house prices, and real stock prices.⁹ The lag order of the model is determined

⁹ Inflation is measured by the annual change in the log of the GDP deflator, and the latter price index is used when deflating house prices and stock prices. We use the Federal Housing Finance Agency (FHFA) house price index (HPI) and Standard & Poor's (S&P) 500 index as measures of house prices and stock prices, respectively. See the Appendix for further details.

using Schwarz and Hannan–Quinn information criteria and the F -forms of likelihood ratio tests for model reductions. The tests suggest that four lags are acceptable. With a relatively short sample, we use four lags in the estimation. With four lags, the estimated VAR model is stable, and thus invertible. That is, all eigenvalues of the companion matrix of our baseline VAR model have a modulus less than one.¹⁰

Furthermore, vector tests with null hypotheses of absence of autocorrelation, heteroskedasticity, or non-normality have not been rejected at standard significance levels.¹¹

Effects of a Monetary-Policy Shock

Figures 1(a)–(e) plot the responses of levels of the interest rate, GDP, inflation, real house prices, and real stock prices, respectively, to a contractionary monetary-policy shock. The responses are plotted with probability bands represented as 0.16 and 0.84 fractiles (as suggested by Doan, 2004).¹² To compare across variables, the monetary-policy shock is normalized in order 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 identified in other international studies: a temporary increase of the interest rate and a lowering of output and inflation gradually. There is a high degree of interest-rate inertia in the model, because 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).

¹⁰ This does not imply that each and every variable in the VAR must be $I(0)$. Generally, in an unrestricted VAR model comprising variables that are $I(1)$ and cointegrated, the cointegrating relationships will be implicitly determined (see Hamilton, 1994). Moreover, Sims *et al.* (1990) have argued in favor of using VAR models in levels as a modeling strategy, because this can avoid the danger of inconsistency in the parameters caused by imposing incorrect cointegrating restrictions, yet at the cost of reducing efficiency.

¹¹ The diagnostic tests have been carried out using PcGive 10 (see Hendry and Doornik, 2001). We used RATS for the remaining part of the empirical results. The reported diagnostic tests were as follows: Vector AR 1-5 test, $F(125,285)=1.2368$ [0.0754]; Vector Normality test, $\chi^2(10) = 16.582$ [0.0841]; Vector hetero test, $F(600,502) = 0.77491$ [0.9986]. Two impulse dummies for the periods 1984 Q4 (controlling for a very high interest rate (outlier)) and 1987 Q4 (controlling for the stock-market crash in October 1987) were also included in the model. The dummies take the value of 1 in the relevant quarter, and 0 otherwise. Robustness to the specification is reported in Section IV.

¹² This is the Bayesian simulated distribution obtained by Monte Carlo integration with 2,500 replications, using the approach for just-identified systems. The draws are made directly from the posterior distribution of the VAR coefficients.

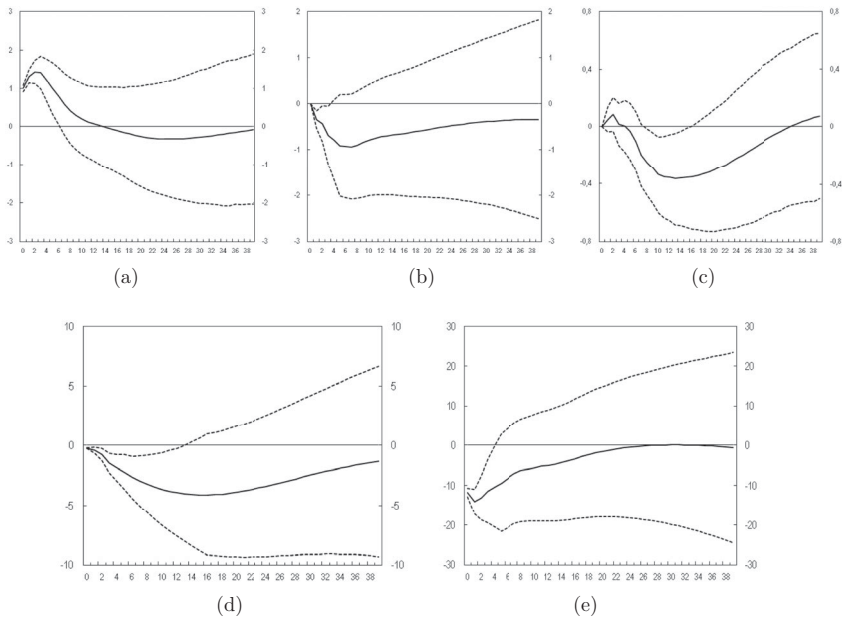


Fig. 1. Responses to a monetary-policy shock: (a) Interest rate (pp); (b) GDP (pct); (c) Inflation (pp); (d) Real house prices (pct); (e) Real stock prices (pct).

Regarding the other variables, output falls by almost 0.5 per cent after two quarters, and is reduced by nearly 1 per cent after a year, when the effect becomes insignificant. The inflation response is initially positive, but the effect is insignificant. The response eventually turns negative and is significant, as expected. After three to four years, inflation has fallen by nearly 0.4 percentage points, and thereafter the response dies out. A certain increase in consumer prices, following a contractionary monetary-policy shock, is a common finding in the VAR body of literature, known as the “price puzzle”. An interpretation could be that monetary policy reacts systematically to anticipated future inflation, while the signal of future inflation is not adequately captured by the VAR model (see Sims, 1992). The puzzle could also 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 (Chowdhury *et al.*, 2006; Ravenna and Walsh, 2006). The VAR model presented here is clearly provided with forward-looking information because two asset prices are incorporated. Moreover, the identification scheme allows for contemporaneous interdependence between monetary policy and asset prices. This could explain why the result displayed in Figure 1(c) suggests the absence of a (significant) price puzzle.

Turning to real house prices, Figure 1(d) shows that monetary policy has an immediate negative effect on real house prices. The effect is small but significant. Thereafter, house prices are pushed further down, and after three years they have fallen by almost 4 percent. In the long term, though, the effect is insignificant. The persistent effect seemingly supports the reasonableness of not imposing (from the outset) the restriction that monetary policy has no long-term effects on the level of real house prices. Yet, the persistent response turns out to be robust to such a long-term restriction, because the response is effectively unchanged when this restriction is imposed.¹³

Are the results plausible? Because a contractionary monetary-policy shock also lowers output, we would expect a negative effect on employment and wages. Higher interest rates also raise household interest payments. Thus, the capacity for household debt servicing will decline when interest payments increase and income is curbed. This can explain the prolonged effect of monetary-policy shocks on house prices.

The results for house prices reported here lie somewhere in between those of Iacoviello (2005) and Del Negro and Otrok (2007).¹⁴ The relatively weaker response (in house prices) found by Iacoviello (2005) might be because he restricts monetary policy from reacting contemporaneously to shocks in house prices and he ignores a possible interaction with stock prices. However, the corresponding results of Del Negro and Otrok (2007) are much larger, because they search for the maximum possible impact when imposing various identification schemes using sign restrictions.

Concerning the other asset price, Figure 1(e) shows that the monetary-policy shock has an immediate negative effect on real stock prices. Stock prices fall by close to 10 percent, but the effect is short-lived. This is consistent with Bjørnland and Leitemo (2009), who have analyzed the interdependence between US monetary policy and stock prices (only).¹⁵

Finally, Figure 2 plots the variance decomposition of real house prices and real stock prices with respect to a monetary-policy shock. While monetary-policy shocks explain almost 30 percent of the initial variation in real stock prices (which then quickly dies out), the contribution to house prices is less than 5 percent initially, increasing slowly to 10 percent after two to three years, before essentially dying out. Hence, monetary-policy

¹³ The result can be obtained on request.

¹⁴ The results are, of course, different from those of Goodhart and Hofmann (2001) and Giuliodori (2005), who have used an identification that restricts house prices from responding contemporaneously to a monetary-policy shock.

¹⁵ Using a monthly structural VAR model augmented with stock prices for the US, Bjørnland and Leitemo (2009) have found great interdependence between US monetary policy and stock prices in the period 1983–2002.

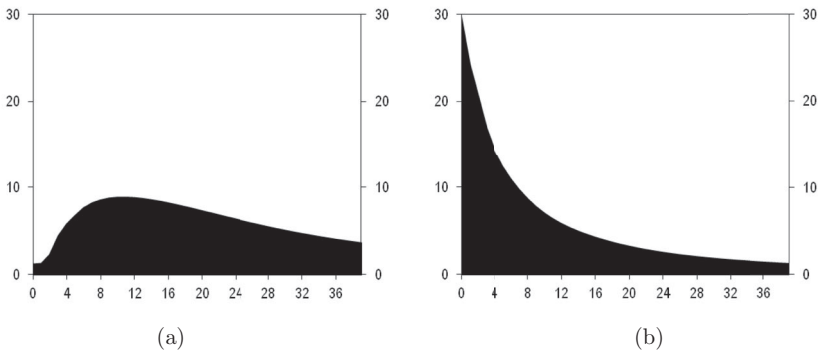


Fig. 2. Variance decomposition (pct) to a monetary-policy shock: (a) Real house prices; (b) Real stock prices.

shocks contribute more to the variation in stock prices than in house prices in the short term, because the effect on house prices is more delayed.

Systematic Effects of Monetary Policy

Having examined the dynamic responses of the variables to a monetary-policy shock, we now investigate the reverse causation, namely the (systematic) response in monetary policy to shocks in house prices and stock prices. Our identified asset-price shocks capture the non-fundamental asset-price variation (i.e., sharp increases or decreases in real asset prices at given interest rates and trends in GDP and inflation). Naturally, the interpretation that these shocks are non-fundamental is subject to uncertainty. We also plot the response in GDP and inflation to the same two shocks, in order to investigate to what extent the response in interest rates relates to economic activity. In each of the subsequent figures, we compare the effects of a house-price shock and a stock-price shock for one variable at a time. That is, Figure 3 plots the effects of a house-price shock (left column) and a stock-price shock (right column) on the interest rate, GDP, and inflation. Because of the much higher volatility in stock prices than in house prices, the stock-price shock is normalized to increase stock prices by 10 percent in the first quarter, while the house-price shock raises house prices by 1 percent in the first quarter. Again, the responses are plotted with probability bands represented as 0.16 and 0.84 fractiles.

The figures emphasize that monetary policy responds more slowly to a shock in house prices than to a stock-price shock. As a consequence, the effect of housing on GDP and inflation is allowed to pick up significantly. The effect of a stock-price shock on GDP and inflation is instead small; in fact, the effect of the stock-price shock on inflation is not even significant.

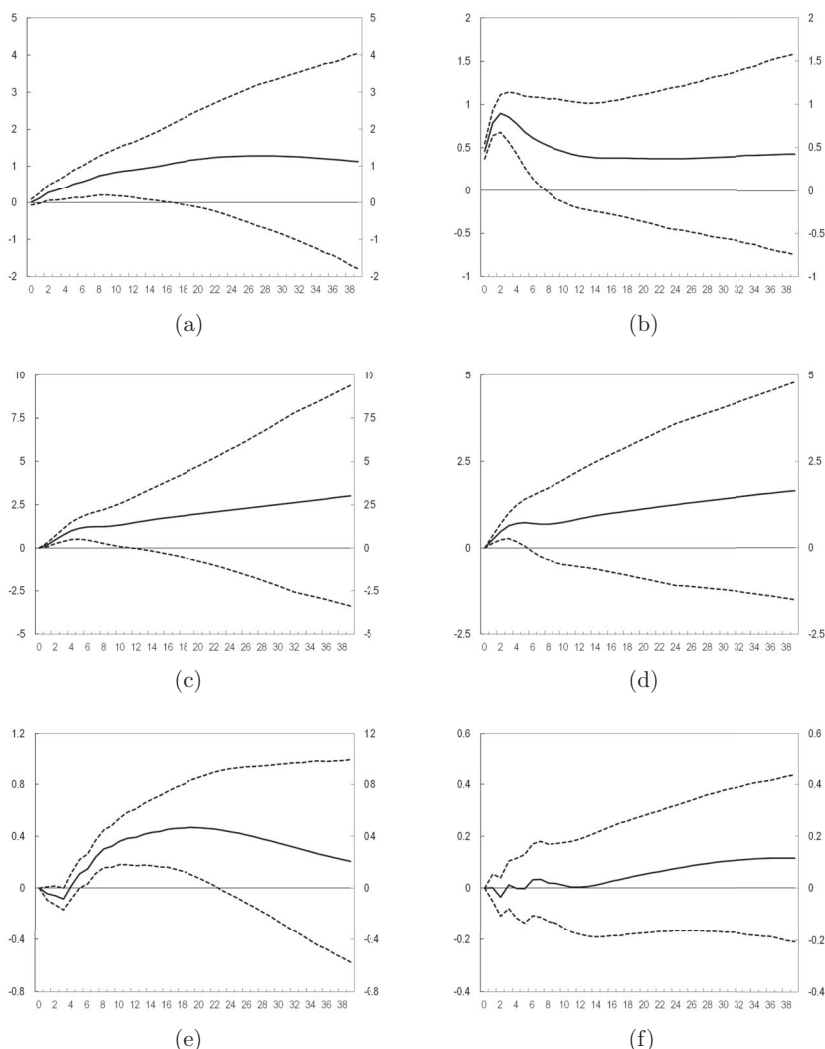


Fig. 3. Responses to a house-price shock (left) and a stock-price shock (right): (a) Interest rate (pp): house-price shock; (b) Interest rate (pp): stock-price shock; (c) GDP (pct): house-price shock; (d) GDP (pct): stock-price shock; (e) Inflation (pp): house-price shock; (f) Inflation (pp): stock-price shock.

This is illustrated further in Figure 4, where we examine variance decompositions. Figures 4(a), 4(c), and 4(e) plot the variance decomposition of interest rates, GDP, and inflation, respectively, with respect to a house-price shock, while Figures 4(b), 4(d), and 4(f) show the variance decomposition of the same three variables with respect to a stock-price shock.

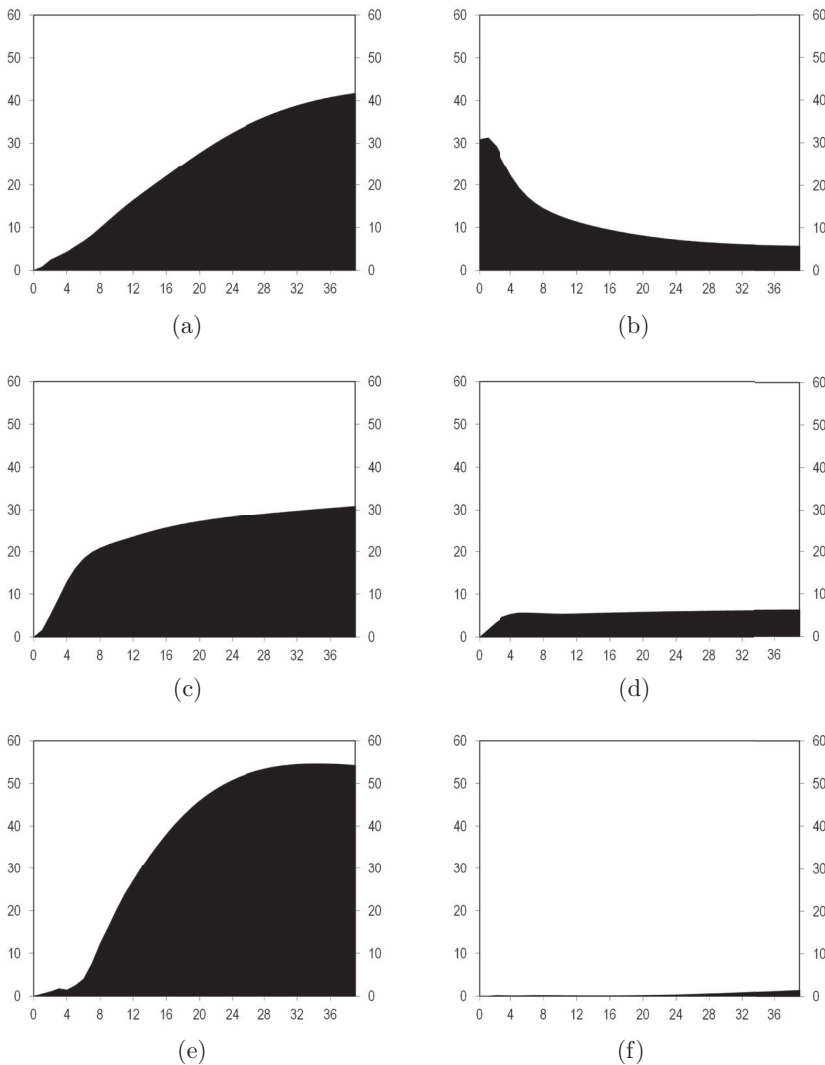


Fig. 4. Variance decomposition (pct) to a house-price shock (left) and a stock-price shock (right): (a) Interest rate: house-price shock; (b) Interest rate: stock-price shock; (c) GDP: house-price shock; (d) GDP: stock-price shock; (e) Inflation: house-price shock; (f) Inflation: stock-price shock.

While stock-price shocks explain almost 30 percent of the initial variation in interest rates, house-price shocks explain less than 5 percent of the interest-rate variation in the first year. Thereafter, the contribution is reversed, so that the effects of stock-price shocks decline quickly,

while house-price shocks increase their contribution, explaining more than 30 percent of the variation in interest rates after five years.¹⁶

Regarding the other variables, house-price shocks already explain 10 percent of the GDP variation after one year, increasing to 20–30 percent after three years, where it stabilizes. The contribution to inflation is practically zero in the first year, but thereafter increases quickly, stabilizing at around 40–50 percent after five years. However, the contribution of stock-price shocks to GDP and inflation is trivial, explaining less than 5 percent of the variation at all horizons.

Hence, monetary-policy responses to shocks in the two asset prices are strikingly different: while a shock to stock prices influences the interest-rate setting immediately, a shock to house prices affects monetary-policy conduct only slowly. This could indicate that monetary policy has primarily reacted to the indirect effects of house-price innovations (i.e., to changes in output and inflation) and not to the initial effect of the shocks. The lack of a swift monetary-policy response to the house-price shock allows for large and persistent effects on the variation of GDP and inflation. In contrast, the stock-price shock, which is followed by an immediate change in interest rates, has small or negligible effects on economic activity. Although we should be cautious of letting an estimated VAR model provide a basis for counterfactual reasoning, the results suggest that if, at least, a stronger short-term monetary-policy response was in effect following house-price shocks, it might neutralize some of the effects on real activity and inflation.

Historical Decomposition

Now, we turn to the historical decompositions that attribute the overall variance to different historical periods. Accordingly, Figure 5(a) portrays the contribution of monetary-policy shocks (dotted line), together with the actual quarterly percentage growth of real house prices (solid line) in each period. Correspondingly, Figure 5(b) displays the contribution of the same shocks to the quarterly growth of real stock prices (solid line) in each period.¹⁷

Figure 5(a) emphasizes how expansionary monetary-policy shocks have contributed to boost house prices in many periods, in particular from

¹⁶ Note that, while the effect is not significant at longer horizons, the shocks still account for the total variance of all variables at every horizon, and therefore also provide information about the long-term relative importance of a shock. Consequently, we report variance decompositions over all horizons, even though long-term impulse responses are essentially zero as shocks die out.

¹⁷ While variance decompositions highlight the relative importance of shocks, on average, the historical decomposition clarifies the time-varying contributions from shocks to the fluctuations of variables.

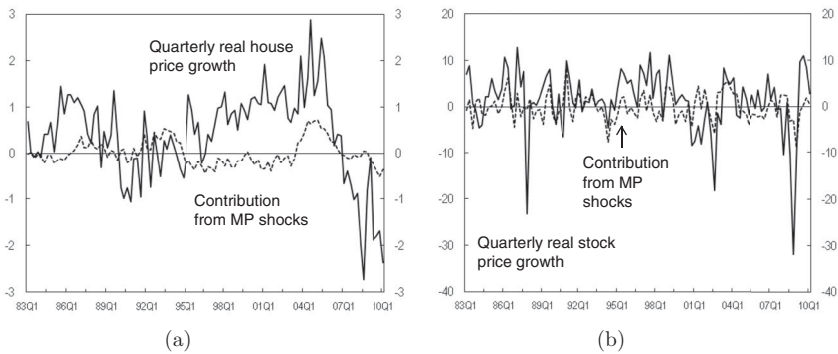


Fig. 5. Contribution from monetary-policy shocks to house-price growth (left) and stock-price growth (right): (a) Real house-price growth (pct); (b) Real stock-price growth (pct).

mid-2003 to mid-2006. This is consistent with the results found by Chauvet and Huang (2010), who have argued that the uncertainty surrounding the end of the 2001 recession led the Federal Reserve to keep interest rates low during the recovery period in 2002–2004, which worked as a seed for the markedly strong run-up of house prices in the 2000s. Concerning the effect of monetary policy on real stock prices, Figure 5(b) illustrates that the volatility of stock prices is quite high relative to the contributions from monetary-policy shocks, yet the two series are fairly correlated.¹⁸ Expansionary monetary-policy shocks contributed positively from the end of 2002 to mid-2004, confirming the significance of monetary-policy shocks in the first half of the 2000s.

Finally, we focus on the reverse causation. In particular, Figure 6(a) shows the contribution of house-price shocks to the federal funds rate in each period, while Figure 6(b) displays the contribution of stock-price shocks to the federal funds rate. Clearly, because of the delayed but persistent effects of housing on monetary policy (see Figure 3), house-price shocks have contributed to the increase of the interest rate since the mid-1990s and until the recent financial crisis. Hence, without the house-price shocks, monetary policy would have been even more expansionary in this period (in particular, after the 2001 recession). This illustrates that house-price developments might have had a substantial effect on the business cycle and (therefore) monetary policy.

Figure 6(b) shows the impact of shocks to real stock prices on monetary policy. The stock market “dot-com bubble”, covering roughly the period 1995–2000, clearly contributed contractionarily to monetary policy in the latter half of the 1990s. However, negative stock-price shocks contributed

¹⁸ A correlation coefficient of 0.42.

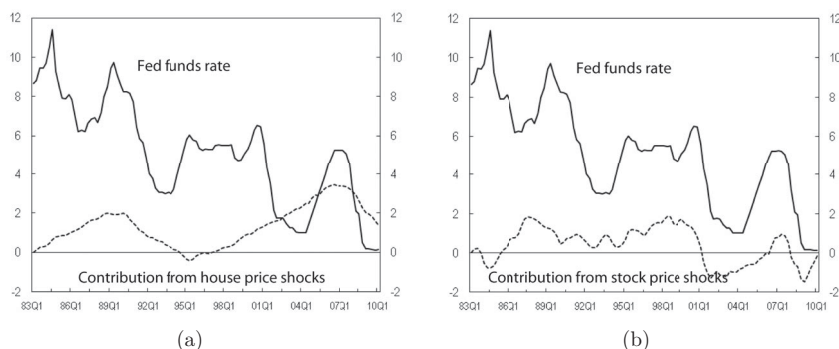


Fig. 6. Contribution from house-price shocks (left) and stock-price shocks (right) to the federal funds rate (a) Interest rate (pp); (b) Interest rate (pp).

to the reduction of the interest rate from Q2 in 2001 until 2006 Q2, and again from 2008 Q1. This emphasizes the importance of stock prices as early warnings of recessions.

IV. Robustness

We report on the robustness tests of our preferred model with regard to the responses of interest rates, house prices, and stock prices (the results for the other variables can be obtained on request). We examine robustness first to the chosen identification and then to model specifications.

Sign Restrictions

We test for a possible interaction between US monetary policy and house/stock prices using sign restrictions. We do this by including house prices and stock prices in two separate VAR models, each consisting of GDP, inflation, and interest rates. As in the baseline model, the VAR model is identified by assuming a recursive order for GDP, inflation, and interest rates. To identify asset prices, we now impose the restriction that house prices and stock prices must react non-positively on impact, following a contractionary monetary-policy shock. This assumption is consistent with the findings of Del Negro and Otrok (2007) regarding house prices, and those of Rigobon and Sack (2004) and Bernanke and Kuttner (2005) concerning stock prices. However, the restriction is in place for one period only, allowing house prices and stock prices to move in any direction after that. More importantly, we do not impose any restrictions on the converse relationship (i.e., whether monetary policy is responding to shocks in asset prices, which is the focal question of this paper).

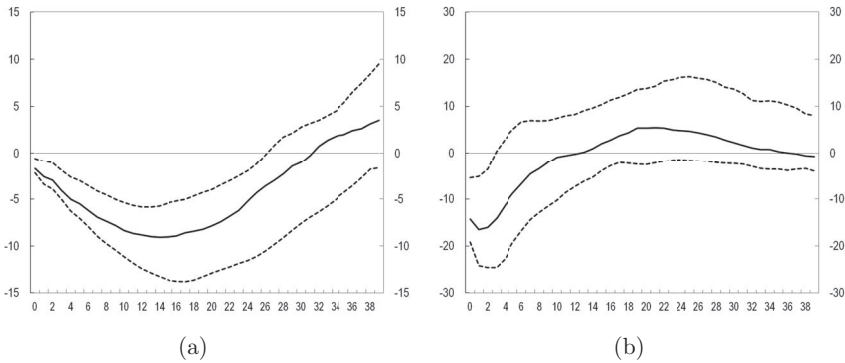


Fig. 7. Responses to a monetary-policy shock, sign restrictions: (a) Real house prices (pct); (b) Real stock prices (pct).

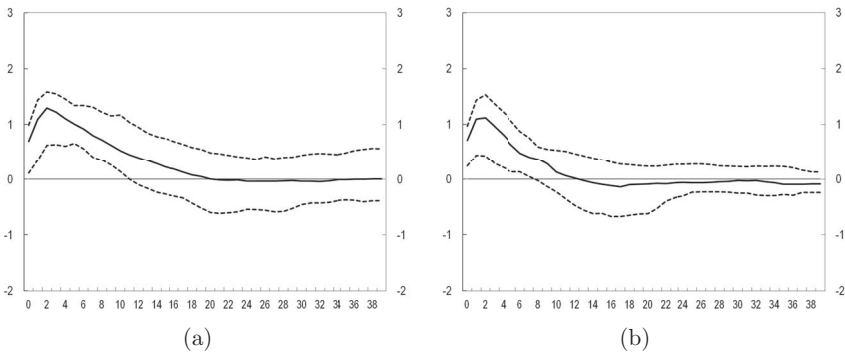


Fig. 8. Responses to a house-price shock (left) and a stock-price shock (right), sign restrictions: (a) Interest rate (pp); (b) Interest rate (pp).

Figure 7(a) portrays the impulse response of house prices to a monetary-policy shock using the VAR model where we have included real house prices. Then, Figure 7(b) displays the response in stock prices to the same monetary-policy shock, except that that real house prices are replaced with real stock prices in the VAR model. In both cases, the monetary-policy shock is normalized to increase the interest rates by one percentage point in the first quarter. Finally, Figures 8(a) and 8(b) plot the response of interest rates from shocks to house prices and to stock prices, respectively (again using the two different structural VAR models). Note that, as above, the stock-price shock is normalized to increase stock prices by 10 percent in the first quarter, while the house-price shock is normalized to increase

house prices by 1 percent initially. The reported median responses are plotted with probability bands represented as 0.16 and 0.84 fractiles.¹⁹

The figures confirm the results presented so far. A contractionary monetary-policy shock reduces both house prices and stock prices on impact, although the contemporaneous response is much larger for stock prices than for house prices. Following the initial reaction, the response of stock prices dies out quickly, while house prices continue to decline gradually for four to five years, until the effect dies out. Hence, monetary policy has a much more persistent and delayed effect on house prices than on stock prices. This confirms the plausibility of the restrictions imposed above.

Turning to systematic monetary policy, as found above, there is clearly a significant interest-rate response following a shock in house prices (Figure 8(a)) or stock prices (Figure 8(b)). Judging by the median response, the interest rate increases for a few quarters following both shocks, before the effect dies out.

Hence, using either long-term or sign restrictions, there is clear evidence of simultaneity between monetary policy and house prices/stock prices, although monetary-policy shocks have a more delayed effect on real house prices than on real stock prices.

Alternative Model Specifications

Figures 9 and 10 report robustness to the following stepwise changes. First, we let the estimation period start in 1987 (1987 Q3) and end just before the financial crisis (2006 Q4), in order to analyze the Greenspan effect in a more stable monetary-policy regime (i.e., 1987–2006).²⁰ Second, we use six lags in the VAR model instead of our preferred four lags (i.e., six lags). Third, we remove the two impulse dummies (1984 Q4 and 1987 Q4) that we have used in the VAR model (i.e., no impulse dummies). Fourth, an impulse dummy for 2008 Q3 is also included to control for a possible break in the variance as a result of the impact of the financial crisis (i.e., controlling for Lehman).²¹

Finally, we include two robustness tests that are specific to stock prices and house prices respectively. That is, we test robustness by adding an

¹⁹ We apply a Bayesian numerical inference method, similar to Uhlig (2005). The approach can be separated into two stages. In the first step, draws are made for the posterior distribution of the reduced-form VAR coefficients. Conditioned on each of these draws, the second part involves a procedure with orthogonal draws for the contemporaneous matrix, where only draws that fulfill the imposed sign restrictions are kept.

²⁰ Alan Greenspan took office in August 1987.

²¹ As an alternative, we included a step dummy in order to control more broadly for the Great Recession. The step dummy is zero prior to 2008 Q3, and takes the value of 1 thereafter. Also, in this case, we obtain responses that are fairly similar to the baseline finding, although slightly weaker at longer horizons.

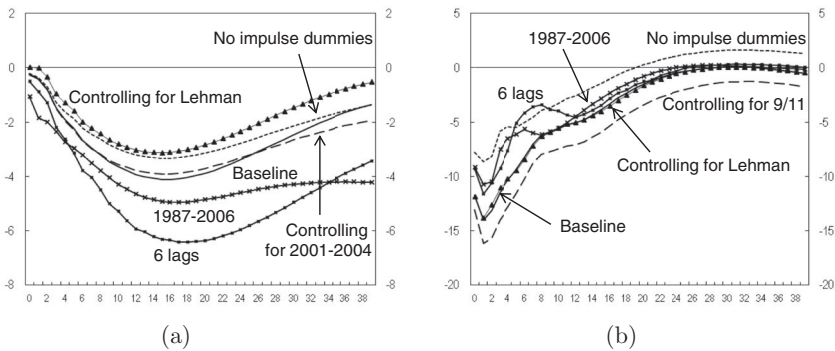


Fig. 9. Robustness: responses to a monetary-policy shock: (a) Real house prices (pct); (b) Real stock prices (pct).

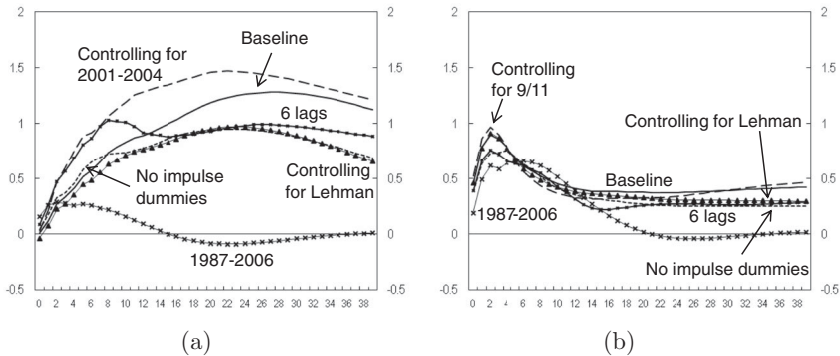


Fig. 10. Robustness: responses to a house-price shock (left) and a stock-price shock (right): (a) Interest rate (pp); (b) Interest rate (pp).

impulse dummy, 2001 Q3, to control for the stock-market turmoil corresponding to 9/11 (i.e., controlling for 9/11). Then, we add a dummy for the period 2001–2004, to examine whether the link between monetary policy and house prices might have been different in this period when interest rates were kept exceptionally low. Again, see Chauvet and Huang (2010), who have argued that the uncertainty surrounding the end of the 2001 recession led the Federal Reserve to keep interest rates low during the recovery period in 2002–2004, which differed from monetary-policy conduct in other early stages of expansion (i.e., controlling for 2001–2004). While these two dummies might potentially affect the whole system, we focus the discussion and report on the results of the first test only to stock prices and the second test only to house prices.

Figures 9 and 10 illustrate that the robustness tests give support to our main conclusions. However, two findings should be pointed out. First, we note that the systematic response in monetary policy to a house-price shock is much smaller in the period 1987–2006, when Alan Greenspan was chairman (Figure 10(a)). However, the monetary-policy response to stock prices is much the same. Hence, monetary policy responded much more to variations in stock prices than to house prices in the Greenspan era (Figure 10(b)).

Second, the addition of a dummy in the period 2001–2004 produces even larger monetary-policy responses to a house-price shock (Figure 10(a)). As pointed out by Chauvet and Huang (2010), the inter-relationship between monetary policy and the housing cycle has changed since the 2001 recession. When including a dummy for this period (accounting for an altered relationship), we obtain a stronger systematic monetary-policy response for the whole period, on average. However, while this implies that monetary policy has responded less to housing and more to other factors in the period 2001–2004, the effect of monetary-policy shocks on house prices was basically unchanged (Figure 9(a)).

Impulse Responses Using Cholesky Decomposition

Finally, we ask what we have gained by 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 and stock prices are ordered above the interest rate), the Cholesky decomposition will imply that asset prices cannot respond contemporaneously to a monetary-policy shock. Similar restrictions have been used by Goodhart and Hofmann (2001) and Giuliodori (2005).

In Figures 11(a) and 11(b), we compare the results for house prices and stock prices using our structural decomposition with the findings from the Cholesky decomposition. The solid line is our baseline impulse response using the structural VAR model, while the dotted line is the impulse response from the Cholesky decomposition. The results emphasize that the effects of monetary-policy shocks on both house prices and stock prices would be much smaller using the Cholesky decompositions than using our preferred identification scheme. In fact, the stock-price response has the wrong sign when using the Cholesky decomposition. Hence, it seems to be important to account for interdependence between monetary policy, house prices, and stock prices.

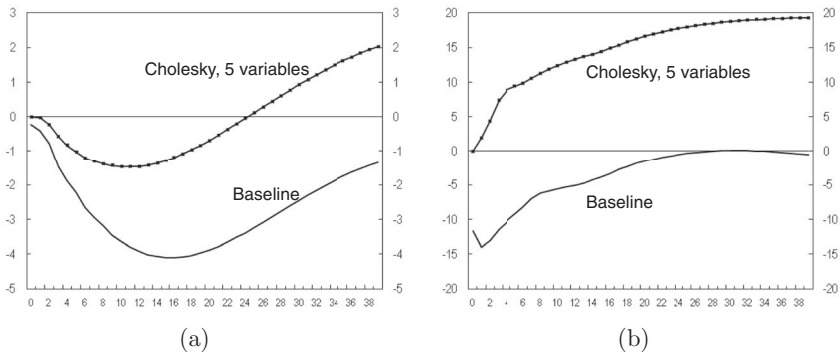


Fig. 11. Response to a monetary-policy shock, Cholesky versus structural VAR: (a) Real house prices (pct); (b) Real stock prices (pct).

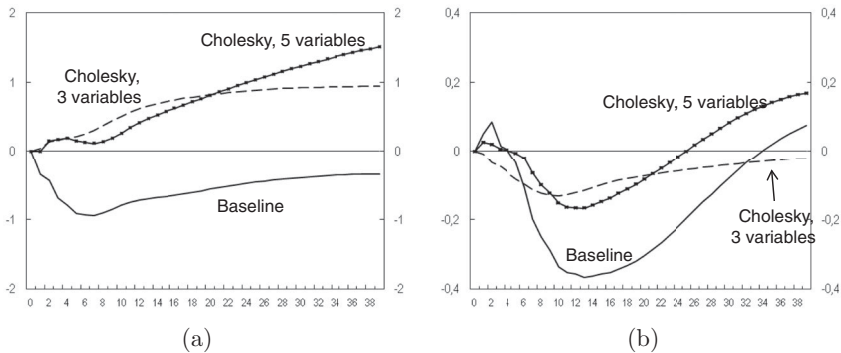


Fig. 12. Response to a monetary-policy shock, Cholesky versus structural VAR: (a) GDP (pct); (b) Inflation (pp).

In Figures 12(a) and 12(b), we 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 model, and ask to what extent the responses in GDP and inflation will depend on the inclusion of these financial variables. Hence, in these figures, we compare our baseline structural VAR results with the following: (i) a VAR model with only three domestic variables, identified using the Cholesky decomposition with the ordering – output, inflation, and interest rate (denoted by Cholesky, 3 variables); (ii) our original baseline VAR model, but now identified using the Cholesky decomposition, where house prices respond with a lag to monetary-policy shocks (denoted by Cholesky, 5 variables).

Figure 12(a) emphasizes that when using either the three- or five-variable VAR model with the Cholesky decomposition, output responds very little

following a contractionary monetary-policy shock and, in fact, with the wrong sign. Only when we include all asset prices and use our structural identification scheme, does GDP respond significantly negatively for a prolonged period. The same holds for inflation in Figure 4(b), although there all models imply an eventual decline in inflation. Hence, we have shown that by adding just a few series of relevant financial variables and by using an identification procedure that allows for contemporaneous interaction between monetary policy and asset prices, we can enhance the negative response in output and inflation that has traditionally been reported in other studies.

V. Concluding Remarks

In this paper, we have analyzed the role of house prices and stock prices in the monetary transmission mechanism in the US. The quantitative effects of monetary-policy shocks are studied through structural VAR models. Contrary to recent studies, we allow for full interdependence between monetary policy and both house prices and stock prices. Identification is achieved by imposing a combination of short-term and long-term restrictions.

By allowing for simultaneity between monetary policy and house/stock prices, we find different roles for asset prices in the monetary transmission mechanism. In particular, following a contractionary monetary-policy shock (which raises the interest rate), stock prices fall immediately, while the response is more gradual for house prices. However, the fall in both house prices and stock prices enhances the negative response in output and inflation that has traditionally been found in the literature. Regarding the systematic interest-rate response, monetary policy responds less to shocks in house prices than to shocks in stock prices in the short term, but the relationship is reversed in the long term. In part because of the delayed monetary-policy response to house-price shocks, house prices have a much larger impact on both GDP and inflation than stock prices.

Appendix: Data

The following data series are used:

- the log of real GDP, s.a., y_t (source: OECD Economic Outlook);
- inflation, π_t , measured as the annual change in the log of the GDP deflator (source: OECD Economic Outlook);
- the log of real house prices, s.a., ph_t , with house prices deflated by the GDP deflator and using the FHFA HPI (source: Thomson Reuters);
- the log of real stock prices, s_t , with stock prices deflated by the GDP deflator and using the S&P 500 as the stock-price index (source: Thomson Reuters);
- the federal funds effective rate, i_t (source: Thomson Reuters).

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