Macroeconomic Dynamics, **17**, 2013, 830–860. Printed in the United States of America.
doi:10.1017/S1365100511000721

MONETARY POLICY, HOUSING BOOMS, AND FINANCIAL (IM)BALANCES

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This paper applies a factor-augmented vector autoregressive model to U.S. data with the aim of analyzing monetary transmission via private sector balance sheets, credit risk spreads, and house prices and of exploring the role of monetary policy in the housing and credit boom prior to the global financial crisis. We find that monetary policy shocks have a persistent effect on house prices, real estate wealth, and private sector debt and a strong short-lived effect on risk spreads in money and mortgage markets. Moreover, the results suggest that monetary policy contributed considerably to the unsustainable precrisis developments in housing and credit markets. Although monetary policy shocks contributed discernibly at a late stage of the boom, feedback effects of other (macroeconomic and financial) shocks via lower policy rates kicked in earlier and appear to have been considerable.

Keywords: Monetary Policy, Private Sector Balance Sheets, Asset Prices, Housing

1. INTRODUCTION

The impact of monetary policy shocks on financial conditions, i.e., asset prices, lending terms, and balance sheets, has been one of the most topical issues in monetary economics over recent years. Interest in the topic has recently gained further impetus from the coincidence of rapid property price inflation ("housing

The views expressed in this paper do not necessarily reflect the views of the European Central Bank, the Bank for International Settlements, or the Deutsche Bundesbank. The paper was mainly written while the second author was affiliated with the European Central Bank. We would like to thank participants in workshops/seminars of the Bundesbank, the ZEW, the People's Bank of China, the ECB, the Reserve Bank of Australia, and the Bank of Canada, as well as the 5th Conference on Growth and Business Cycles in Theory and Practice (Manchester), the 15th International Conference on Panel Data (Bonn), the conference on Computing in Economics and Finance (Sydney), the BIS/ECB workshop on Monetary Policy and Financial Stability (Basel), and the 12th Annual DNB Research Conference on "Housing and Credit Dynamics: Causes and Consequences" (Amsterdam), for useful comments. In particular, helpful comments and suggestions by our discussants Katrin Assenmacher-Wesche, Guido Bulligan, Mathias Drehmann, Gabriele Galati, Gert Peersman, and Timo Wollmershäuser, as well as by Heinz Herrmann, Wolfgang Lemke, Roberto Motto, Massimo Rostagno, Harald Uhlig, Alexander Wolman, and three anonymous referees, are gratefully acknowledged. All errors are our own responsibility. Address correspondence to: Boris Hofmann, Bank for International Settlements, Centralbahnplatz 2, 4002 Basel, Switzerland; e-mail: boris.hofmann@bis.org.

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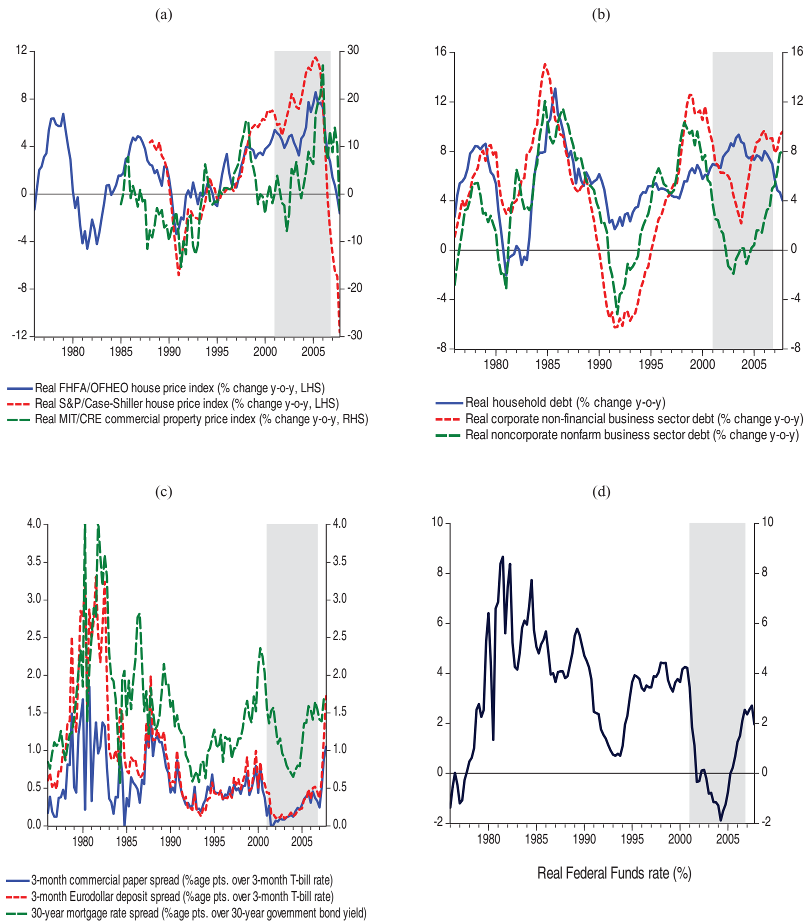

FIGURE 1. Property prices (a), private sector debt (b), credit risk spreads (c), and monetary policy rate (d). Real property prices and real debt have been computed by deflating with the GDP deflator. The real Federal Funds rate is the effective Federal Funds rate less the year-on-year change in the GDP deflator. *Sources:* St. Louis FRED, OFHEO, Bureau of the Census, Federal Reserve Board, authors' calculations.

bubble"), a massive expansion of private sector indebtedness ("credit bubble"), and very low risk spreads in credit markets ("underpricing of risk") on one side, and, on the other, exceptionally low levels of policy rates in the United States prior to the outbreak of the global financial crisis, i.e., between 2001 and 2006, as shown in Figure 1. This coincidence has led a number of observers—most prominently the Bank for International Settlements (2007, 2008) and Taylor (2007, 2009)—to argue that an excessively loose monetary policy stance was one of the key factors contributing to the imbalances in housing and credit markets prior to the crisis.[1]

The goal of this paper is to contribute to the literature on the transmission of monetary policy via financial conditions and to explore the role of monetary policy in the buildup of imbalances in property and credit markets before the financial crisis. To this end, we employ a factor-augmented vector autoregressive (FAVAR) model, a novel empirical tool proposed by Bernanke et al. (2005). The model enables us to analyze monetary transmission over a wide range of financial variables, i.e., property and stock prices, interest rates, credit risk spreads, and nonfinancial private sector assets and liabilities,[2] based on a unified, consistent modeling framework exploiting the close correlation between these variables indicated by Figure 1. More specifically, the FAVAR model developed in this paper extends a standard macroeconomic vector autoregressive (VAR) model with a set of (financial) factors summarizing more than 200 quarterly financial variables.[3] To identify the monetary policy shock, we adopt an identification scheme that combines contemporaneous zero restrictions and theoretically motivated sign restrictions on short-term impulse-response functions (see, e.g., Peersman 2005 and Uhlig 2005), allowing for contemporaneous interaction between the policy rate and financial factors. This identification scheme further enables us to disentangle macroeconomic shocks (which are defined here as shocks to real growth and inflation) and shocks to financial factors.

The two main contributions of the paper are the following. First, we provide a unified and comprehensive characterization of the transmission of monetary policy shocks via financial conditions, covering a broad range of asset prices, interest rates, risk spreads and private sector balance sheet components by means of impulse-response analysis. This is novel, as the related existing literature has so far focused on specific aspects of monetary transmission,[4] whereas a comprehensive analysis of the transmission of monetary policy shocks via financial conditions encompassing all these specific aspects is still missing. The impulse-response analysis allows assessment of the relative strength of monetary transmission via different asset markets, credit markets, and balance sheets and sheds light on the relevance of financial frictions in the transmission process.

Second, we assess the role of monetary policy in the buildup of the precrisis imbalances in housing and credit markets. A number of recent academic studies have explored the contribution of monetary policy shocks, i.e., the deviation of policy rates from their estimated usual reaction patterns or some postulated reaction pattern (Taylor rule) to the housing boom [Del Negro and Otrok (2007), Taylor (2007), Iacoviello and Neri (2010), Jarociñski and Smets (2008)], but without coming to consistent conclusions. In this paper we assess, based on historical decompositions, the role of monetary policy shocks in the housing boom as well as in the two other precrisis phenomena highlighted in Figure 1—the excessive debt accumulation in the private nonfinancial sector and the low risk spreads in credit markets, which have so far remained unexplored. In this context, we also show that the inconsistencies in the results regarding the role of monetary policy shocks in the housing boom produced by previous studies can be linked to differences in sample periods.

Besides assessing the role of monetary policy shocks, we also explore, based on counterfactual simulations, the role of systematic monetary policy, i.e., of the estimated reaction of the policy rate to shocks to financial factors and to macroeconomic shocks. Because we allow for contemporaneous interaction between policy rates and financial factors, we can explore not only the effects of monetary policy shocks on financial variables, but also the effect of innovations in financial factors on the path of policy rates over time. Via counterfactual simulations, we then explore to what extent the reaction of monetary policy to these innovations has fed back to housing and credit markets. In this way, we can tentatively assess the widely held view that the monetary easing in reaction to the bursting of the stock market bubble after 2000 contributed to the subsequent housing and debt boom.

The main findings of our analysis are as follows. (i) Monetary policy shocks have a highly significant and persistent effect on property prices, real estate wealth, and private sector debt, as well as a strong short-lived effect on risk spreads in the money and mortgage markets. (ii) Monetary policy contributed considerably to the unsustainable developments in housing and credit markets that were observable between 2001 and 2006. Although monetary policy shocks discernibly contributed at a late stage of the boom, feedback effects of other (macroeconomic and financial) shocks via lower policy rates on property and credit markets probably kicked in earlier and were considerable.

The remainder of the paper is organized as follows. We present the data in Section 2 and explain the methodology in Section 3. In Section 4 we analyze the dynamic effects of monetary policy shocks on asset prices, interest rates, and balance sheets. In Section 5 we assess the role of monetary policy in the precrisis financial imbalances. Section 6 concludes.

2. DATA

The quarterly data set used in this study is composed of three standard macro variables, real GDP growth, GDP deflator inflation, and the effective Federal Funds rate [retrieved from the St. Louis Federal Reserve Economic Data (FRED) database], as well as 232 financial variables comprising 69 property prices, 62 stock market indices, 50 money, capital, and loan interest rates and spreads, 2 monetary aggregates, and 49 series from private nonfinancial sector balance sheets. Stock prices, property prices, monetary aggregates, and balance sheet variables were converted to real units by deflation with the GDP deflator. The choice of variables is determined by data availability, as well as the aim to estimate the financial factors accurately by including a sufficiently large number of financial series [Bai and Ng (2002)] and, in this vein, to balance the data set among the different groups of financial series sufficiently to give them a similar weight when the factors are estimated. In the following we provide a brief description of the main characteristics of the different data categories. A complete list of all the financial variables, the data sources, and how the data series have been transformed for the empirical analysis is provided in the Online Data Appendix (Table A.1).

The property price block of our database is mainly composed of the set of FHFA/OFHEO house price indices for the U.S. national level and the 51 U.S. states, the national Freddie Mac conventional home loan price indices, the national and regional Census Bureau house price series measuring the mean and median price developments of new single-family homes, the National Association of Realtors (NAR) house price index, the S&P/Case–Shiller national house price index, and the MIT/CRE commercial property price index.[5]

The stock price block of our data set is composed of the S&P 500, summarizing the share price development of the 500 largest listed U.S. companies weighted by market capitalization, and its 59 sectoral subindices. Besides the S&P indices, we also include the Dow Jones Industrials Average, which summarizes the share price development of 30 companies listed on the NYSE, and the NASDAQ composite index, which summarizes the share prices of more than 3,000 firms listed on the NASDAQ stock market.

The set of interest rates included in our data set comprises a large range of money and capital market interest rates, including Treasury bill rates, Treasury bond yields, commercial paper rates, and corporate bond yields, as well as rates on certificates of deposit and Eurodollar deposits. We further include a wide range of retail lending interest rates, such as mortgage loan rates, consumer loan rates, and commercial and industrial (C&I) loan rates. Based on these interest rates, we construct various risk spreads by taking the difference between the respective interest rate and an appropriate risk-free benchmark interest rate.

The two monetary aggregates included in the database are the Federal Reserve Board's two money stock measures, M1 and M2. The balance sheet data from the Federal Reserve's Flow of Funds Accounts (Tables B.100, B.102, and B.103) cover the household sector (also including nonprofit organizations), the nonfinancial corporate sector, and the nonfarm noncorporate sector. Balance sheets for the financial sector are not available. The main difference between the flow of funds accounts, which have been used in Christiano et al. (1996), and the balance sheets is that the former provide information exclusively on flows of financial assets and liabilities of the different sectors, whereas the latter provide information on the value of the stock of the various components of the three sectors' assets and liabilities (including nonfinancial assets) and their net worth, i.e., the difference between total assets and total liabilities. Stock market and real estate wealth are valued at market prices; other tangible assets (equipment and software, consumer nondurable goods, and inventories) are valued at replacement costs. All other components of assets and liabilities are valued at book value. For more details on the balance sheet data, see Federal Reserve Board (2009).

The data are transformed in the usual manner for factor analysis; i.e., they are standardized to have zero mean and unit variance. Stationarity of the variables is ensured through differencing if necessary: all variables enter in log differences except for interest rates and spreads, which enter in levels. Finally, outliers are removed as follows. Outliers are defined as observations of the stationary data with absolute median deviations larger than six times the interquartile range. They are replaced by the median values of the preceding five observations; see also Stock and Watson (2005).

The baseline sample period for the analysis is 1987Q3 to 2007Q4. This period covers essentially the Greenspan chairmanship and therefore focuses the analysis on a single monetary policy regime. In Section 5.1 we also consider a longer sample period starting in 1975Q1 in order to reconcile the already mentioned inconsistencies in the results reported by previous studies on the role of monetary policy in the recent housing boom, which appear to be related to the choice of sample period.

3. METHODOLOGY

We start from a small-scale macroeconomic VAR model that includes real GDP growth (Δy_t), GDP deflator inflation (Δp_t), and the Federal Funds rate (ffr_t) as endogenous variables that can be summarized in the $\boldsymbol{M}(= 3) \times 1$-dimensional vector $\mathrm{G}_t = [\,\Delta y_t\ \Delta p_t\ ffr_t\,]'$. This set of variables represents the standard block of variables included in monetary policy VARs [e.g., Christiano et al. (1996), Schorfheide and Del Negro (2003), Peersman (2005)]. We augment G_t with a set of factors summarizing a large number of financial variables (or "financial factors") H_t, which yields the $r \times 1$-dimensional vector $\mathrm{F}_t = [\,\mathrm{G}_t'\ \mathrm{H}_t'\,]'$, where $\boldsymbol{r}-\boldsymbol{M}\times 1$ is the dimension of the vector of financial factors. $\mathrm{H}_t = [\,h_{1t}\ \cdots\ h_{r-Mt}\,]'$ is unobserved and needs to be estimated as explained later.

We model the joint dynamics of macro variables and financial factors as a VAR(p) process,

$$\mathrm{A}(L)\mathrm{F}_t = \mathrm{c} + \mathrm{Q}\mathrm{w}_t, \tag{1}$$

where $\mathrm{A}(L) = I - \mathrm{A}_1 L - \cdots - \mathrm{A}_p L^p$ is a lag polynomial of finite order p, c is a constant, and w_t is a vector of structural shocks that can be recovered by imposing restrictions on Q.

Let the elements of F_t be the common factors driving the $N \times 1$ vector X_t, which summarizes our 232 ($= \boldsymbol{N}$) financial variables. It is assumed that X_t follows an approximate dynamic factor model [e.g., Bai and Ng (2002), Stock and Watson (2002)],

$$\mathrm{X}_t = \Lambda'\mathrm{F}_t + \Xi_t, \tag{2}$$

where $\Xi_t = [\,\xi_{1t}\ \cdots\ \xi_{Nt}\,]'$ denotes an $N \times 1$ vector of idiosyncratic components.[6] The matrix of factor loadings $\Lambda = [\,\boldsymbol{\lambda}_1\ \cdots\ \boldsymbol{\lambda}_N\,]$ has dimension $\boldsymbol{r} \times \boldsymbol{N}$ and $\boldsymbol{\lambda}_i, \boldsymbol{i} = 1, \ldots, \boldsymbol{N}$, are of dimension $\boldsymbol{r} \times 1$. Typically, $\boldsymbol{r} \ll \boldsymbol{N}$. Common and idiosyncratic components are orthogonal, the common factors are mutually orthogonal, and idiosyncratic components can be weakly mutually and serially correlated in the sense of Chamberlain and Rothschild (1983).[7]

Both equations (1) and (2) thus represent the FAVAR model suggested by Bernanke et al. (2005).[8]

TABLE 1. Monetary policy shock identifying restrictions

horizon	y	p	ffr	Monet. aggregates
0	0	0	≥ 0	≤ 0
1–3	≤ 0	≤ 0	≥ 0	≤ 0

Note: y, p, and ffr refer to GDP, the GDP deflator, and the Federal Funds rate, respectively. Monetary aggregates are defined as M1 and M2 divided by the GDP deflator.

The model is estimated in five steps. First, the dimension of F_t, i.e., the number of common (latent and observable) factors r, is determined to be six, which explain roughly two-thirds (64%) of the variance of the data set. This represents a reasonable degree of comovement between the variables.[9,10]

Second, the latent factors summarized in H_t span the space spanned by F_t after removal of the three observable factors. H_t is estimated by means of the iterative procedure suggested by Boivin and Giannoni (2010). We start with an initial estimate of H_t, denoted by $\hat{H}_t^{(0)}$ and obtained as the first $\boldsymbol{r} - \boldsymbol{M} = 3$ principal components of X_t. We then regress X_t on $\hat{H}_t^{(0)}$ and G_t to obtain $\hat{\Lambda}_G^{(0)}$, the loadings associated with G_t. We compute $\tilde{X}_t^{(0)} = X_t - \hat{\Lambda}_G^{(0)} G_t$ and estimate $\hat{H}_t^{(1)}$ as the first $r - M$ principal components of $\tilde{X}_t^{(0)}$. This procedure is repeated until convergence, and we are left with final estimates of H_t and the loadings' matrix Λ.

Third, a VAR(2) model is fitted to $[\,G_t' \;\hat{H}_t'\,]'$.

The fourth step involves identifying the monetary policy shocks. We follow Bernanke et al. (2005) by separating the variables into a block of slow-moving variables, which are assumed not to be contemporaneously affected by monetary policy shocks, and a block of fast-moving variables, which are allowed to react within a quarter to interest rate innovations. The group of slow-moving variables is formed by the macro variables, i.e., real GDP growth and GDP deflator inflation. The financial factors constitute the group of fast-moving variables. Instead of applying a full-fledged recursive identification scheme to identify the monetary policy shock, we use a scheme that combines contemporaneous zero and short-run sign restrictions on impulse-response functions, allowing contemporaneous interaction between the Federal Funds rate and the financial factors. This is important, as the financial factors, which also include financial variables such as stock prices and bond yields, would not be expected to respond instantaneously only to shocks to, or news about, the monetary policy stance. Monetary policy makers would also be expected to instantaneously process information on high-frequency financial variables. Thus, in order to obtain an unbiased characterization of the transmission of monetary policy shocks as well as of the monetary policy stance, it is necessary to allow contemporaneous interaction between the policy rate and the financial factors.

The restrictions for the identification of monetary policy shocks are summarized in Table 1. A contractionary monetary policy shock is defined to be a shock that (i) has no effect on prices and output on impact; (ii) has nonpositive effects on prices and output at horizons one, two, and three quarters; and (iii) has a nonnegative effect on the Federal Funds rate and a nonpositive effect on the monetary aggregate on impact and at horizons one, two, and three quarters. Other structural shocks are left unidentified.

The identification scheme is implemented in two steps. In a first step, we carry out a Cholesky decomposition of the covariance matrix of the reduced-form VAR residuals, where GDP and prices are ordered above the Federal Funds rate and the (latent) financial factors are summarized in $\hat{\mathrm{H}}_t$. This yields the restrictions that real GDP and prices are not contemporaneously affected by both monetary policy shocks, as is commonly assumed in monetary transmission studies relying on recursive identification schemes, and shocks to the financial factors $\hat{\mathrm{H}}_t$. At the same time, financial factors and the policy rate can immediately respond to shocks to real growth and inflation.

In a second step, we rotate the Cholesky residuals associated with the $\boldsymbol{M}$th to $\boldsymbol{r}$th equations (i.e., the equations of the Federal Funds rate and $\hat{\mathrm{H}}_t$) and impose sign restrictions in order to disentangle the monetary policy shocks from other shocks. To identify the monetary policy shocks, we impose a set of standard restrictions, employed, e.g., by Peersman (2005), Benati and Mumtaz (2008), and Canova and Gambetti (2009), and consistent with a large number of theoretical models. The Federal Funds rate increases in the current and the following three quarters in response to the monetary policy shock, whereas real GDP and prices are assumed to fall in the first to third quarter after the shock. Furthermore, we restrict monetary aggregates (real M1 and real M2) to fall instantaneously and for another three quarters after a monetary policy shock. The former restrictions help to distinguish the monetary policy shock further from real aggregate supply and demand shocks. The latter restriction serves to ensure that the monetary policy shock is not contaminated by a money demand shock.[11] The empirical results are robust with respect to the number of restricted lags. More technical details on the identification scheme are provided in Appendix B.

As a byproduct, the identification scheme for the monetary policy shock also enables us to separate macroeconomic shocks and shocks to the financial factors. The identification scheme outlined earlier implies that the shocks to the financial factors are restricted not to have the characteristics of monetary policy shocks and not to affect output and prices contemporaneously. The shocks therefore reflect changes in the financial factors that are unrelated to monetary policy shocks and shocks to growth and inflation. The Cholesky residuals associated with the GDP growth and GDP deflator inflation equations can affect both the policy rate and the financial factors contemporaneously and can be labeled macroeconomic shocks.[12] The separation of macro and financial shocks is important for the assessment of the role of systematic monetary policy performed in Section 5.2. It enables us to assess the respective contribution of innovations in the financial factors and of innovations in the macro variables on the path of policy rates and the associated feedback effects on financial and asset markets.

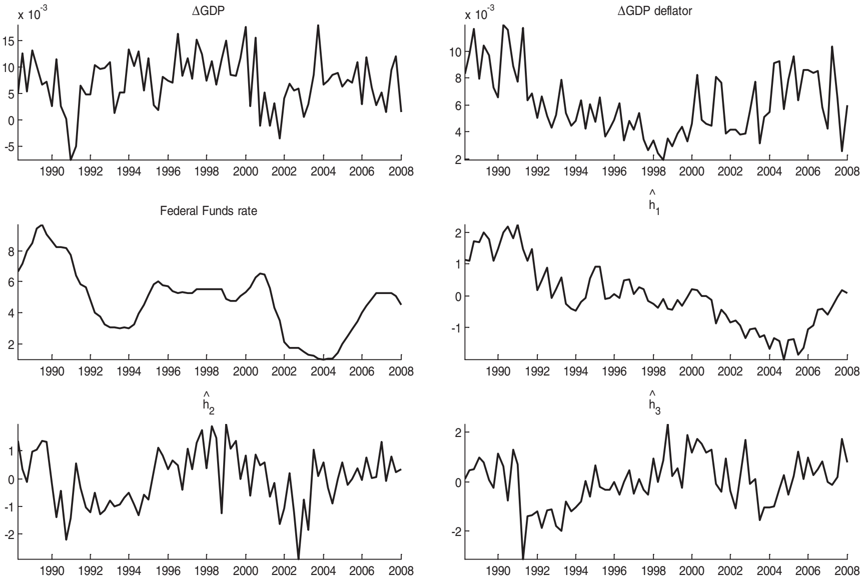

FIGURE 2. Time series of the factors. Each factor is normalized to be positively correlated with the variable that is most highly correlated with it in absolute terms.

In the fifth and final step of the estimation, confidence bands of the impulse-response functions are constructed using the bootstrap-after-bootstrap technique proposed by Kilian (1998). This technique allows us to remove a possible bias in the VAR coefficients, which can arise because of the small sample size. The number of bootstrap replications equals 500. Notice that, because $N > T$, we neglect the uncertainty involved with the estimation of the factors, the loadings, and hence the idiosyncratic components, as also suggested by Bernanke et al. (2005).

4. THE TRANSMISSION OF MONETARY POLICY SHOCKS VIA FINANCIAL CONDITIONS

4.1. Comovement of Financial Variables and Interpretation of the Factors

As the first step of our analysis, we formally assess the comovement of financial variables. The commonality, i.e.. the variance share explained by the common factors, is large for all groups of variables. It is (on the average over all series belonging to a group) 38% for property price inflation measures, 51% for balance sheet components, 82% for credit market interest rates and spreads, and 48% for changes in stock prices.

Figure 2 shows the time series of the observable and the latent financial factors (after removal of observable factors from the factor space). Table 2 shows for each factor the fifteen variables that are most highly correlated (in absolute terms) with

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TABLE 2. Correlation coefficients between factors and most highly correlated variables

	Variable	Δy_t	Variable	Δp_t	Variable	ffr_t	Variable	$\hat{h}_{1t}$	Variable	$\hat{h}_{2t}$	Variable	$\hat{h}_{3t}$
1	111	0.420	18	0.692	185	0.998	221	0.942	122	0.759	113	0.658
2	163	0.373	96	0.668	188	0.998	220	0.941	120	0.759	112	0.629
3	115	0.370	12	0.583	189	0.996	216	0.938	159	0.744	162	0.626
4	88	0.363	7	0.575	186	0.996	218	0.938	164	0.726	130	0.619
5	92	0.356	26	0.565	182	0.994	217	0.937	125	0.703	136	0.610
6	119	0.343	13	0.550	183	0.994	219	0.937	123	0.693	141	0.610
7	118	0.343	31	0.535	200	0.994	213	0.936	176	0.676	229	0.604
8	107	0.336	44	0.507	190	0.992	215	0.936	121	0.675	155	0.601
9	112	0.331	17	0.503	187	0.992	214	0.935	131	0.658	116	0.596
10	93	0.325	37	0.498	184	0.989	193	0.933	163	0.638	119	0.594
11	164	0.323	25	0.492	191	0.978	194	0.929	94	0.631	118	0.594
12	227	0.321	45	0.489	192	0.922	222	0.916	156	0.630	161	0.593
13	70	0.319	19	0.488	196	0.872	192	0.911	126	0.629	103	0.591
14	73	0.317	21	0.479	193	0.862	202	0.909	88	0.619	107	0.588
15	110	0.316	38	0.474	220	0.859	196	0.908	181	0.598	139	0.586

Note: This table shows which 15 variables are most highly correlated with the $\boldsymbol{r}$ (observable and latent) factors and the corresponding correlation coefficients. Which number refers to which variable can be seen from Table A.1 in the Online Data Appendix.

the respective factors, together with the respective correlation coefficients. The latent factors are not uniquely identified, but a look at the factor loadings allows some tentative interpretation of the factors. The first factor (GDP growth) is most tightly linked with balance sheets and stock prices, the second factor (GDP deflator inflation) with house prices, and the third factor (Federal Funds rate) with other (mainly short-term) interest rates. The fourth factor (and first latent factor $\hat{\boldsymbol{h}}_{1t}$) is also highly correlated with interest rates (mainly mortgage loan rates and corporate bond yields), the fifth factor ($\hat{\boldsymbol{h}}_{2t}$) is primarily a stock price factor, and the sixth factor ($\hat{\boldsymbol{h}}_{3t}$) is highly correlated with balance sheet components and stock prices. The finding that some of the factors are highly correlated with variables belonging to different groups lends further empirical support to the notion that developments in asset prices and private sector balance sheets are closely correlated and should hence be modeled jointly.

4.2. Impulse Responses[13]

Figures 3–7 present the impulse responses of a number of selected variables to a monetary policy shock that raises the Federal Funds rate by 100 basis points. We show median impulse responses and 90% confidence bands. In Figure 3 we show the responses of the observable variables, real GDP, the GDP deflator, and the Federal Funds rate. An unexpected monetary tightening triggers a hump-shaped fall in real GDP, a persistent decline in the price level, and a temporary increase in the Federal Funds rate. These reaction patterns are qualitatively in line with results established in previous studies on monetary transmission in the United States [e.g., Christiano et al. (1996), Peersman (2005)].

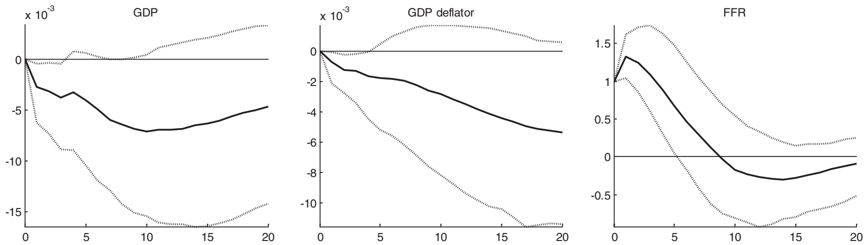

FIGURE 3. Impulse-response functions of key macroeconomic variables to monetary policy shocks. The charts show the median and 90% confidence intervals. The sample period of the analysis is 1987Q3–2007Q4.

We next turn to the dynamic reactions of property prices (Figure 4). All property price measures display a strong, sluggish, and persistent decline after the monetary policy shock, with peak effects reached between 9 and 16 quarters after the shock. Although the reactions of the different property prices are qualitatively similar, discernible differences in the quantitative reactions emerge. The peak (median) responses of the residential price indices range between around −2% (NAR house price index) and −5% (Case–Shiller price index). Commercial property prices display the strongest response, falling by more than 8% percent at maximum after the shock. These findings suggest that the choice of the house price index in previous empirical analyses was not completely innocuous,[14] although it should be noted that the confidence bands are rather wide and overlapping. The reason for the quantitative differences in the responses of the various house price measures

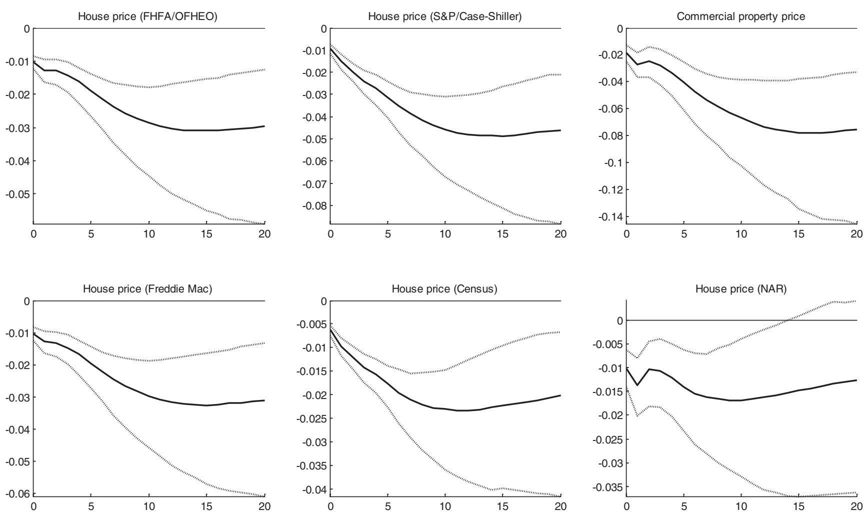

FIGURE 4. Impulse-response functions of property prices. The charts show the median and 90% confidence intervals. The sample period of the analysis is 1987Q3–2007Q4.

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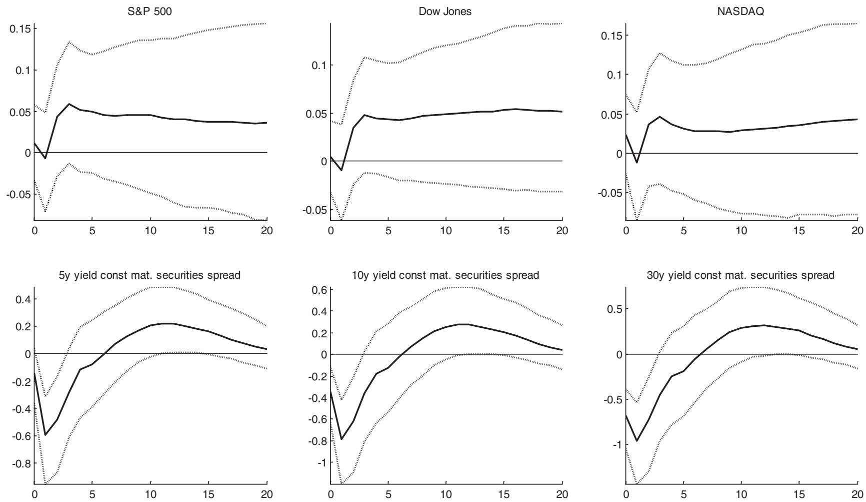

FIGURE 5. Impulse-response functions of stock prices and government bond yield spreads. The charts show the median and 90% confidence intervals. The sample period of the analysis is 1987Q3–2007Q4.

cannot be clearly identified, as the construction of the indices differs in various dimensions, such as weighting schemes, geographical coverage, and coverage of particular segments of the property and mortgage market, such as the subprime segment.[15] The finding that commercial property prices respond considerably more strongly than residential property prices to a monetary policy shock can be explained by longer construction lags, i.e., very inelastic supply, and stronger responsiveness of commercial rents (Zhu 2003).

Figure 5 shows the impulse responses of three key stock market indices, the S&P 500, the Dow Jones Industrials Average, and the NASDAQ composite, in the upper panel and the response of three government bond yield spreads, the spreads of the 5-year, 10-year, and 30-year yields over the Federal Funds rate in the bottom panel. The reactions of the stock market indices are not significant, lending support to the view that stock prices move rather independently. Consistent with the rational expectations hypothesis of the term structure, the reaction of long-term bond yields to the policy shock is smaller than the reaction of the Federal Funds rate and decreases with the maturity of the bond. Importantly, the finding that yield spreads decrease suggest that the monetary policy shock is not mixed up with a "term spread shock," such as the effect of a possible "global savings glut," which some observers regard as an alternative key driver of the precrisis financial imbalances.[16]

The responses of selected credit risk spreads are shown in Figure 6. The 3-month commercial paper spread and the 3-month Eurodollar deposit spread (both over the 3-month T-bill rate), the 30-year mortgage rate spread (over the 30-year

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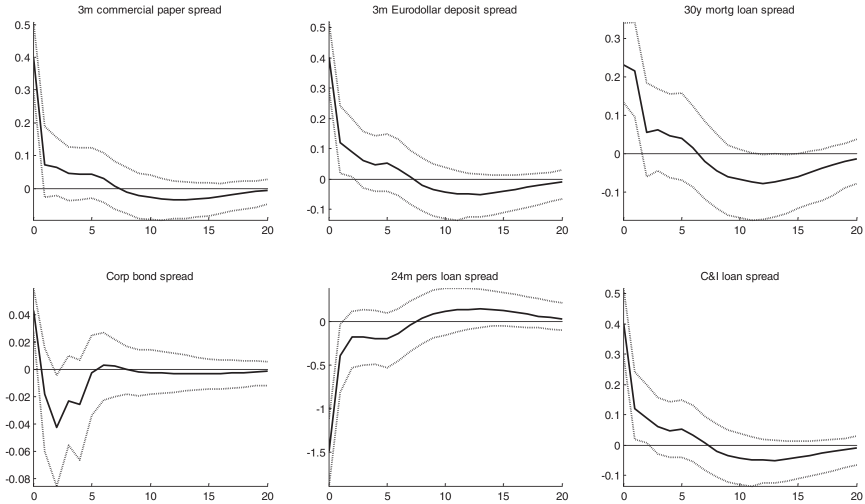
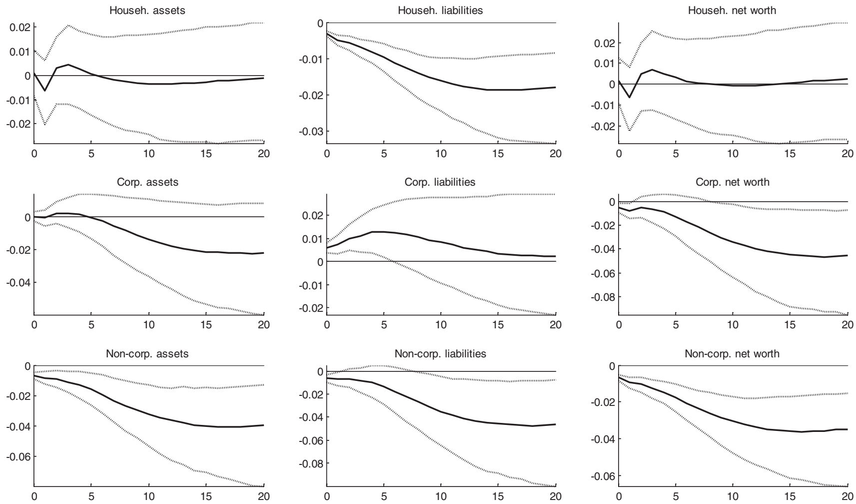


FIGURE 6. Impulse-response functions of credit risk spreads. The charts show the median and 90% confidence intervals. The sample period of the analysis is 1987Q3–2007Q4.

government bond yield), and the C&I loan rate spread (over the 2-year government bond yield) are very similar. A 100–basis point monetary policy shock leads to a significant instantaneous increase in these spreads by more than 20 basis points. The effect then quickly fades away, remaining significant for around 4 quarters. This response pattern is also present in the other money market risk spreads and the other mortgage market risk spreads, which we do not report. The positive response of credit risk spreads to a monetary policy shock is supportive of the existence of a balance sheet channel and/or a risk-taking channel,[17] because risk spreads should not react to monetary policy shocks if such channels are absent. It is, however, not possible to disentangle the two channels further. For other classes of capital market and loan market risk spreads, we get a more dispersed picture. Moody's corporate bond spread (BAA over AAA corporate bond yield) is essentially unaffected by a monetary policy shock, a finding that also obtains for other corporate bond spreads (not reported). The personal loan rate spread (2-year personal loan rate over the 2-year government bond yield) initially falls sharply and remains significantly negative for more than a year before increasing slightly. This finding suggests that pass-through to this type of loan rates is extremely sluggish, and is consistent with the finding reported later that consumer loans are barely affected by a monetary policy tightening.

Figure 7 reports impulse responses of key balance sheet positions of the household sector, the corporate nonfinancial business sector, and the noncorporate business sector. To facilitate interpretation of the results, we report in Table 3 the nominal valued of total assets, total liabilities, and net worth of the three sectors, as well as the shares of the various asset and liability components as of 2007.

(a)



(b)

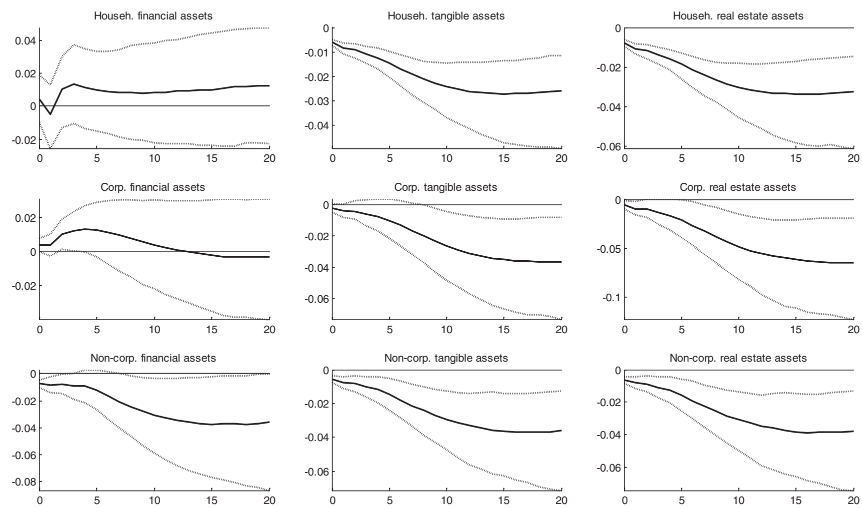


FIGURE 7. Impulse-response functions of assets and liabilities of the nonfinancial private sector: (a) total assets, total liabilities and net worth; (b) assets; (c) debt. The charts show the median and 90% confidence intervals. The sample period of the analysis is 1987Q3–2007Q4.

(c)

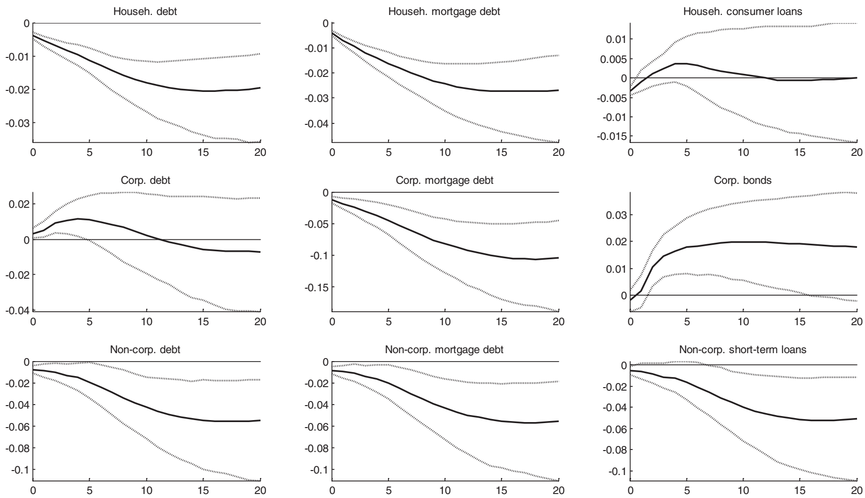


FIGURE 7. Continued.

Figure 7a reports the impulse responses of total assets, total liabilities, and net worth. A contractionary monetary policy shock is found to be associated with a significant fall in both assets and liabilities, except for corporate sector liabilities, which temporarily rise, and household assets, which do not react significantly. Net worth in the business sectors declines significantly and persistently, consistent with the potential existence of a financial accelerator in the transmission process. The response of household net worth is nonsignificant, reflecting, as we will see in the following paragraph, the nonsignificant response of financial assets as the largest part of total assets.

Figure 7b reports impulse responses for three key components of total assets, namely financial assets, tangible assets, and real estate assets, which are the largest component of the tangible asset category in all three sectors (see Table 3). There are notable differences in the reaction of financial assets, reflecting the heterogeneous composition of financial assets in the three sectors (Table 3). The dynamic reaction of tangible and real estate assets in the three sectors is very similar. A contractionary monetary policy shock triggers a sluggish and persistent fall in tangible and real estate assets. Given that real estate assets are valued at market prices, it is not surprising that their reaction pattern is very similar, both qualitatively and quantitatively, to that of property prices. Noncorporate and corporate real estate wealth reacts somewhat more strongly (maximum effects of −4% and −6%) than household real estate assets (peak response of −3%), which corresponds to our finding that commercial property prices react more strongly to a monetary policy shock than residential real estate prices.

TABLE 3. Nonfinancial private sector balance sheets in 2007

	Households and nonprofit organizations	Nonfarm noncorporate business	Nonfarm nonfinancial corporate business
Assets (Bil. $)	78,229	12,210	28,689
of which (share)			
Financial assets	0.65	0.29	0.48
of which (share)			
Deposits	0.15	0.28	0.09
Credit market instruments (securities and loans)	0.08	0.03	0.02
Corporate equity and mutual fund shares	0.28	—	0.02
Noncorporate equity	0.17	—	—
Pension fund and life insurance reserves	0.29	—	—
Trade receivables	—	0.15	0.16
Miscellaneous financial assets	0.03	0.54	0.71
Tangible assets	0.35	0.71	0.52
of which (share)			
Real estate assets	0.83	0.93	0.61
Consumer durables	0.16	—	—
Equipment and software	—	0.06	0.27
Inventories	—	0.01	0.12
Liabilities (Bil. $)	14,318	5,193	12,807
of which (share)			
Credit market debt	0.96	0.69	0.53
of which (share)			
Mortgage debt	0.78	0.71	0.14
Consumer loans	0.19	—	—
Other loans	0.03	0.29	0.29
Corporate bonds	—	—	0.52
Corporate paper and municipal securities	—	—	0.05
Trade payables	—	0.08	0.15
Tax payables	—	0.02	0.01
Miscellaneous liabilities	0.04	0.21	0.31
Net worth (Bil. $)	63,911	7,018	15,882

Note: Real estate assets and corporate equity (also mutual fund holdings of corporate equity) are valued at market value; all other assets and liabilities are valued at book value. More detailed information on the balance sheets can be found in Federal Reserve Board (2009), Tables B.100, B.102, and B.103 (pp. 104–106). Consumer durables, Inventories, and Equipment and software are valued at replacement costs.
Source: Federal Reserve Board (2009), own calculations.

Figure c shows the reaction of the three sectors' total debt, their mortgage debt, and one other important debt category, which is consumer loans in the case of households, corporate bonds in the case of corporates, and other bank and nonbank loans and advances in the case of noncorporates. For households, the results reveal that total debt and mortgage debt persistently decline by a maximum of more than 2% in response to the monetary policy shock, whereas consumer loans barely respond. Noncorporate debt is also found to fall very strongly and persistently in response to a monetary policy shock (−6%), with the reaction patterns of mortgage debt and short-term loans being very similar to that of total debt. Corporate debt, in contrast, first increases significantly before it turns nonsignificant. This result is owing to the persistent and significant increase in corporate bond issuances (the largest component of corporate debt, Table 3) after the shock. Corporate mortgage debt persistently decreases by as much as 10%, which is substantially greater than the decrease in the other two sectors. But because of the low share of mortgage debt in total corporate debt, this strong reaction does not lead to a fall in total debt.

The results of the impulse-response analysis of the debt components support the notion that financial frictions may play a role in the transmission of monetary policy. The results suggest that lending by (small) noncorporate firms is more negatively affected by a monetary policy shock than lending by (larger) corporate firms, because small firms do not have access to capital market financing. The shift in financing patterns of the corporate sector from bank to capital market financing is found to occur via corporate bond issuances, which is a new result, as previous studies from the 1990s found that corporates or large firms respond to a monetary contraction by raising short-term debt [Kashyap et al. (1993), Bernanke et al. (1996)], whereas there was no evidence of an increase in long-term debt [Christiano et al. (1996)]. Moreover, the reaction pattern of mortgage debt is very similar to that of property prices and real estate wealth, which could be interpreted as suggesting that the ability of the nonfinancial private sector to raise mortgage financing is closely linked to the development of real estate collateral.

5. THE ROLE OF MONETARY POLICY IN THE PRECRISIS FINANCIAL IMBALANCES

5.1. The Role of Monetary Policy Shocks

To explore the quantitative contribution of the monetary policy shocks to the dynamics of the various variables included in X_t over time, we perform historical decompositions based on the analysis of the preceding section. These decompositions reflect the accumulated effect of the sequence of monetary policy shocks over time. Concerning the most recent period, Figure 8 reveals a sequence of expansionary monetary policy shocks in 2001 and then again between 2003 and 2005. This shock pattern is reflected in the historical decompositions, which we show for the variables that are of most interest in the context of this paper, namely property prices, risk spreads, and debt, in Figure 9. The black line shows the forecast error explained by all (common and idiosyncratic) shocks; the red lines show the forecast error explained by monetary policy shocks.

For property prices, we find that the contribution of monetary policy shocks is considerably larger for the FHFA/OFHEO house price index—about one-third of the increase after 2003 is attributable to the monetary policy shock—than for the Case–Shiller and the commercial property price index (Figure 9a). The finding that the contribution of monetary policy shocks to the latter two price indices is rather small, despite the strong dynamic effects of monetary policy shocks uncovered in the impulse-response analysis, suggests that shocks other than monetary policy played a more important role in their dynamics over this period.

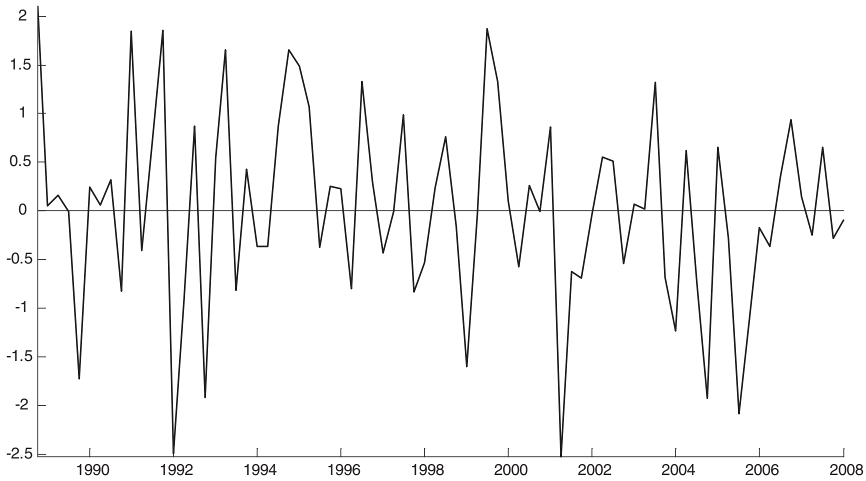


FIGURE 8. Time series of the monetary policy shock. The shock was scaled to have an impact of 100 basis points on the Federal Funds rate.

Regarding the contribution of monetary policy shocks to debt accumulation, we find a discernible contribution to the dynamics of household and noncorporate debt (Figure 9b). Almost half of the growth of these variables between 2004 and 2006 is attributable to monetary policy shocks. With regard to the corporate sector, a contribution of monetary policy shocks to corporate debt is visible only in 2006 and 2007.

The contribution of monetary policy shocks to the low levels of mortgage market and short-term money market risk spreads after 2001 is also found to be nonnegligible, but limited to the period 2004–2005 (Figure 9c). Over this period, about one-fourth of the below-average level of risk spreads is attributable to expansionary monetary policy shocks.

Overall, the results of the historical decompositions suggest that monetary policy shocks contributed in a discernible way to the above-average levels of property price inflation and debt growth and the below-average level of the risk spreads, but only at a relatively late stage of the housing and credit boom (between 2004 and 2005). This suggests that expansionary monetary policy shocks may have reinforced and prolonged the boom. But they were not the trigger of the excesses, as the takeoff in property price inflation and debt accumulation, as well as the drop in risk premia, occurred well before the contribution of the policy shocks kicked in.

How do our results compare with those found by previous studies? As we mentioned in the Introduction, previous studies have exclusively focused on the contribution of monetary policy to the housing boom, so our comparison is limited to that aspect of our analysis. There is no consensus in the literature on the contribution of monetary policy to the 2001–2006 housing boom. The FAVAR/VAR-based

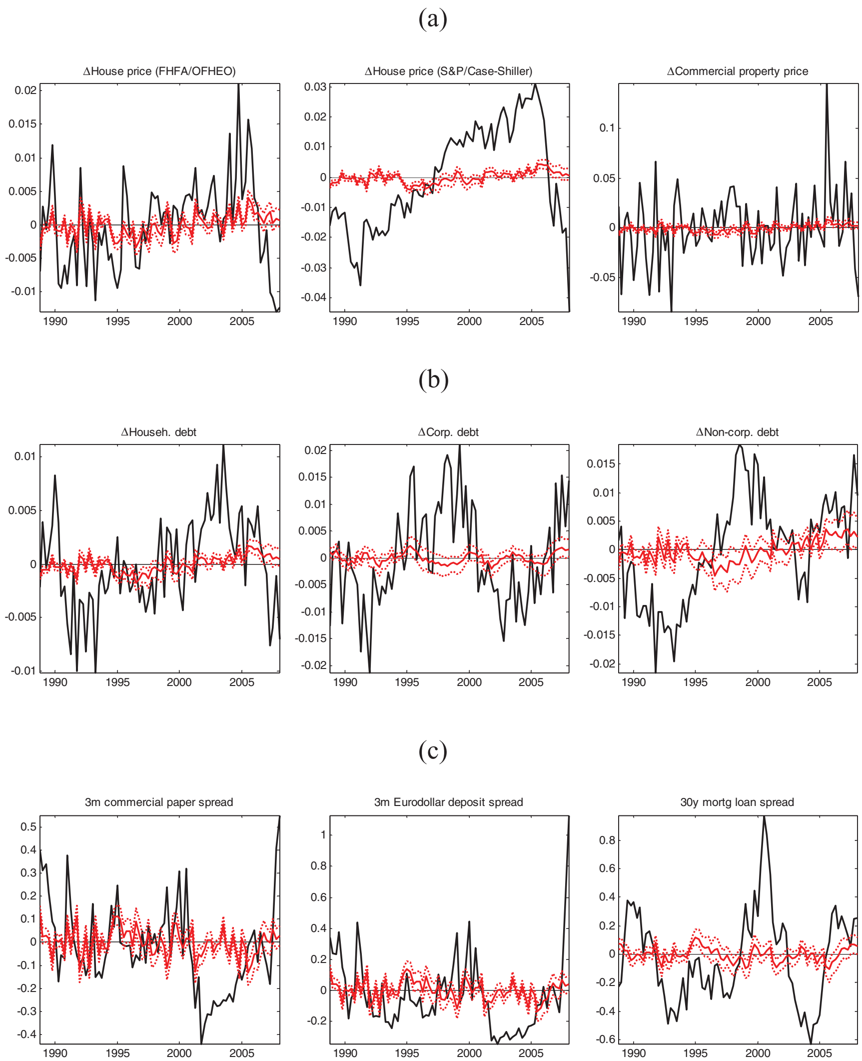


FIGURE 9. Historical decomposition of selected financial variables: (a) property prices; (b) debt; (c) credit risk spreads. The black line refers to the forecast error explained by all (common and idiosyncratic) shocks, the red line to the forecast error explained by monetary policy shocks. The forecast error explained by idiosyncratic shocks was estimated by fitting an AR(1) model to each idiosyncratic component. Historical contributions are computed for period 0 as the shock estimate at period 0 times the contemporaneous impulse-response functions, for period 1 as the shock estimate at period 0 times the impulse-response function at horizon 1 plus the shock estimate at period 1 times the contemporaneous impulse-response-function, etc. Thus, the forecast horizon is 0 for the first observation, 1 for the second, ... and $T-1$ for the last observation. The solid lines represent the median historical contributions (to the stationary variables), the dotted red lines the 90% confidence bands.

https://doi.org/10.1017/S1365100511000721 Published online by Cambridge University Press

studies by Del Negro and Otrok (2007) and Jarociński and Smets (2008) find little role for monetary policy, whereas Taylor (2007), based on a reduced-form single-equation estimation, and Iacoviello and Neri (2010), based on a DSGE model, find that the role of monetary policy shocks was quite important, accounting for between one-fourth and one-half of the run-up in house prices between 2001 and 2006. The reasons for these marked discrepancies are not fully clear and have not yet been systematically explored. Potential explanations could be, for instance, the use of different house price indices or differences in the methodology. A striking pattern is, however, that studies based on longer samples starting in the 1960s or 1970s [e.g., Iacoviello and Neri (2010), Taylor (2007)] tend to find a larger role of monetary policy shocks than studies based on a shorter sample period starting in the mid- to late 1980s [e.g., Del Negro and Otrok (2007), Jarociński and Smets (2008)], which indicates that the choice of sample period has an influence on the results. Indeed, Kohn (2008) suggests, with reference to the papers by Del Negro and Otrok (2008) and Iacoviello and Neri (2010), that studies covering a longer sample tend to find larger effects of monetary policy because they include the Regulation Q period.

To examine more closely whether different underlying sample periods used in the literature can explain different results regarding the role of monetary policy shocks in the 2001–2006 housing boom, we extend our data set and replicate our analysis for a longer sample period starting in 1975Q1. This is the longest possible sample given the availability of the FHFA/OFHEO house price indices.

As mentioned, the fundamental drawback of long samples, which also led us to choose a shorter sample period as the baseline, is that the analysis may be impaired by instability in the estimated empirical relationships owing to structural changes in the economy. The structural changes that may have altered the monetary transmission mechanism compose a more stability-oriented monetary policy leading to lower mean inflation and interest rates, as well as lower macroeconomic volatility ("the Great Moderation"), since the mid-1980s. At the same time, as already mentioned, there have also been structural changes in the financial sector in the 1970s and 1980s, which may have affected the transmission of monetary policy via financial variables.

When running the FAVAR over the longer sample period, we keep the specification unchanged. The (heteroskedasticity-robust version of the) test for parameter stability suggested by Nyblom (1989) and Hansen (1992) did not indicate instability in the FAVAR over the longer sample. Although it is well known that these stability tests have low power [see, for example, Cogley and Sargent (2005)], these test results at least do not stand against performing the analysis over a longer sample.

Since the S&P/Case–Shiller and the commercial property price indices are not available for the longer sample, we focus for comparison of the contribution of monetary policy shocks to the recent housing boom on the two samples from the FHFA/OFHEO house price index. The historical decomposition shown in the left-hand chart of Figure 10 suggests that the estimated contribution of monetary policy shocks to the house price boom is indeed larger for the longer sample. To

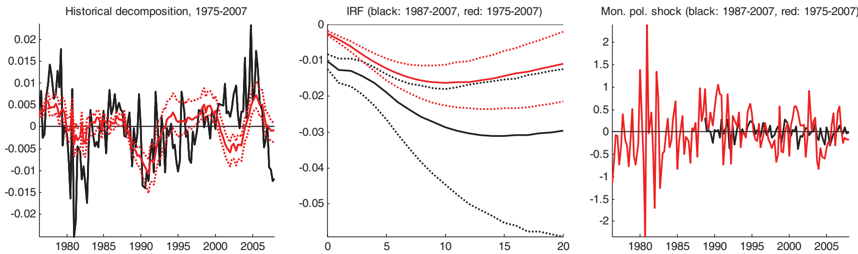


FIGURE 10. Contribution of monetary policy shocks to house price inflation (FHFA/OFHEO) in the long sample compared to the short sample. The long sample spans the period 1975Q1–2007Q4. The short sample is as before 1987Q3–2007Q4. The historical decomposition refers to house price inflation, the impulse-response functions to the levels of house prices. In the chart for the impulse-response function and the monetary policy shock, the red line refers to the long sample and the black line to the short sample. For further details see notes to Figures 3, 8, and 9.

shed light on the cause of this stronger contribution, we further report in Figure 10 the impulse-response functions (middle chart) of the house price to a 100–basis points monetary policy shock and the (normalized) monetary policy shock series (right-hand chart) for the long sample (red lines) and, for comparison again, for the short sample (black line). The charts reveal that the larger contribution of monetary policy shocks to the precrisis boom in house prices found over the longer sample period is entirely due to larger estimated monetary policy shocks, reflecting the worse fit of the monetary policy reaction function when estimated over the longer sample, whereas the estimated dynamic effect of a monetary policy shock on the house price is smaller over the long sample, although the confidence bands overlap.

The long sample analysis also reveals notable differences in the monetary transmission to a number of financial variables across sample periods. Although for the sake of brevity we do not report the results of the longer sample analysis, a number of differences between the longer and the shorter sample are worth highlighting.[18] Monetary policy effects on house prices and risk spreads are found to be stronger over the shorter sample, whereas the effects on stock prices and financial wealth are found to be weaker. Also, the ability of the corporate sector to increase its debt after a monetary policy shock by issuing corporate bonds is a more recent phenomenon that cannot be observed over longer sample periods and could therefore not be uncovered by earlier studies such as Christiano et al. (1996). Therefore, the analysis of the remainder of the paper is based on our benchmark sample period, 1987Q3 to 2007Q4.

5.2. The Role of Systematic Monetary Policy

Having analyzed the role of monetary policy shocks, i.e., the unexplained or unsystematic part of monetary policy, in the precrisis buildup of imbalances in housing and credit markets, we now draw our attention to the role of systematic

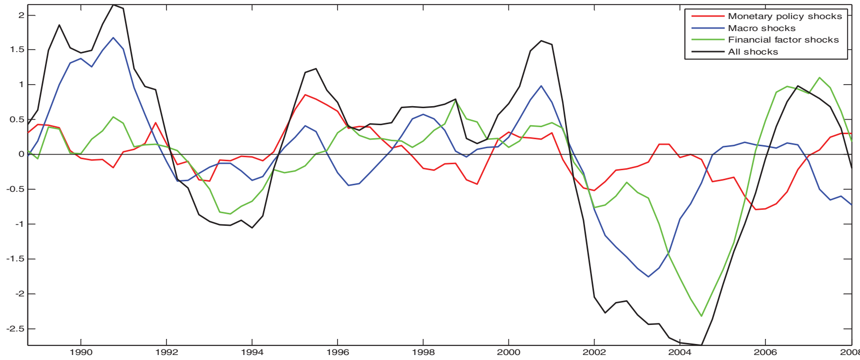


FIGURE 11. Historical decomposition of the Federal Funds rate. The black line refers to the contribution of all (common and idiosyncratic) shocks; the other lines indicate the contribution of shocks. For more details, see note to Figure 9.

monetary policy, i.e., the contribution of the reaction of policy rates to macro shocks (shocks to real GDP growth and GDP deflator inflation) and to financial shocks (shocks to the financial factors H_t).

The analysis of this section proceeds in two steps. We first investigate, based on a historical decomposition, the underlying drivers of the path of policy rates over time and assess to what extent financial shocks and macro shocks contributed to the exceptionally low levels of policy rates before the crisis. In the second step, we carry out a counterfactual experiment in order to quantify the feedback effects of the policy rate reaction to these shocks on housing and credit markets.

The interest rate equation in our FAVAR can be seen as an interest rate rule comprising, besides the standard macro variables, also financial factors, thereby accommodating the notion that central banks monitor and take into account the information content of a large range of asset prices and financial indicators.[19] Because our shock identification scheme allows for a contemporaneous reaction of policy rates to financial factors, we can use our empirical framework to assess the contribution of innovations to the financial factors as well as to the macro variables to the systematic conduct of monetary policy.

Figure 11 shows the historical decomposition of the Federal Funds rate, reporting the contribution of monetary policy shocks (red line) as well as of the macro shocks (blue line) and of the shocks to the financial factors (green line).[20] The decomposition suggests that the low level of policy rates between 2001 and 2004 is mainly attributable to negative macro shocks, reflecting the post-2000 economic downturn, and to financial shocks, possibly reflecting the bursting of the dot-com bubble and the decline in long-term interest rates, but only initially to expansionary monetary policy shocks. After 2003, the decomposition attributes the low level of the Federal Funds rate mainly to expansionary monetary policy shocks. Possible explanations for the sequence of expansionary monetary policy shocks after mid-2003 are that potential output growth had been overestimated, probably under the impression of the preceding "New Economy" boom and the acceleration in financial innovation, and a perceived risk of deflation at that time [e.g., Bernanke (2002), Greenspan (2007)] were exaggerated.[21] Interestingly, the decomposition suggests that the post-2005 increase in the Fed Funds rate was driven to a large extent by contractionary monetary policy shocks, but also by shocks to financial factors, probably reflecting the recovery of stock markets after 2004, the increase in long-term interest rates after 2005, and the boom in housing and credit markets which peaked in 2006.

The results of the decomposition also fit nicely with other anecdotal evidence on the role of financial factors in the conduct of U.S. monetary policy. In particular, the decomposition suggests that the largest part of the reduction in the Fed Funds rate that occurred after the recession in 1990/91 was attributable to a reaction to shocks to the financial factors. This finding is consistent with the view that during this period, which is commonly referred to as the "financial headwinds" episode, financial developments played an important role in the Fed's policy considerations, as has also been implied by statements of Fed officials.[22]

To explore the role of the systematic monetary policy reaction to shocks to financial factors and macro shocks in the precrisis booms in housing and credit markets, we carry out a counterfactual experiment in the vein of Bernanke et al. (1997) and Sims and Zha (1998). The experiment is based on a counterfactual path of policy rates, which would have prevailed in absence of shocks to financial factors or of both financial and macro shocks.[23] The quantitative contribution of systematic monetary policy is then computed by performing a historical decomposition based on the counterfactual sequence of monetary policy shocks that would have placed the Federal Funds rate on the counterfactual path.

Figure 12 shows for a few variables the contributions of the original monetary policy shocks (red line), the combined contributions of the original monetary policy shocks and the systematic reaction of monetary policy to shocks to financial factors (green dashed line), and the combined contributions of the original monetary policy shocks and the systematic reaction of monetary policy to shocks to both financial factors and real GDP growth and inflation (blue dashed line).

The charts suggest that the systematic reaction of monetary policy in particular to financial factor shocks seems to have contributed in a considerable way to the precrisis house price and credit boom. As would be expected from the decomposition of the Federal Funds rate in the previous section, the contribution of the systematic policy reaction to shocks to financial factors kicks in already in early 2002 and thus much earlier than the contribution of the monetary policy shocks. Quantitatively, the contribution of systematic monetary policy seems to be at least as important as the contribution of policy shocks.

Overall, the results of the counterfactual analysis support the view that monetary policy was a key driver of the housing and credit boom. It would, however, be premature to draw strong policy conclusions based on these findings, because counterfactual experiments in reduced-form models are prone to the Lucas critique: changes of private sector expectations of the policy process that may result

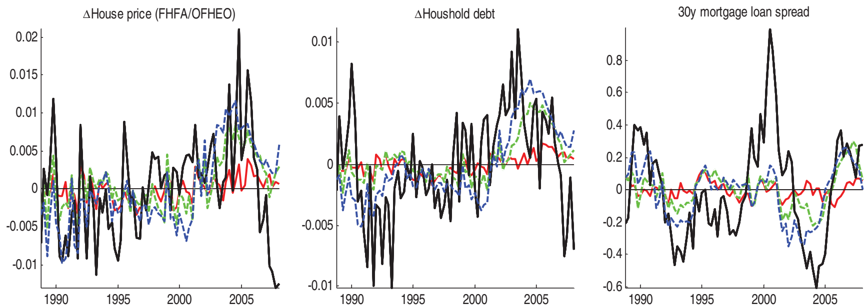


FIGURE 12. Historical decompositions and counterfactual simulations—the role of monetary policy shocks and of systematic monetary policy. The black line refers to the contribution of all (common and idiosyncratic) shocks, the solid red lines to the contribution of monetary policy shocks, and the dashed lines to the contributions of monetary policy shocks and the systematic reaction of monetary policy to financial shocks (green) and the contributions of monetary policy shocks and the systematic reaction of monetary policy to both financial and macro shocks (blue). The contribution of the systematic response of monetary policy was obtained based on a counterfactual experiment. For details on the counterfactual experiment, see the main text. For more details on the historical decomposition, see note to Figure 9.

from the policy changes implied by the counterfactual and that may alter the parameters of the model are not accounted for [Sims and Zha (1998)]. The results of the counterfactual simulation presented in this section should therefore be taken with caution.

6. CONCLUSIONS

This paper uses a factor-augmented vector autoregressive model (FAVAR) estimated on quarterly data over the sample period 1987–2007 to explore the interaction between monetary policy and more than 200 financial and asset variables in the United States The paper contributes to the literature in the following ways. (i) We provide a unified and comprehensive characterization of the transmission of monetary policy shocks via financial conditions, covering a broad range of asset prices, interest rates, risk spreads and private sector balance sheet components by means of impulse-response analysis. (ii) We assess the role of monetary policy in the three phenomena that characterized the U.S. financial landscape prior to the outbreak of the financial crisis, i.e., the housing and debt booms and the low risk spreads in credit markets. We assess the role of monetary policy shocks using a historical decomposition. In addition, we explore, based on counterfactual simulations, the role of systematic monetary policy, i.e., of the estimated reaction of the policy rate to shocks to financial factors and macro shocks.

The main findings of our analysis are as follows.

(i) Monetary policy shocks have a highly significant and persistent effect on property prices, real estate wealth, and private sector debt, as well as a strong short-lived effect on risk spreads in the money market, the mortgage market, and the C&I loan market. The impulse-response analysis supports the notion that financial frictions probably play a role in the transmission of monetary policy. In particular, the finding that risk spreads increase significantly after a monetary policy shock points to the relevance of balance-sheet or risk-taking channels. Also, the finding that borrowing by (small) noncorporate firms is more negatively affected by a monetary policy shock than borrowing by (larger) corporate firms, which in fact increases after a policy tightening because of higher corporate bond issuance, is in line with the view that small firms are more prone to become borrowing-constrained because they do not have access to capital market financing.

(ii) Monetary policy is found to have contributed considerably to the unsustainable dynamics in housing and credit markets that were observed between 2001 and 2006. Monetary policy shocks are found to have contributed at a late stage of the boom. This suggests that expansionary monetary policy shocks may have reinforced and prolonged the housing and credit booms. But they were not the trigger for the excesses, as the takeoff in property price inflation and debt accumulation, as well as the drop in risk premia, occurred well before the contribution of the policy shocks kicked in. However, feedback effects of negative financial and macroeconomic shocks via lower policy rates on property and credit markets are found to have played a considerable role already at an earlier stage of the boom. The counterfactual analysis, together with the historical decomposition, therefore supports the view held by Taylor (2007) that monetary policy was an important driver of the housing and credit booms.

NOTES

1. For comprehensive assessments of the causes of the financial turmoil, see, e.g., Borio (2008), Brunnermeier (2009), Buiter (2009), and Gorton (2009).

2. For ease of reference we refer to all these variables as financial variables, being aware that this terminology is somewhat sloppy in the case of house prices and real estate and other tangible assets.

3. A valid alternative to FAVAR models is large Bayesian VAR (BVAR) models, as proposed by Banbura et al. (2010). Whereas FAVAR models handle large data sets by imposing a factor structure on the data, large BVAR models handle the estimation of large unrestricted systems by imposing prior beliefs on the parameters. Both approaches have advantages and disadvantages, and the decision as to which approach to use ultimately depends on the application. For the analysis performed in this paper, a FAVAR model was chosen because the identification scheme we use for the monetary policy shock and the different steps of the counterfactual experiment would very be difficult, if not impossible, to implement with a large BVAR model.

4. This includes studies on the transmission via flow of funds [Christiano et al. (1996)], stock prices [e.g., Bernanke and Kuttner (2005), Bjørnland and Leitemo (2009)], house prices [e.g., Del Negro and Otrok (2007), Bjørnland and Jacobsen (2008), Iacoviello and Neri (2010), Jarocíñski and Smets (2008)], or lending standards [e.g., Jiménez et al. (2007), Ionnadou et al. (2008), Altunbas et al. (2009)].

5. For a more detailed description and comparison of the construction of the different residential house price indices see, e.g., Peek and Wilcox (1991), Leventis (2008), and National Association of Realtors (2008). More details on the construction of the commercial property price index can be found under http://web.mit.edu/cre/research/credl/tbi.html.

6. F_t can contain dynamic factors and lags of dynamic factors. Insofar, equation (2) is not restrictive.

7. The variables in our data set have a sufficiently high degree of commonality (i.e., variance share explained by common factors) and a sufficiently low degree of cross-sectional correlation of idiosyncratic components to yield accurate factor estimates, as explained in Appendix A. This also suggests that extracting the factors from the full data set rather than from subgroups of specific data categories, such as house prices or stock prices, is appropriate.

8. Whereas Bernanke et al. (2005) include the Federal Funds rate as the only observable factor in the FAVAR model we include three observable variables in our model, as this may help to better capture the monetary policy reaction function. Indeed, Amir Ahmadi and Uhlig (2008) suggest that variables that are highly relevant to monetary policy, such as GDP and prices, should be included as observables in the FAVAR model.

9. The information criteria suggested by Bai and Ng (2002) gave inconclusive results, so we could not rely on them. Robustness checks suggest that similar results for the impulse–response analysis are obtained for FAVAR specifications with a larger number of factors.

10. All static factors seem also to be dynamic factors, as six dynamic principal components explain the same bulk of variation in the large data set (also 64%) as the six static factors.

11. The sign restrictions should also ensure that the monetary policy shocks are not contaminated by financial shocks. An expansionary financial shock would generally be associated with an increase in asset prices, an increase in debt, or a decrease in credit spreads and at the same time be expected to exert a positive effect on output and prices. As monetary policy would be expected to be tightened at least in response to these expansionary macroeconomic effects, the policy rate would also be expected to rise. In contrast, a policy rate increase brought about by a monetary policy shock would, according to our identification scheme, have contractionary effects on output and prices and would also be expected to have contractionary effects on financial variables, which is supported by the empirical results. As discussed in Section 4.2, our identified monetary policy shock is also not contaminated by a global savings glut shock, i.e., an autonomous reduction of long-term interest rates and the yield spread, as we find that an expansionary monetary policy shock leads to an increase in the yield spread, consistent with the rational expectations hypothesis of the term structure.

12. We do not aim to achieve a structural identification of macro and financial shocks, for instance, by imposing additional sign restrictions. Although it would be possible to further decompose the macro shocks into an aggregate demand and an aggregate supply shock via standard sign restrictions, a structural identification of financial shocks would be more difficult. In contrast to monetary policy shocks, there is very little or no a priori guidance how different types of financial shocks (e.g., credit supply shock or risk-taking shock) could be identified and separated via theoretically justified restrictions. Against this background, we see a detailed and thorough analysis of the nature and effects of different types of macro and financial shocks as beyond the scope of this paper.

13. The variance decompositions, which are not particularly informative for the issues addressed in this paper, are available in the working paper version of this paper and from the authors upon request.

14. Indeed, previous VAR/FAVAR-based studies on monetary transmission via house prices focus on different price indices. Jarociński and Smets (2008) use the S&P/Case-Shiller index, Del Negro and Otrok (2007) use the FHFA/OFHEO house price indices, and Iacoviello (2005) and Bjørnland and Jacobsen (2008) use the Freddie Mac house price index. The FAVAR-based study of the U.S. housing market by Ng and Mönch (2011) includes a wide range of national and regional house price indices, but does not cover commercial property prices. The house price reaction patterns uncovered by these studies are very similar to ours. In contrast to this, DSGE model-based studies such as those by Iacoviello and Neri (2008) Darracq Pariès and Notarpietro (2008) and find a quite different, front-loaded reaction of house prices.

15. Leventis (2008) concludes that one main reason for divergences in the development of the FHFA/OFHEO and the Case–Shiller house price indices was the inclusion of many non–agency financed homes with subprime loans in the Case–Shiller index. Against this background, our finding that the Case–Shiller index responds considerably more strongly than the FHFA/OFHEO index could be interpreted as reflecting at least in part a stronger responsiveness of house prices in the subprime segment of the mortgage market.

16. A contractionary "term spread shock" would also be associated with a decrease in output and prices and potentially also an increase in policy rates but, in contrast to a monetary policy shock, with an increase in the yield spread.

17. The basic references for the balance sheet channel, which is also referred to as the financial accelerator, are Bernanke and Gertler (1989), Kiyotaki and Moore (1997), and Bernanke et al. (1999). The risk-taking channel suggests that monetary policy affects risk premia via lenders' or investors' willingness to take risk, e.g., via sticky return targets or an inherent countercyclicality of investor risk aversion. See Borio and Zhu (2008) and the references therein.

18. The full set of results of the longer sample analysis is available upon request.

19. See, e.g., Lansing (2008) for some formal evidence on the role of stock market variables in an estimated policy reaction function for the Fed and in the path of the Fed Funds rate over time.

20. The confidence bands for the historical decompositions, which we do not report, are rather tight.

21. This interpretation is supported by the fact that output growth and inflation forecasts of the Fed at that time, e.g., presented in the Greenbook published in December 2003, were clearly above the (today available) final estimates. It is further supported by downward revisions of potential output growth estimates for the years 2002–2008 (and 2002–2012, respectively) by the CBO between, e.g., August 2002 and August 2009.

22. For instance, former Chairman Greenspan (1994) stated that the monetary easing during this period was prompted by "the consequences of balance-sheet strains resulting from increased debt, along with significant weakness in the collateral underlying that debt. Households and businesses became much more reluctant to borrow and spend, and lenders to extend credit. In an endeavour to defuse these financial strains we moved short-term rates in a long series of steps through the summer of 1992, and we held them at unusually low levels through the end of 1993—both absolutely and, importantly, relative to inflation."

23. More precisely, we add a sequence of artificial monetary policy shocks to the identified monetary policy shocks, which eliminates the reaction of the Federal Funds rate either to financial shocks or to both financial and macroeconomic shocks. We then carry out a historical decomposition of the Federal Funds rate to obtain the contribution over time of both the new artificial monetary policy shocks and the original monetary policy shocks.

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APPENDIX A: VERIFYING THE VALIDITY OF ASSUMPTIONS OF THE APPROXIMATE FACTOR MODEL FOR OUR DATA SET

An important assumption of the approximate dynamic factor model we employ is weak correlation of idiosyncratic components and a high commonality (i.e., share of variation explained by the common component). Boivin and Ng (2006) have shown, based on simulations, that low commonality and highly cross-correlated idiosyncratic components may seriously worsen the factor estimates. This problem has been discussed and taken into account in various empirical forecasting studies [see Eickmeier and Ziegler (2008) and references therein], but rarely in more structural studies.

To assess whether this may be an issue in our data set, we estimate r principal components from X_t, remove series with low commonality (e.g., here defined as a variance share explained by common factors of < 0.2 and < 0.3, respectively) and, alternatively, highly cross-correlated idiosyncratic components from the data set following Rule 1 suggested in Boivin and Ng (2006). This rule involves looking at each series $\boldsymbol{i} = 1, \ldots, \boldsymbol{N}$ in X_t and dropping from the rest of the data set the series j whose idiosyncratic component is most correlated with the idiosyncratic components of series i. If the idiosyncratic components of series i and j are most correlated with each other, the series with the lower commonality is selected for dropping. We then reestimate factors from the reduced data set, remove, as before, the observable factors from the space spanned by all $\boldsymbol{r}$ factors, and compare the remaining $\boldsymbol{r} - \boldsymbol{M}$ factors with the estimated latent factors $\hat{\boldsymbol{h}}_{1t}$, $\hat{\boldsymbol{h}}_{2t}$ and $\hat{\boldsymbol{h}}_{3t}$ that were extracted from the full data set.

Table A.2 in the Online Data Appendix shows that the factors extracted from the entire data set (which we use in our estimation) are almost perfectly correlated with the factors extracted from the reduced data sets. We therefore can conclude that low commonality and cross-correlated idiosyncratic errors are not problems in our data set and that the factors we estimated from X_t are likely to be accurate.

APPENDIX B: SHOCK IDENTIFICATION

Suppose $\hat{u}_t$ is the $\boldsymbol{r} \times 1$ vector of reduced-form VAR residuals where the latent and observable factors are the endogenous variables. The $\boldsymbol{r} \times 1$ vector of (orthogonalized) Cholesky residuals v_t is estimated as

$$\hat{v}_t = \hat{A}\hat{u}_t, \qquad \textbf{(B.1)}$$

where $\hat{A}$ is the lower triangular Cholesky matrix of $\text{cov}(\hat{u}_t)$. We partition $\hat{v}_t$ into two parts, the $\boldsymbol{M} - 1 \times 1$ vector of Cholesky residuals associated with GDP growth and GDP deflator inflation $\hat{v}_t^{1\ldots M-1}$ and the $\boldsymbol{r} - \boldsymbol{M} + 1 \times 1$ vector of Cholesky residuals associated with the Federal Funds rate and the latent factors $\hat{v}_t^{M\cdots r}$ and $\hat{v}_t = [\hat{v}_t^{\prime 1\cdots M-1} \quad \hat{v}_t^{\prime M\cdots r}]'$. The estimated vector of structural shocks $\hat{w}_t = [\hat{w}_t^{1\cdots M-1'} \quad \hat{w}_t^{M\cdots r'}]'$ is related to $\hat{v}_t$ as follows. Let $\hat{w}_t^{1\cdots M-1} = \hat{v}_t^{1\cdots M-1}$ and $\hat{w}_t^{M\cdots r} = R\hat{\upsilon}_t^{M\cdots r}$, where R is the $\boldsymbol{r} - \boldsymbol{M} + 1 \times \boldsymbol{r} - \boldsymbol{M} + 1$ rotation matrix, $R'R = I_{r-M+1}$, and, by construction, $\text{cov}(\hat{w}_t) = I_{r+M-1}$.

The rotation matrix R is chosen so that the identifying restrictions specified in the main text are satisfied. Any $\boldsymbol{r} - \boldsymbol{M} + 1$-dimensional rotation matrix can be parameterized as follows:

$$R(\theta) = \prod_{l,n} \begin{bmatrix} 1 & 0 & \cdots & & & & \cdots & 0 \\ 0 & \ddots & & & & & & 0 \\ \vdots & & \cos(\theta) & & & -\sin(\theta) & & \vdots \\ & & & \ddots & & & & \\ & & & & 1 & & & \\ & & & & & \ddots & & \\ & & \sin(\theta) & & & \cos(\theta) & & \vdots \\ \vdots & & & & & & \ddots & 0 \\ 0 & \cdots & & & & \cdots & 0 & 1 \end{bmatrix}, \tag{B.2}$$

where only rows l and n are rotated by the angle θ_i, and there are $(\boldsymbol{r}-\boldsymbol{M}+1)((\boldsymbol{r}-\boldsymbol{M}+1)-1)/2$ possible bivariate rotations. Hence, $\boldsymbol{\theta} = \boldsymbol{\theta}_1, \ldots, \boldsymbol{\theta}_{(r-M+1)((r-M+1)-1)/2}$.

It turns out that more than one θ satisfies the sign restrictions. Previous studies usually consider them all. This leads to large uncertainty bands reflecting not only sampling uncertainty but also identification uncertainty, as illustrated by Paustian (2007). Recently, Fry and Pagan (2007) called attention to another possible problem. They argue that the literature often presents summary measures of impulse-response functions, such as medians, that come from different models or, put differently, that reflect shocks that are not orthogonal. To avoid these problems, they suggest choosing, out of all θ that satisfy the sign restrictions, the θ that leads to impulse-response functions that are as close as possible to their median values, and we follow their suggestion. We first draw each rotation angle randomly from a uniform distribution between 0 and π, until we have obtained $K\theta$'s that satisfy the restrictions. K is set at 200 to keep it computationally tractable. For each θ, we compute impulse responses of the restricted variables to monetary policy shocks. To make them unit-free, we standardize them by subtracting their medians and dividing by their standard deviation over all models. For each θ and some fixed horizon, we group the standardized impulse responses into an $L \times 1$ vector ϑ (L is the number of restricted variables/impulse-response functions). We pick the θ that minimizes $\vartheta'\vartheta$, denoted by θ^*. Based on θ^*, we compute the rotation matrix $R(\theta^*)$.