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# Monetary policy, housing booms and financial (im)balances

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**Abstract:**

This paper uses a factor-augmented vector autoregressive model (FAVAR) estimated on U.S. data in order to analyze monetary transmission via private sector balance sheets, credit risk spreads and asset markets in an integrated setup and to explore the role of monetary policy in the three imbalances that were observed prior to the global financial crisis: high house price inflation, strong private debt growth and low credit risk spreads. The results suggest that (i) monetary policy shocks have a highly significant and persistent effect on house 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 shocks have contributed discernibly, but at a late stage to the unsustainable developments in house and credit markets that were observable between 2001 and 2006; (iii) financial shocks have influenced the path of policy rates prior to the crisis, and the feedback effects of financial shocks via lower policy rates on property and credit markets are found to have probably been considerable.

**Key words:** Monetary policy, asset prices, housing, private sector balance sheets, financial crisis, factor model

**JEL classification:** E52, E44, C3, E3, E43

**Non-technical summary**

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 the last years. The interest in the topic has recently gained further impetus from the coincidence of unprecedented property price inflation ("housing bubble"), a massive expansion of private sector indebtedness ("credit bubble") and very low risk-spreads in credit markets ("under-pricing of risk") on the one side, and, on the other side, exceptionally low levels of policy rates in the U.S. prior to the outbreak of the global financial crisis, i.e. between 2001 and 2006. This coincidence has led a number of observers – most prominently John Taylor (2007, 2009) and the BIS (2007, 2008) – 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.

This paper uses a factor-augmented vector autoregressive model (FAVAR) estimated on quarterly data over the sample period 1987 to 2007 to explore the interaction between monetary policy and more than 200 financial and asset variables in the U.S. It contributes to the literature in the following ways. First, it provides 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 an impulse response analysis. Second, the paper assesses the role of monetary policy shocks in the build-up of the pre-crisis imbalances in housing and credit markets based on historical decompositions. Third, the paper also explores based on counterfactual simulations the role of the systematic reaction of monetary policy to financial (as well as macro) shocks. The analysis is based on an identification scheme which allows for contemporaneous interaction between policy rates and financial variables and hence allows exploring not only the effects of monetary policy shocks on financial variables, but also the role of financial shocks for the path of policy rates over time.

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 play a role in the transmission of monetary policy. (ii) Monetary policy shocks have contributed discernibly, but at a late stage to the unsustainable dynamics in housing and credit markets that were observed between 2001 and 2006. (iii) Negative financial shocks in the wake of the bursting the dot-com bubble have significantly contributed to the low level of policy rates observed prior to the global financial crisis. The feedback effects of these negative financial shocks via lower policy rates on property and credit markets are found to have probably been considerable.

**Nicht-technische Zusammenfassung**

Seit einigen Jahren zählen die Auswirkungen geldpolitischer Schocks auf die Finanzierungsbedingungen zu den wichtigsten geldpolitischen Forschungsthemen. In jüngster Zeit hat das Interesse an dieser Thematik weiter zugenommen. Ursächlich hierfür war das Zusammentreffen eines beispiellosen Anstiegs der Immobilienpreise, einer starken Expansion der Verschuldung des privaten Sektors und äußerst niedriger Risiko-Spreads an den Kreditmärkten mit einem außergewöhnlich niedrigen Leitzinsniveau in den Vereinigten Staaten in den Jahren 2001 bis 2006, also vor Ausbruch der weltweiten Finanzkrise. Zahlreiche Beobachter kamen zu dem Schluss, dass der übermäßig lockere geldpolitische Kurs einer der Hauptfaktoren war, die zu den Ungleichgewichten an den Immobilien- und Kreditmärkten beitrugen.

Im vorliegenden Forschungspapier wird anhand eines Factor-Augmented-Vector-Autoregressive-Modells (FAVAR), das die Wechselwirkung zwischen Geldpolitik und mehr als 200 vierteljährlichen Finanz- und Vermögensvariablen in den Vereinigten Staaten zwischen 1987 und 2007 untersucht. Dabei wird die vorhandene Literatur in verschiedener Hinsicht ergänzt: Erstens liefert die vorliegende Arbeit eine einheitliche und umfassende Darstellung der Transmission geldpolitischer Schocks über Finanzierungsbedingungen, wobei mithilfe einer Impuls-Antwort-Analyse eine große Bandbreite an Vermögenspreisen, Zinssätzen, Risiko-Spreads und Bilanzpositionen des Privatsektors abgedeckt wird. Zweitens wird die Rolle geldpolitischer Schocks bei der Entstehung der Ungleichgewichte an den Immobilien- und Kreditmärkten vor der Krise mit Hilfe einer historischen Zerlegung analysiert. Darüber hinaus wird mittels kontrafaktischer Simulationen die Bedeutung systematischer geldpolitischer Reaktionen auf finanzielle Schocks sowie Makroschocks untersucht. In der Forschungsarbeit kommt ein Identifikationsschema zur Anwendung, das eine gleichzeitige Wechselwirkung von Leitzinsen und Finanzvariablen zulässt und somit nicht nur eine eingehende Betrachtung der Auswirkungen geldpolitischer Schocks auf Finanzvariablen, sondern auch die Bedeutung finanzieller Schocks für die Entwicklung der Leitzinsen im Zeitverlauf ermöglicht.

Die wesentlichen Ergebnisse unserer Analyse lassen sich wie folgt zusammenfassen: (i) Geldpolitische Schocks haben starke und nachhaltige Auswirkungen auf Immobilienpreise, Immobilienvermögen und die Verschuldung des privaten Sektors sowie einen deutlichen kurzzeitigen Einfluss auf die Risiko-Spreads am Geldmarkt, am Hypothekenmarkt und am Markt für Unternehmenskredite. Die Impuls-Antwort-Analyse stützt die Einschätzung, dass finanzielle Friktionen bei der geldpolitischen Transmission eine Rolle spielen. (ii) Geldpolitische Schocks haben spürbar, aber verzögert zu den Ungleichgewichten an den Immobilien- und Kreditmärkten, die von 2001 bis 2006 zu beobachten war, beigetragen. (iii) Negative finanzielle Schocks im Zuge der geplatzten Aktienmarktblase haben merklich zum niedrigen Leitzinsniveau vor der Krise beigetragen. Die Rückkopplungseffekte, die sich aus diesen Schocks über die niedrigeren Leitzinsen auf die Immobilien- und Kreditmärkte übertrugen, dürften erheblich gewesen sein.

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# Monetary Policy, Housing Booms and Financial (Im)Balances

## 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 the last years. The interest in the topic has recently gained further impetus from the coincidence of unprecedented property price inflation ("housing bubble"), a massive expansion of private sector indebtedness ("credit bubble") and very low risk-spreads in credit markets ("under-pricing of risk") on the one side, and, on the other side, exceptionally low levels of policy rates in the U.S. 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 Taylor (2007, 2009) and the BIS (2007, 2008) – 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 scope 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 build-up of imbalances in property and credit markets before the financial crisis. To this end, we employ a factor-augmented vector autoregressive model (FAVAR), a novel empirical tool proposed by Bernanke et al. (2005). The FAVAR enables us to analyze monetary transmission over a large range of financial variables, i.e. property

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[1] For comprehensive assessments of the causes of the financial turmoil, see e.g. Borio (2008), Buiter (2007), Brunnermeier (2008) and Gorton (2009).

and stock prices, interest rates, credit risk spreads and non-financial private sector assets and liabilities[2], based on a unified, consistent modelling framework exploiting the close correlation between these variables indicated by Figure 1. More specifically, the FAVAR developed in this paper extends a standard macroeconomic vector autoregressive model (VAR) with a set of (financial) factors summarizing more than 200 quarterly financial variables. 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 financial shocks and macro shocks.

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,[3] while a comprehensive analysis of the transmission of monetary policy shocks via financial conditions encompassing all these specific aspects has still been missing. The impulse response analysis allows to assess 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 build-up of the pre-crisis 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 (Taylor 2007, Iacoviello and Neri 2008, Jarociński and Smets 2008, Del Negro and Otrok 2007), 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 pre-crisis phenomena highlighted in Figure 1, i.e. the excessive debt accumulation in the private

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

non-financial 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 financial (as well as macro) shocks. Since we allow for contemporaneous interaction between policy rates and financial variables, we can not only explore the effects of monetary policy shocks on financial variables, but also the role of financial shocks for the path of policy rates over time. Via counterfactual simulations we then assess to what extent the reaction of monetary policy to financial (and macro) shocks has fed back to housing and credit markets. That way we can assess the widely held view that the monetary easing in reaction to the bursting of the stock market bubble after 2000 has 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 shocks have contributed discernibly, but at a late stage to the unsustainable dynamics in house and credit markets that were observable between 2001 and 2006; (iii) financial shocks have influenced the path of policy rates prior to the crisis, and the feedback effects of financial shocks via lower policy rates on property and credit markets has probably been considerable.

The remainder of the paper is organized as follows. In section 2 we present the data and explain in section 3 the methodology. In section 4 we present our keys results for the effect of monetary policy shocks on asset prices, interest rates, lending terms and balance sheets: we provide and discuss the results of the impulse response analysis, the variance and the historical decompositions. In section 5, we assess the respective role of monetary policy, macro and financial shocks for the path of policy rates and present the results of the counterfactual simulations for the assessment of the role of systematic monetary policy in the pre-crisis boom. Section 6 concludes.

## 2. Data

The quarterly dataset 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 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 non-financial sector balance sheets. Stock prices, property prices, monetary aggregates, and balance sheet variables were converted to real units by deflation with the GDP deflator. 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 data appendix (Table A.1).

The property price block of our database[4] is mainly comprised of the set of FHFA/OFHEO[5] house price indices for the U.S. national level and the 51 U.S. states. The FHFA/OFHEO house price indices are repeat-sales based indices of existing single-family homes, measuring average price changes in repeat sales or refinancings on the same properties. The indices are based on information obtained by reviewing repeat mortgage transactions on single-family properties whose mortgages have been purchased or securitized by Fannie Mae or Freddie Mac. Besides the FHFA/OFHEO house price indices, we have also included a number of other relevant property price measures. The national Freddie Mac conventional home loan price indices, which are constructed in a way very similar to the FHFA/OFHEO indices; the national and regional Census Bureau house price series measuring the mean and the median price developments of new single family homes; the National Association of Realtors (NAR) house price index measuring the median sales price of existing homes gathered from Multiple Listing Services (MLSs); and the S&P/Case-Shiller national house price index, constructed based on information on purchase prices obtained from county assessors and recorder offices, covering all loans including exotic nonconforming and sub-prime.[6] Finally, besides all these residential property price

[4] Note that we do not include housing activity indicators such as home sales and housing construction in the analysis since these are real activity variables and therefore do conceptually not fit in our factor model exclusively comprised of asset prices and financial variables. For a recent analysis of housing activity indicators see Ng and Mönch (2009).

[5] OFHEO stands for Office of Federal Housing Oversight, which was an agency within the U.S. Department of Housing and Urban Development. In 2008, OFHEO was combined with the Federal Housing Finance Board (FHFB) to form the Federal Housing Finance Agency (FHFA).

[6] For a more detailed description and comparison of the construction of the different house price indices see e.g. Peek and Wilcox (1991), National Association of Realtors (2008) and Leventine (2008).

measures, we also include the MIT/CRE commercial property price index, a transactions-based price index constructed based on data from the National Council of Real Estate Investment Fiducaries (NCREIF) by the MIT Center for Real Estate.[7]

The stock price block of our dataset 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 sub-indices. 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 dataset comprises a large range of money and capital market interest rates, including Treasury bills, Treasury bonds, commercial paper rates, corporate bond rates as well as rates on certificates of deposit and Eurodollar deposits. We further include a large range of retail lending interest rates, including 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 non-profit organizations), the non-financial corporate sector and the non-farm non-corporate sector while 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 changes in (flows of) financial assets and liabilities of the different sectors, while the latter provides information on the stock of the various components of the three sectors' assets and liabilities (including real estate assets and mortgage debt) 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.[8]

[7] More details on the construction of this price index can be found under: http://web.mit.edu/cre/research/credl/tbi.html.
[8] 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 a zero mean and a 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.[9]

The baseline sample period for the analysis for which the database is compiled is 1987Q3 to 2007Q4. This period covers essentially the Greenspan chairmanship and therefore focuses the analysis on a single monetary policy regime. Further motivations for this choice of sample period are structural changes in the banking sector in the 1970s and early 1980s as well as the change in the monetary policy regime and the associated drop in the mean of inflation and in the volatility of output growth and inflation ("Great Moderation") in the early/mid 1980s. In section 4.5 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. The starting period of the longer sample analysis is determined by the availability of the FHFA/OFHEO house price indices. Except for the S&P/Case-Shiller house price index and the MIT/CRE commercial property price index, all the financial data series listed in Table A.1. are also available over the longer sample period.

## 3. Methodology

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

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

[9] 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 value of the preceding five observations. See also Stock and Watson (2005).

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

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

Let the elements of $\mathrm{F}_t$ be the common factors driving the $N \times 1$ vector $\mathrm{X}_t$ which summarizes our 232 ($= \boldsymbol{N}$) financial variables. It is assumed that $\mathrm{X}_t$ 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 $\Xi_t = [\xi_{1t} \quad \cdots \quad \xi_{Nt}]'$ denotes a $N \times 1$ vector of idiosyncratic components.[10] The matrix of factor loadings $\Lambda = [\boldsymbol{\lambda}_1 \quad \cdots \quad \boldsymbol{\lambda}_N]$ has dimension $\boldsymbol{r} \times \boldsymbol{N}$ and $\boldsymbol{\lambda}_i, \boldsymbol{i} = 1,...,\boldsymbol{N}$ are of dimension $\boldsymbol{r} \times 1$. Typically, $\boldsymbol{r} << \boldsymbol{N}$. 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).[11]

Both equations (1) and (2) thus represent the FAVAR model suggested by Bernanke et al. (2005).[12]

The model is estimated in five steps. First, the dimension of $\mathrm{F}_t$ , i.e. the number of common (latent and observable) factors $r$ is determined to be 6, which explain roughly two thirds (64 percent) of the dataset. This represents a reasonable degree of comovement between the variables.[13, 14]

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[10] $\mathrm{F}_t$ can contain dynamic factors and lags of dynamic factors. Insofar, equation (2) is not restrictive.

[11] We have made sure that the variables in our dataset 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 1. This also suggests that extracting the factors from the full data set rather than from sub-groups of specific data categories, such as house prices, stock prices, etc. is appropriate. For an example of a FAVAR with factors estimated from sub-groups of variables, see Belviso and Milani (2006), who estimate the factors and the dynamic model jointly using Bayesian methods.

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

[13] We have re-run the FAVAR based on 7 factors and obtained very similar impulse response functions. Given this finding and the relatively short sample period we prefer the more parsimonious specification with 6 factors. The information criteria suggested by Bai and Ng (2002) gave inconclusive results so that we could not rely on them.

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 (2008). 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 $\Lambda$.

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

The fourth step involves identifying the monetary policy shocks and distinguishing between macro shocks and financial shocks without identifying macro and financial shocks further, e.g. splitting the macro shocks into real supply and demand shocks or distinguishing between share price or credit shocks, which would require imposing controversial restrictions. For this purpose we combine contemporaneous zero and short-run sign restrictions on impulse response functions.[15,16] The restrictions for the identification of monetary policy shocks are summarized in Table 1. They are 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 summarized in $\hat{H}_t$. This yields the restrictions that real GDP and prices are not contemporaneously affected by both monetary policy shocks, which is a common assumption in the monetary transmission studies relying on recursive identification schemes, and shocks to the financial factors $\hat{H}_t$.

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 $\hat{H}_t$), and impose sign restrictions in order to disentangle the monetary policy shocks from other shocks. We

[14] All static factors seem to be also dynamic factors. As for the determination of the number of static factors, we adopt also an informal approach to determine the number of dynamic factors. We find that 6 dynamic principal components explain the same bulk of variation in the large dataset (also 64 percent) as the 6 static factors.

[15] Such an identification scheme combining zero and sign restrictions is also used by Jarociński and Smets (2008). In contrast to our paper, they use sign restrictions to disentangle housing supply and housing demand shocks, but not for the identification of the monetary policy shock.

[16] We do not apply a pure sign restrictions approach such as the ones originally proposed by Uhlig (2005) or by Peersman (2005). The former approach involves identifying only one column of Q in order to identify a single shock which is computationally inexpensive but prevents interpretability of the other shocks. The latter approach involves rotating all VAR residuals and allows eventually identifying more than one shock but is computationally intensive for large systems such as ours and requires theoretically founded sign restrictions for each shock. We adopt an intermediate identification scheme which is relatively fast and allows us to disentangle different types of shocks.

impose a set of standard restrictions to identify the monetary policy shock, employed e.g. by Peersman (2005), Canova and Gambetti (2009) and Benati and Mumtaz (2008), and consistent with a large number of theoretical models. The Federal Funds rate initially increases, and real GDP and prices initially decline after the shock. Furthermore, we restrict monetary aggregates (real M1 and real M2) to initially fall after a monetary policy shock. The former restrictions help to distinguish the monetary policy shock further from real aggregate supply and demand shocks.[17] The latter restriction serves to ensure that the monetary policy shock is not contaminated by a money demand shock.[18]

Besides these standard restrictions we impose additional, conceptually motivated restrictions on two sets of variables included in $X_t$ in order to achieve a more precise identification of the monetary policy shock. First, we restrict the spreads of long-term (5-, 10- and 30-year) government bond yields over the Fed Funds rate to initially decrease after a monetary policy shock. This restriction is implied by the Rational Expectations Hypothesis given that short-term rates increase only temporarily after a monetary policy shock[19] and helps to disentangle the monetary policy shock from a "term spread shock" which increases the yield spread and the Fed Funds rate and lowers output and prices. An example of a contractionary shock of that kind is the inflation scare of 1994, which led to a sudden increase in longer-term bond yields as a result of higher inflation expectations. An example of an expansionary shock is the "global savings glut" which has probably occurred prior to the global financial crisis. A number of observers have argued that it was not expansionary monetary policy shocks, but excessively low long-term interest rates, held down by an excess of global savings invested in U.S. Treasury Securities, that fuelled the pre-crisis housing and

[17] After a supply shock, GDP and prices move in different directions, and after a real demand shock, all three observable factors move in the same direction (see e.g. Peersman 2005).

[18] Like a contractionary monetary policy shock, a positive money demand shock (i.e. a shock that autonomously increases the demand for money balances) is associated with a reduction in real GDP and prices and an increase in interest rates. Thus, the two shocks can only be disentangled by imposing the restriction that the monetary policy shock is associated with a reduction of monetary aggregates, which can be rationalized by a negative effect of a contractionary monetary policy shock on money demand.

[19] Given that policy rates increase only temporarily after a monetary policy shock, long-term bond yields, which should reflect the average expected future level of policy rates, should increase by less than the policy rate after the shock, so that the yield spread declines. The potential reaction of term premia would be expected to reinforce this effect. Inflation risk premia would be expected to fall as a result of the disinflationary effects of the policy shock. Real term premia would also be expected to decline. Since short-term real rates are more volatile than long-term real rates, real term premia should be negative (Cochrane 2007) and, according to that logic, to decline after a monetary policy shock that leads to increased variability in short-term real rates. Hördahl et al. (2004) indeed show based on an affine term structure model that term premia fall in response to a contractionary monetary policy shock.

credit boom, and also contributed to low levels of policy rates.[20] Separating the monetary policy shock from this type of shock is therefore particularly relevant in the context of this paper. Robustness checks suggest, however, that the imposition of this restriction does not have a major effect on the empirical results.

Second, we impose the restriction that a contractionary monetary policy shock has negative initial effects on stock prices (i.e. the real S&P 500, the Dow Jones and the NASDAQ). This restriction can be theoretically justified based on standard asset pricing models[21] and helps to better disentangle expected and unexpected changes in policy rates. This is suggested by the empirical study of Bernanke and Kuttner (2005) who decomposed the Federal Funds rate in an expected and an unexpected part based on high frequency financial data and find that unexpected increases in the Fed Funds rate exert a negative effect on stock prices, while the effect of expected increases is found to be positive. Imposing these restrictions does alter the estimated effects of monetary policy shocks on stock prices and household financial wealth, which become insignificant if the restrictions are not imposed, but does not affect the other results.

All restrictions are imposed on the contemporaneous response and the first lag. The shocks to the financial factors summarized in $\hat{\mathrm{H}}_t$ (i.e. the other rotated Cholesky residuals) are restricted not to have the characteristics of monetary policy shocks and not to affect output and prices contemporaneously. We label them financial shocks in the following. The Cholesky residuals associated with the GDP growth and GDP deflator inflation equations are labelled macro shocks. More technical details on the identification scheme are provided in Appendix 2.

This identification scheme has the advantage that it allows for simultaneous interaction between the monetary policy instrument and financial factors rather than imposing some kind of recursive ordering which is still common in many VAR- or

[20] Gerlach et al. (2008) present evidence showing that short-term nominal rates decline in response to negative shocks to long-term real interest rates and suggest that the decline in short-term rates after 2000 is at least in part attributable to central banks' reaction to the downward movement in long-term rates observed over this period.

[21] From the perspective of standard asset pricing models, such as the dividend discount model or the consumption-based asset pricing model, stock prices should fall in response to a contractionary monetary policy shock as expected dividends would be expected to fall (as a result of the negative output reaction) and both the risk-free component of the discount rate (as a result of higher interest rates) as well as the equity risk premium (as a result of the shock-induced increase in economic volatility and uncertainty) would be expected to rise. A formal validation of the negative effect of monetary policy shocks on the equity risk premium is provided by the consumption-based asset pricing models with habit persistence (Campbell and Cochrane 1999), which implies that asset risk premia are counter-cyclical and would hence be expected to increase in reaction to the counter-cyclical effects of a monetary policy shock.

FAVAR-based studies. This is important as the latent factors are linear combinations of many financial variables in our data set, such as stock prices and bond yields, which can respond instantaneously to policy shocks. At the same time, monetary policy is able to immediately take into account the information content of 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 for contemporaneous interaction between the policy rate and the financial factors.

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 due to the small sample size. The number of bootstrap replications equals 500. Notice that, since $N > T$, we neglect the uncertainty involved with the factor estimation, 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 economic 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 average over all series belonging to a group) at 38 percent for property price inflation measures, 51 percent for balance sheet components, 82 percent for credit market interest rates and spreads, and 48 percent for changes in stock prices. The first column of Table 3 also reveals a relatively high commonality for the variables which were in the focus before the outbreak of the financial crisis and which we have shown in Figure 1, with the exception of the Census house price index which has a commonality of only 13 percent.

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 15 variables that are most highly correlated (in absolute terms) with 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, 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 of variables lends further empirical support to the notion that developments in asset prices and private sector balance sheets are closely correlated and justifies *ex post* to model the dynamics of these variables jointly based on a factor model approach that exploits their comovement.

## 4.2. Impulse response functions

Figures 3-7 present the impulse responses of a number of selected variables to a monetary policy shock which raises the Federal Funds rate by 100 basis points. We show median impulse responses and one standard deviation 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 delayed and persistent decline in the price level and a temporary increase in the Federal Funds rate. These reaction patterns are qualitatively in line with stylized facts established in previous studies on monetary transmission in the U.S. (e.g. Christiano et al. 1996, Peersman 2005).

We next turn to the dynamic reactions of property prices presented in 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. While the reaction of the different property prices is qualitatively similar, discernible differences in the quantitative reactions emerge. The peak (median) responses of the residential price indices range between around -2 percent (NAR house price index) and -5 percent (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 is not completely innocuous,[22] although it should be noted that the confidence bands are rather wide and overlapping.

[22] 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, Iacoviello (2005) and Bjørnland and Jacobsen (2008) use the Freddie Mac house price index. The FAVAR-based study on the U.S. housing

The explanation for the rather strong, sluggish and persistent responses of the property price indices are to be found in the many specific features which make property distinct from other assets like equity and bonds. Property markets are characterized by lengthy approval and construction processes on the supply side and a lack of transparency as the availability of price information is often very limited. The reason for the quantitative differences in the responses of the various house price measures cannot be pinned down with any great precision, 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 sub-prime segment.[23] The finding that commercial property prices respond considerably more strongly to a monetary policy shock than residential property prices can be explained by longer construction lags, i.e. very inelastic supply, and a stronger responsiveness of commercial rents (Zhu 2003).

In contrast to the sluggish reaction of house prices, the responses of stock prices and bond yields are front-loaded, consistent with the notion that financial markets quickly respond to news such as monetary policy shocks. 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 negative and significant only immediately and in the first quarter after the shock when the sign restrictions are binding. Consistent with the REHTS, the reactions of long-term bond yields to the policy shock are found to be sub-proportional to the reaction of the Federal Funds rate and to decrease with the maturity of the bond. The former pattern is not completely owed to the sign restriction we have imposed, as the reaction of bond yield spreads is significantly negative for around four quarters after the shock.

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market by Ng and Mönch (2009) includes a large 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 Iacoviello and Neri (2008) and Darracq Pariès and Notarpietro (2008) find a quite different, front-loaded reaction of house prices.

[23] 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 sub-prime 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 sub-prime segment of the mortgage market.

Figure 6 reports impulse responses of a number of important credit risk spreads. The responses of the risk spreads shown in Figure 1, i.e. 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 government bond yield), as well as the C&I loan rate spread (spread of C&I loan rate over the 2-year government bond yield)[24] are very similar. A 100 basis point monetary policy shock leads to a significant instantaneous increase in these spreads of 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 evidence of the existence of a balance sheet transmission channel[25] and/or a risk-taking transmission channel[26], since risks spreads should not react to monetary policy shocks if such channels were absent. It is, however, not possible to further disentangle the two channels.

For other classes of capital market and loan market risk spreads we get a more dispersed picture. The Moody's corporate bond spread (spread of BAA corporate yield over AAA corporate yield) is essentially unaffected by a monetary policy shock, which suggests that, after a monetary tightening, bond financing via lower rated bonds does not become more expensive than bond financing via high rated bonds. This finding also obtains for other corporate bond spreads (not reported). The personal loan rate spread (spread of 2-year personal loan rate over the 2-year government bond

[24] The 2-year government bond yield is the appropriate reference rate for the C&I loan rate. The maturity of this rate varies but is usually close to two years. In the November 2007 release of the "Survey of terms of business lending" (Federal Reserve Board Statistical Release E.2.) the weighted average maturity of C&I loans was 612 days.

[25] The balance sheet channel suggests that a monetary policy tightening has a positive effect on risk premia via its negative effect on the net worth and thus the creditworthiness of borrowers, who can only borrow at a premium over internal financing against collateral (net worth) because of informational frictions in credit markets. Borrower net worth, in turn, is positively linked to cash-flow and the value of collateralizable assets, which are in turn negatively linked to the monetary policy stance. In fact, as we show below, private sector net worth is found to fall significantly after a monetary policy shock, which is consistent with this view. 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).

[26] 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 counter-cyclicality of investor risk aversion. Sticky return targets, arising e.g. from money illusion of investors, the design of compensation schemes of fund managers, or pre-contracted liabilities (e.g. of insurance companies), would imply that risk premia are positively correlated with risk-free rates as the effect of higher (lower) risk-free rates on returns is sought to be compensated by less (more) risk taking (Rajan 2005). A positive link between policy rates and risk premia would also arise if investor risk aversion was inherently counter-cyclical, as in consumption-based asset pricing models with habit persistence in consumption (Campbell and Cochrane 1999), since monetary policy has counter-cyclical effects. For a more detailed discussion of the various facets of the risk-taking channel and further references, see Borio and Zhu (2008).

yield) is found to initially fall sharply to an extent which implies that consumer loan rates are essentially unaffected by monetary policy shocks. This suggests that policy rate pass-through to this type of loan rates is extremely sluggish.[27] The spread remains significantly negative for more than a year before increasing slightly. At the same time, the finding of unresponsiveness of consumer loan rates to policy shocks is consistent with the finding reported below that consumer loans are barely affected by a monetary policy tightening.

Figure 7 reports impulse responses of key balance sheet positions of the household, the corporate non-financial business sector and the non-corporate business sector. In order to facilitate the interpretation of the results, we report in Table 4 the nominal value 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. Figure 7 (a) 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. Net worth declines significantly in all three sectors, but there are differences in the response patterns. The response of household net worth is front-loaded and rather small with a maximum response of -1 percent, reflecting, as we will see in the following section, the weak response of financial assets as the largest part of total assets. The reaction of corporate and non-corporate net worth is considerably stronger, with maximum reactions of -4 percent, and very sluggish and persistent. The negative response of net worth to a monetary policy shock in all three sectors is consistent with the potential existence of a financial accelerator in the transmission process.

Figure 7 (b) reports impulse responses for three key components of total assets, namely financial assets, tangible assets as well as real estate assets, which is the largest component of the tangible asset category in all three sectors (see Table 4). There are notable differences in the reaction of financial assets, reflecting the heterogeneous composition of financial assets in the three sectors. Household financial assets respond in a very short-lived way to the policy shock, which looks very similar to the response we found for equity prices and interest rates. This similarity may be explained by the fact that the bulk of household financial assets are held in corporate equities and mutual fund shares and pension fund and life insurance reserves, which are all linked to the movements of financial asset prices and yields. In

[27] For example, Hofmann and Mizen (2004) and Hofmann (2006) document the sluggish adjustment of retail rates to monetary policy shocks. The focus of this literature is, however, on European countries rather than the U.S., reflecting the more important role of bank financing in the former countries' financial systems.

contrast to this, corporate financial assets temporarily increase in response to the shock, while non-corporate financial assets persistently decline. We are not really able to come up with a clear cut explanation for these differences, as the composition of financial assets in the two business sectors makes an interpretation rather difficult. The largest component of financial assets in the business sectors is the miscellaneous asset category, which is an assortment of financial assets that do not fit in the other main categories but are individually too small to be listed as a separate asset category (Table 4).

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. Non-corporate and corporate real estate wealth reacts somewhat stronger (maximum effects of -4 percent and -6 percent) than household real estate assets (peak response of -3 percent), which corresponds to our finding that commercial property prices react more strongly to a monetary policy shock than residential real estate prices.

Figure 7 (c) shows the reaction of the three sectors' total debt, their mortgage debt and one other important debt category, which are consumer loans in the case of households, corporate bonds in the case of corporates and other bank and non-bank loans and advances in the case of non-corporates. For households, the results reveal that total debt and mortgage debt persistently decline by a maximum of more than 2 percent in response to the monetary policy shock. Consumer loans, in contrast, are found to barely respond to the policy shock.

Non-corporate debt is also found to fall persistently in response to a monetary policy shock, but the reaction is three times stronger (-6 percent) than that of household debt. The reaction patterns of mortgage debt and short-term loans are very similar to that of total debt. Corporate debt, in contrast, first increases significantly before it turns insignificant. This result is owed to the persistent and significant increase in corporate bond issuances (the largest component of corporate debt, Table 4) after the shock. Corporate mortgage debt persistently decreases even by 10 percent, which is substantially higher than the decrease in the other two sectors. But due to 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) non-corporate 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 have found that corporates or large firms respond to a monetary contraction by raising short-term debt (Kashyap et al. 1993, Bernanke et al. 1996), while there was no evidence of an increase in long-term debt (Christiano et al. 1996). As we will see in section 4.5, this reaction of corporate bond issuances to a monetary tightening is a more recent phenomenon that could therefore not be uncovered by earlier studies. 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 non-financial private sector to raise mortgage financing is closely linked to the development of real estate collateral.

## 4.3. Variance decompositions

As the next step we explore the role of monetary policy shocks in the overall variability of the various variables over the sample period based on variance decompositions. Columns 2 and 3 of Table 3 present the forecast error variance shares of selected variables explained by monetary policy shocks at the 1- and 5-year horizons.

The results suggest that the importance of monetary policy shocks for the different variables varies considerably. On the balance sheet side, monetary policy shocks explain a relatively large share (between 11 percent and 17 percent at the five-year horizon) of the variance of real estate assets and of mortgage debt. They also explain a considerable fraction of the variability of household and non-corporate total debt (almost 15 percent at the five-year horizon), while they appear to play no role for total corporate debt. These results further support the notion that financial frictions play a role in the transmission of monetary policy shocks, as it suggests that monetary policy shocks play an important role for household and non-corporate debt but not for corporate debt.

Despite the high similarity found in the impulse responses, the variance explained by the monetary policy shock in the various property price indicators varies considerably.

Monetary policy shocks account for a relatively large share of the variation in the FHFA/OFHEO, the Freddie Mac, the Census and the commercial property price index (around 10 percent at the five-year horizon), but almost nothing of the variation in the Case-Shiller and the NAR house price index. This implies that in case of the latter two house price indices the effects of monetary policy shocks are almost entirely superseded by the effects of other shocks.

Monetary policy shocks are finally found to explain essentially nothing of the variance of corporate bond spreads and stock prices which lends further support to the finding that corporate sector financing conditions are barely affected by monetary policy shocks.

## 4.4. Historical decompositions

In order 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. 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 a 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 9 (a)). 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 for their dynamics over this period.

Regarding the contribution of monetary policy shocks to debt accumulation, we find a discernible contribution to the dynamics of household and non-corporate debt (Figure 9 (b)). Almost half of the growth of these variables between 2003 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 considerable, but limited to the period 2003-2005 (Figure 9 (c)). Over this period, about half of the below average level of short-term money market spreads, such as the 3-months commercial paper and the 3-months Eurodollar deposit spread, are attributable to expansionary monetary policy shocks. For the mortgage spread, the contribution is found to be around one third.

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, debt growth and the below average level of the risk spreads, but only at a relatively late stage of the property and credit boom (between 2003 and 2005). This suggests that expansionary monetary policy shocks may have reinforced and prolonged the housing and credit boom but were not the trigger of the excesses, as the take-off 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 to 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 studies by Del Negro and Otrok (2007) and Jarociński and Smets (2008) find little role of monetary policy, whereas Taylor (2007), based on a reduced form single equation estimation, and Iacoviello and Neri (2008), based on a DSGE model, find that the role of monetary policy shocks was quite important, accounting for between a quarter and a 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 (e.g. Iacoviello and Neri 2008, 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 (2008), that studies covering a longer sample tend to find larger effects of monetary policy because they include the Regulation Q period. The following sub-section elaborates on this issue in more detail.

### 4.5. A longer sample period: Reconciling the evidence on the role of monetary policy shocks in the housing boom

In order 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 dataset 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.

The obvious advantage of choosing a long sample period is that all available information is exploited so that the empirical relationships can be pinned down with greater precision. These advantages in principle also apply in the context of this study. In the longer sample period we can also exploit the information from previous housing and debt boom episodes at the end of the 1970s and the mid-1980s which should enhance the precision of empirical estimates. Furthermore, by including the Volcker disinflation the sample contains an important natural experiment of a sequence of monetary policy shocks, which should be useful to pin down their dynamic effects with greater precision. Indeed, many studies on the transmission mechanism, in particular those using FAVARs (e.g. Bernanke et al. 2005, Boivin et al. 2009) base the analysis on long sample periods going back to the 1970s or even the 1960s.

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 owed to structural changes in the economy The structural changes that may have altered the monetary transmission mechanism comprise changes in the macroeconomic environment in the form of a more stability-oriented monetary policy conduct leading to lower means of inflation and interest rates as well as, at least in part, lower macroeconomic volatility ("Great Moderation") since the mid-1980s. At the same time, 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. Deregulation and innovation in the U.S. financial system since the late 1970s, in particular the phasing out of Regulation Q and the spreading of securitization, may have weakened the transmission of monetary policy via housing and credit markets.[28] On the other hand, other structural changes in the financial system, such as the creation of an interstate banking system, the introduction of risk-oriented capital adequacy requirements and the promotion of fair-value accounting since the late 1980s, may have worked in the direction of increasing the procyclicality of the financial system and a strengthening of the monetary transmission via the balance sheet and the risk-taking channels.[29]

When running the FAVAR over the longer sample period, we keep the specification unchanged. Prior to looking at impulse responses and historical decompositions, we apply the (heteroscedasticity-robust version of the) test for parameter stability suggested by Nyblom (1989) and Hansen (1992) to our FAVAR. The null hypothesis we test is the joint stability of the (VAR coefficient and innovation variance) parameters of each equation. The test statistics are 0.79 for the first (output) equation, 1.82 for the second (price) equation, 1.12 for the third (policy rate) equation and 0.58, 0.30 and 1.42 for the three financial factor equations. The test statistics are all lower than the 5% critical value of 3.34 for 14 (number of regressors including the constant plus error variance) degrees of freedom implying that we cannot reject the null hypothesis of parameter stability. While 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 over the two samples on the FHFA/OFHEO house price index. The historical decomposition shown in the left chart of Figure 10 suggests that the estimated contribution of monetary policy shocks to the house price boom is indeed larger than for the shorter sample. In order to shed light on the cause of this stronger contribution we further report in Figure 10 the

[28] Phasing out of Regulation Q and spreading of securitization would be expected to have weakened the bank lending channel of monetary policy. Regulation Q essentially imposed a ceiling on bank's deposit rates which caused an outflow of deposits when interest rates increase, thereby reinforcing the effect of the interest rate change (Mertens 2008). The spreading of securitization has improved banks' ability to raise funds on the capital market by selling previously not tradable assets in repackaged form, which is also likely to have weakened the bank lending channel (Estrella 2002).

[29] The creation of an interstate banking system, i.e. the ability of banks to compete across state border, during the 1970s enhanced competition in the financial sector which should in principle have strengthened monetary transmission, e.g. via faster pass-through of policy rates to retail rates. The introduction of more risk-oriented capital requirements and fair value accounting would be expected to have strengthened monetary transmission via the balance sheet channel and the risk-taking channel (Borio and Zhu 2008). E.g. balance sheets adjust more strongly to monetary policy-induced changes in asset prices under fair-value accounting and banks will respond stronger to policy-induced changes in the macroeconomic environment under more risk sensitive capital adequacy standards.

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 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 pre-crisis 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, while the estimated dynamic effect of a monetary policy shock on the house price is much smaller over the long sample although the confidence bands overlap.

The longer sample analysis also enables us to assess changes in the transmission of monetary policy via the other financial variables included in the FAVAR. Indeed, time variation in monetary transmission is in general a topical issue which has been taken up in a number of recent studies (e.g. Boivin et al. (2009) and references therein as well). Since the topic is however somewhat beyond the scope of our analysis, we only touch upon the issue in passing. In the Appendix (Figures A.1-A.5) we report impulse response functions of the macro variables and a number of key financial variables to a (normalized) monetary policy shock for the long sample (red line) and, for comparison, our shorter baseline sample (black line). The charts point to a number of interesting changes in the transmission of monetary policy. First, the effect of monetary policy shocks on output and prices appears to have become somewhat weaker, in line with Boivin and Giannoni (2006), but the differences do not appear to be significant as the confidence bands overlap. The reaction of the Fed Funds rate is found to be considerably more persistent over the short sample, which points to a higher degree of gradualism in the conduct of monetary policy over the more recent period. Second, monetary transmission via property and mortgage markets appears to have become more potent over time. Also, the monetary transmission on money market and C&I loan rate spreads seems to have increased considerably. At the same time, the pass-through to stock prices and financial assets seems to have weakened over time. Third, 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).

Overall, the long sample analysis has revealed notable differences in the monetary transmission to a number of financial variables across sample periods. Therefore, the analysis of the remainder of the paper is based on our benchmark sample period 1987Q3 to 2007Q4.

## 5. The role of systematic monetary policy in the pre-crisis housing and credit boom

Having so far analyzed the role of monetary policy shocks, i.e. the unexplained or unsystematic part of monetary policy, in the pre-crisis build-up of imbalances in housing and credit markets, we now draw our attention to the role of systematic monetary policy, i.e. the contribution of the reaction of policy rates to financial and macro shocks. Of particular interest is obviously the role of the systematic reaction of monetary policy to financial shocks, as this would capture the hypothesis that the monetary easing in reaction to the bursting stock market bubble after 2000 has contributed to the subsequent housing and debt boom.[30]

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 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.

### 5.1. The drivers of the path of policy rates

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. Since our shock identification scheme allows for a contemporaneous reaction of policy rates to financial factors, we can use our empirical framework to assess in a realistic way the contribution of financial shocks to the systematic conduct of monetary policy. Furthermore, we also assess the role of macro shocks for the path of policy rates.

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 financial shocks (green line).[31] The decomposition suggests that the low level of policy rates between 2001 and 2004 has been mainly attributable to negative macroeconomic and financial shocks, but only initially to expansionary monetary policy shocks. Negative macro shocks may reflect the post-2000 economic

[30] 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.
[31] The confidence bands for the historical decompositions, which we do not report, are rather tight.

downturn, and negative financial shocks probably reflect the bursting of the dotcom bubble and the decline in long-term interest rates. By 2003, the contribution of the monetary policy shocks to the level of the Federal Funds rate had already turned slightly positive again. 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 hence, the output gap and inflationary pressures had been underestimated.[32] In fact policy makers at that time even expressed concerns of a deflation (e.g. Bernanke 2002, Greenspan 2007). Interestingly, the decomposition suggests that the post-2005 increase in the Fed Funds rate was to a large extent driven by contractionary monetary policy shocks, but also by financial shocks. The latter probably reflects 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 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. This has also been implied by statements of Fed officials, such as the statement by former Chairman Greenspan (1994) 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*".

[32] 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.

In order to show how the inclusion of financial factors in the model influences the interpretation of the drivers of the observed path of the Fed Funds rate, we replicate the decomposition of the Federal Funds rate based on a simple VAR(2) which only comprises the three observables (GDP growth, GDP deflator inflation and the Federal Funds rate) as endogenous variables but not the latent financial factors and compare the results with those obtained based on the FAVAR. We adopt the same identification scheme as before to identify a monetary policy shock (except that we are now of course not able to restrict yield spreads, money balances and stock prices).[33]

Two results are worthwhile noting. First, Figure 12 suggests that the contributions of financial shocks to the historical path of the Federal Funds rate estimated based on the FAVAR (the green line in Figure 11) are now partly attributed to monetary policy shocks (mainly between 1992 and 2001) and partly to macro shocks (before 1992 and after 2001). Second, the size of the monetary policy shock (i.e. the instantaneous impact of a one standard deviation monetary policy shock on the Federal Funds rate) estimated based on the VAR exceeds the size of the monetary policy shock estimated based on the FAVAR by roughly ¼ (24 compared to 19 basis points). Overall, this suggests that monetary policy shocks estimated based on a model without financial factors may capture omitted financial shocks and that not including financial factors in empirical models of monetary policy may give rise to misleading interpretation of the drivers of the path of policy rates.

## 5.2. A counterfactual experiment

In order to explore the role of the systematic monetary policy reaction to financial and macro shocks in the pre-crisis 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 financial shocks or of both financial and macro shocks. The quantitative contribution of systematic monetary policy is then computed by performing a historical decomposition based on the counterfactual sequence of

[33] The implementation of this identification scheme in this VAR is less straightforward compared to the FAVAR. As before we first carry out a Cholesky decomposition of the covariance matrix of the reduced-form VAR residuals. We then rotate the three Cholesky residuals as described in the Appendix. To identify monetary policy shocks we keep of all the draws those which satisfy the sign restrictions presented in Table 1 for GDP and the GDP deflator for horizon 1 and the Federal Funds rate for horizons 0-1. In addition, we allow the impact response of GDP and the GDP deflator to only deviate from zero by some very small fixed number. The other two rotated Cholesky residuals (which are orthogonal to the policy shock) can be labelled macro shocks.

monetary policy shocks that would have placed the Federal Funds rate on the counterfactual path.

Figure 13 shows for a number of key variables the contributions of the original monetary policy shocks (red line), of the combined contribution of the original monetary policy shocks and the systematic reaction of monetary policy to financial shocks (green dashed line) and of the combined contribution of the original monetary policy shocks and the systematic reaction of monetary policy to both financial and macro shocks (blue dashed line). Accordingly, the contribution of the systematic reaction of monetary policy to financial shocks is the difference between the green dashed line and the red line, and the additional contribution of the policy reaction to macro shocks is the difference between the blue dashed line and the green dashed line.

The charts suggest that the systematic reaction of monetary policy in particular to financial shocks seems to have also contributed in a considerable way to the pre-crisis house price and credit boom. As would be expected from the decomposition of the Federal Funds rate in the previous subsection, the contribution of the systematic policy reaction to financial shocks 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 since counterfactual experiments in reduced form models are prone to the Lucas critique: changes of private sector expectations of the policy process that may result from the policy changes that are implied by the counterfactual and 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 to 2007 to explore the interaction between monetary policy and more than 200 financial and asset variables in the U.S. We adopt an identification scheme that allows for contemporaneous interaction between financial factors and policy interest rates and enables a more accurate identification of the monetary policy shock by imposing additional theoretically motivated sign restrictions in the FAVAR besides the standard restrictions used in the literature. 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, based on historical decompositions, the role of monetary policy shocks 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 boom and the low risk spreads in credit markets; (iii) 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 financial 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) non-corporate 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 issuances, 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 shocks have contributed discernibly, but at a late stage to the unsustainable dynamics in housing and credit markets that were observed between 2001 and 2006. This suggests that expansionary monetary policy shocks may have reinforced and prolonged the housing and credit boom but were not the trigger of the excesses, as the take-off 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.

(iii) Negative financial shocks in the wake of the bursting the stock market bubble have significantly contributed to the low level of policy rates observed prior to the crisis. The feedback effects of these negative financial shocks via lower policy rates on property and credit markets are found to have probably been considerable. The counterfactual analysis, together with the historical decomposition, therefore supports the view held by Taylor (2007) that monetary policy was a key driver of the housing boom. It would however be premature to draw strong policy conclusions based on these findings since counterfactual experiments in reduced form models are prone to the Lucas critique. Hence, the results of the counterfactual simulation should be taken with caution.

Besides these main results a number of findings from a comparative longer sample analysis starting in the mid-1970s are worth highlighting. Monetary transmission via property and mortgage markets as well as several credit risk spreads appears to have become more potent over time. 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). Finally, different findings in the literature with regard to the importance of monetary policy shocks for the pre-crisis house price boom seem to be due to differences in the choice of the sample period. A larger contribution is found over the longer sample period, which is attributable to larger estimated policy shocks.

While these results have proved robust to considerable perturbations in the specification of the empirical model, there are, as always, a number of interesting potential extensions of the analysis which we saw as being beyond the scope of this paper. Two potential extensions appear to be particularly interesting avenues for future research. First, it is often suggested that the response of the U.S. Fed to financial market developments might be asymmetric to the extent that there is no tightening in the boom, but an aggressive loosening in the bust.[34] However, so far

[34] An asymmetric policy conduct of the Fed in response to financial market gyrations under the Greenspan chairmanship, also referred to as the "Greenspan put", is inferred by some observers from a number of statements by former chairman Greenspan. For instance, in a speech in 1999, Greenspan stated: *"[O]bviously, if we could find a way to prevent or deflate emerging bubbles, we would be better off. But identifying a bubble in the process of inflating may be among the most formidable challenges confronting a central bank, pitting its own assessment of fundamentals against the combined judgment of millions of investors …. The danger is that … an unwarranted, perhaps euphoric, extension of recent*

there is no empirical study providing evidence of such an asymmetric policy conduct by the Fed. If such asymmetry were present, the analysis we have performed might understate the role of the systematic policy reaction to financial shocks, as the reaction to the negative shocks would have been stronger while that to the positive shocks would have been weaker. Second, since the focus of this paper is on monetary policy, we do not explicitly assess the role of alternative drivers of the U.S. housing and credit boom such as a "global savings glut" shock, i.e. excessively low long-term interest rates held down by an excess of global savings invested in U.S. Treasury Securities, expansionary fiscal policy shocks, or exogenous increases in housing demand. Via our modelling set-up, we have, however, made sure that our analysis of the role of monetary policy for financial conditions is not impaired by other forces not explicitly explored.

*developments can drive equity prices to levels that are unsupportable even if risks in the future become relatively small. Such straying above fundamentals could create problems for our economy when the inevitable adjustment occurs. It is the job of economic policymakers to mitigate the fallout when it occurs and, hopefully, ease the transition to the next expansion."* (Greenspan 1999).

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## Table 1: Monetary policy shock identifying restrictions

| horizon | y | p | ffr | monet. aggregates | term spreads | stock prices |
|---|---|---|---|---|---|---|
| 0 | 0 | 0 | ≥ | ≤ | ≤ | ≤ |
| 1 | ≤ | ≤ | ≥ | ≤ | ≤ | ≤ |

Note: y, p and ffr refer to GDP, the GDP deflator and the Federal Funds rate, respectively. The term spreads are the spreads of the 5-, the 10- and the 30-year government bond yields over the Federal Funds rate, monetary aggregates are M1 and M2 divided by the GDP deflator, and stock prices are the S&P 500, the Dow Jones and the NASDAQ divided by the GDP deflator.

## Table 2: Correlation coefficients between factors and most highly correlated variables

| | Variable | $\Delta y_t$ | Variable | $\Delta p_t$ | 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 $r$ (observable and latent) factors and the corresponding correlation coefficients. Which number refers to which variable can be seen from Table A1.

## Table 3: Variance decompositions

| | Variance shares explained by common factors | Forecast error variance shares explained by monetary policy shocks 1 year | 5 years |
|---|---|---|---|
| Macro variables | | | |
| GDP | 1.00 | 0.01 | 0.06 |
| GDP deflator | 1.00 | 0.00 | 0.04 |
| Federal funds rate | 1.00 | 0.26 | 0.18 |
| Property prices | | | |
| House price (FHFA/OFHEO) | 0.65 | 0.06 | 0.13 |
| House price (S&P/Case-Shiller) | 0.37 | 0.02 | 0.01 |
| Commercial property price index | 0.19 | 0.02 | 0.09 |
| House price (Freddie Mac) | 0.59 | 0.05 | 0.12 |
| House price (Census) | 0.13 | 0.04 | 0.09 |
| House price (NAR) | 0.21 | 0.02 | 0.03 |
| Stock prices, credit and money and capital market rates and spreads | | | |
| 3m commercial paper spread | 0.76 | 0.08 | 0.09 |
| 3m Eurodollar deposit spread | 0.71 | 0.07 | 0.08 |
| 30y mortgage loan spread | 0.63 | 0.04 | 0.06 |
| Corp. bond spread | 0.17 | 0.00 | 0.01 |
| 24m personal loan spread | 0.71 | 0.09 | 0.09 |
| C&I loan spread | 0.71 | 0.07 | 0.08 |
| S&P 500 | 0.74 | 0.01 | 0.01 |
| Dow Jones | 0.70 | 0.01 | 0.02 |
| NASDAQ | 0.33 | 0.00 | 0.01 |
| 5y yield const mat securities spread | 0.72 | 0.04 | 0.06 |
| 10y yield const mat securities spread | 0.77 | 0.05 | 0.08 |
| 30y yield const mat securities spread | 0.79 | 0.07 | 0.08 |
| Assets and liabilities of the non-financial private sector | | | |
| Househ. assets | 0.41 | 0.01 | 0.02 |
| Househ. liabilities | 0.43 | 0.03 | 0.14 |
| Househ. net worth | 0.40 | 0.01 | 0.01 |
| Corp. assets | 0.64 | 0.00 | 0.04 |
| Corp. liabilities | 0.35 | 0.01 | 0.01 |
| Corp. net worth | 0.59 | 0.01 | 0.08 |
| Non-corp. assets | 0.91 | 0.03 | 0.15 |
| Non-corp. liabilities | 0.85 | 0.01 | 0.09 |
| Non-corp. net worth | 0.67 | 0.04 | 0.14 |
| Househ. financial assets | 0.40 | 0.01 | 0.01 |
| Househ. tangible assets | 0.62 | 0.04 | 0.10 |
| Househ. real estate assets | 0.64 | 0.04 | 0.11 |
| Corp. financial assets | 0.40 | 0.00 | 0.01 |
| Corp. tangible assets | 0.66 | 0.01 | 0.09 |
| Corp. real estate assets | 0.64 | 0.01 | 0.12 |
| Non-corp. financial assets | 0.59 | 0.00 | 0.03 |
| Non-corp. tangible assets | 0.88 | 0.04 | 0.16 |
| Non-corp. real estate assets | 0.88 | 0.04 | 0.17 |
| Househ. debt | 0.52 | 0.04 | 0.14 |
| Househ. mortgage debt | 0.39 | 0.04 | 0.13 |
| Househ. consumer loans | 0.29 | 0.00 | 0.00 |
| Corp. debt | 0.64 | 0.01 | 0.03 |
| Corp. mortgage debt | 0.37 | 0.02 | 0.11 |
| Corp. bonds | 0.45 | 0.02 | 0.03 |
| Non-corp. debt | 0.88 | 0.02 | 0.13 |
| Non-corp. mortgage debt | 0.79 | 0.02 | 0.12 |
| Non-corp. short-term loans | 0.63 | 0.01 | 0.08 |

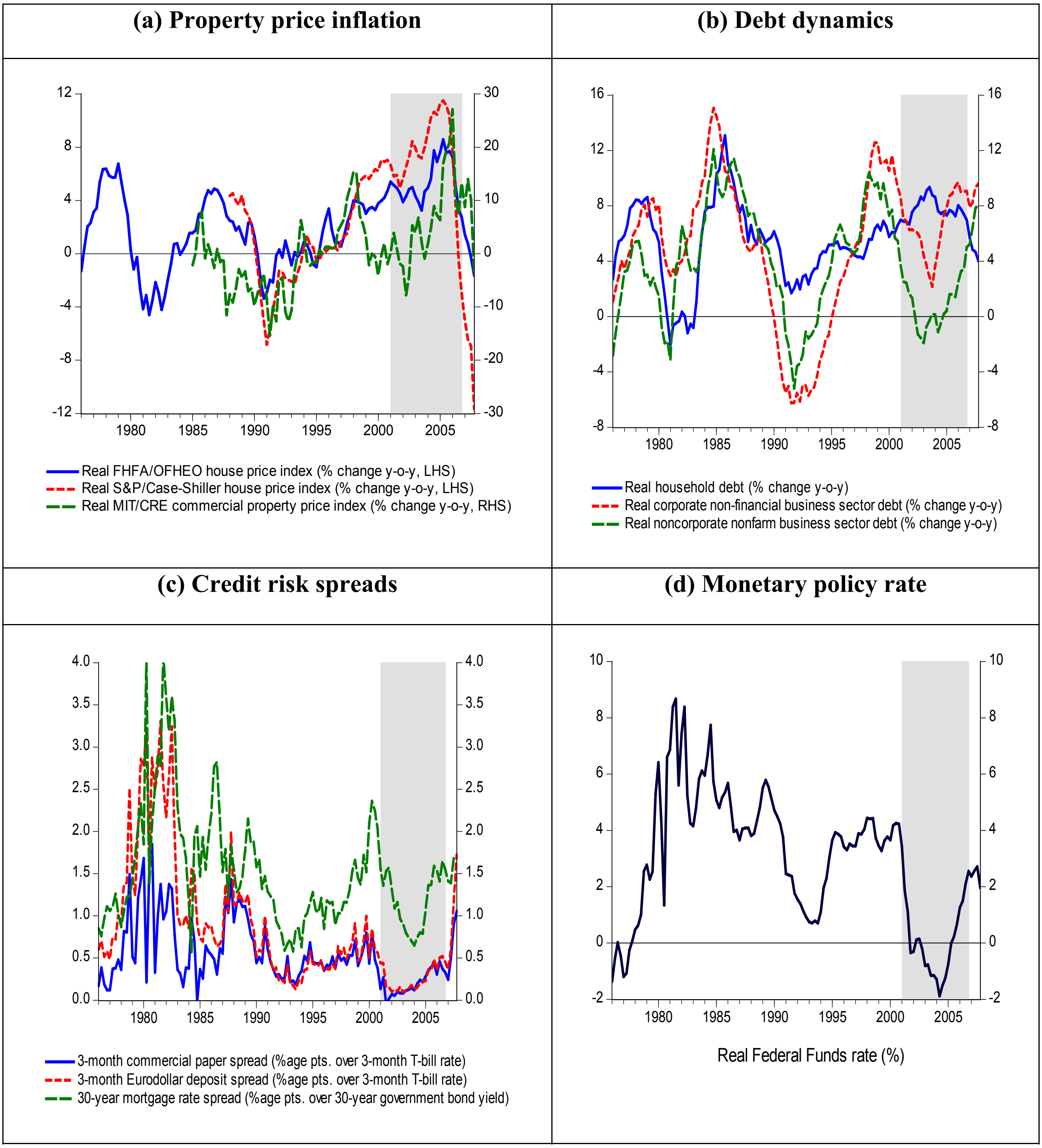
Note: The variance shares explained by the common factors refer to the stationary variables (i.e. growth rates in general), whereas the (median) forecast error variance shares explained by monetary policy shocks refer to the levels of the variables at the 1- and 5-year horizons. The total forecast error variance (to which the forecast error variance explained by monetary policy shocks is put in relation) was computed by summing up the forecast error variance explained by common (latent and observed) factors and the forecast error variance explained by idiosyncratic shocks. The latter was estimated by fitting an AR(1) model to each individual idiosyncratic component. The sample period is 1987Q3-2007Q4.

## Table 4: Non-financial private sector balance sheets in 2007

| | Households & nonprofit organizations | | Nonfarm noncorporate business | | Nonfarm non-financial corporate business | |
|---|---|---|---|---|---|---|
| Assets (Bil. $) | 78229 | | 12210 | | 28689 | |
| *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 & loans) | | 0.08 | | 0.03 | | 0.02 |
| Corporate equity & mutual fund shares | | 0.28 | - | | | 0.02 |
| Noncorporate equity | | 0.17 | - | | - | |
| Pension fund & 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* | | | | | | |
| 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. $) | 14318 | | 5193 | | 12807 | |
| *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 & 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. $) | 63911 | | 7018 | | 15882 | |

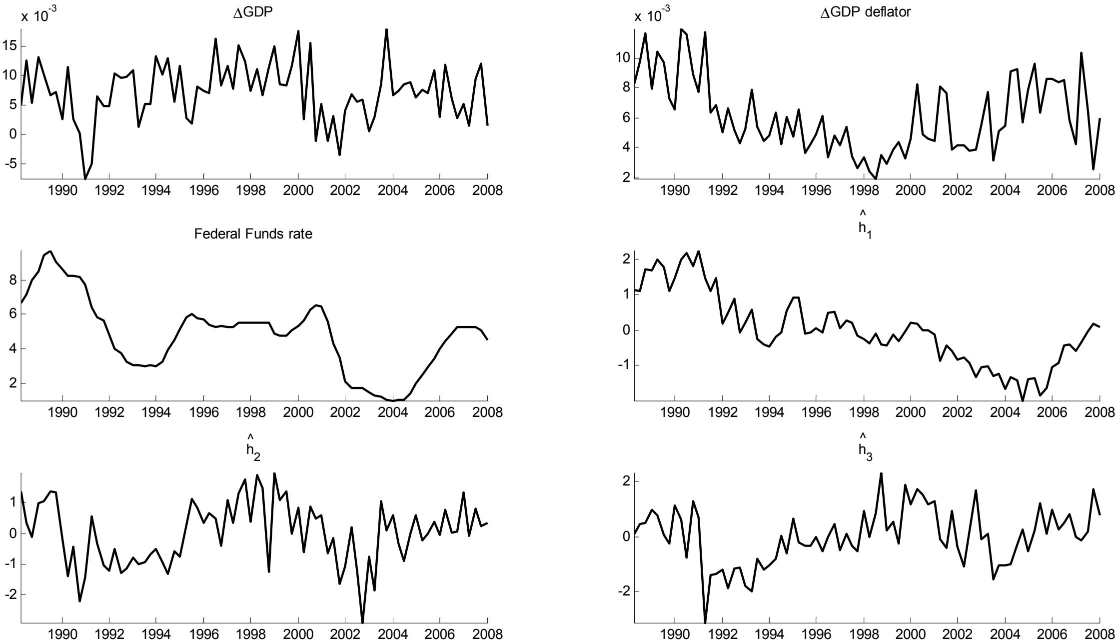
Note: Real estate assets and corporate equity (also mutual fund holdings of corporate equity) are valued at market value, all other assets and liabilities are valued at book value. More detailed information on the balance sheets can be found in Federal Reserve Board (2009), Table B.100, B.102, B.103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

**Figure 1: Property prices, private sector debt, credit spreads and monetary policy**



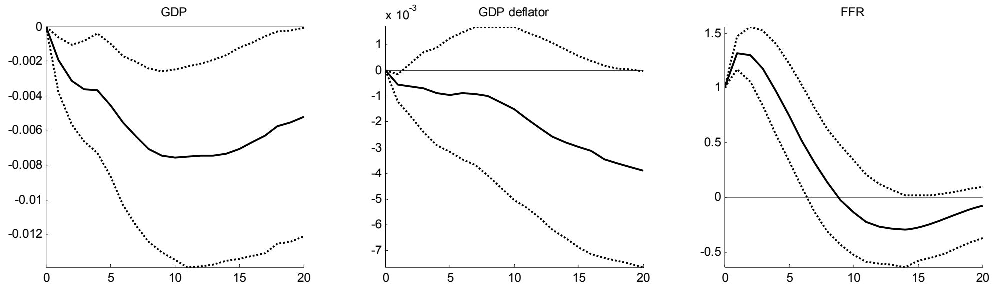

Note: Real property prices and real debt have been computed by deflating with the GDP deflator. The real Federal Funds rate is the effective Federal Funds rate less the year-on-year change in the GDP deflator. Sources: St. Louis FRED, OFHEO, Bureau of the Census, Federal Reserve Board, own calculations.

## Figure 2: Time series of the factors



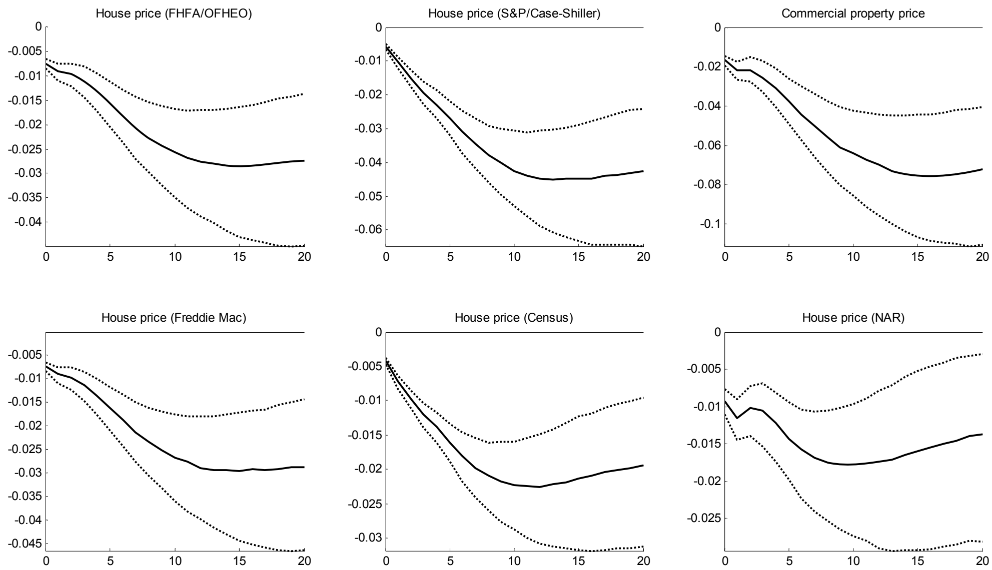

Note: Each factor is normalized to be positively correlated with the variable which is most highly correlated with it in absolute terms.

## Figure 3: Impulse response functions of key macroeconomic variables to monetary policy shocks



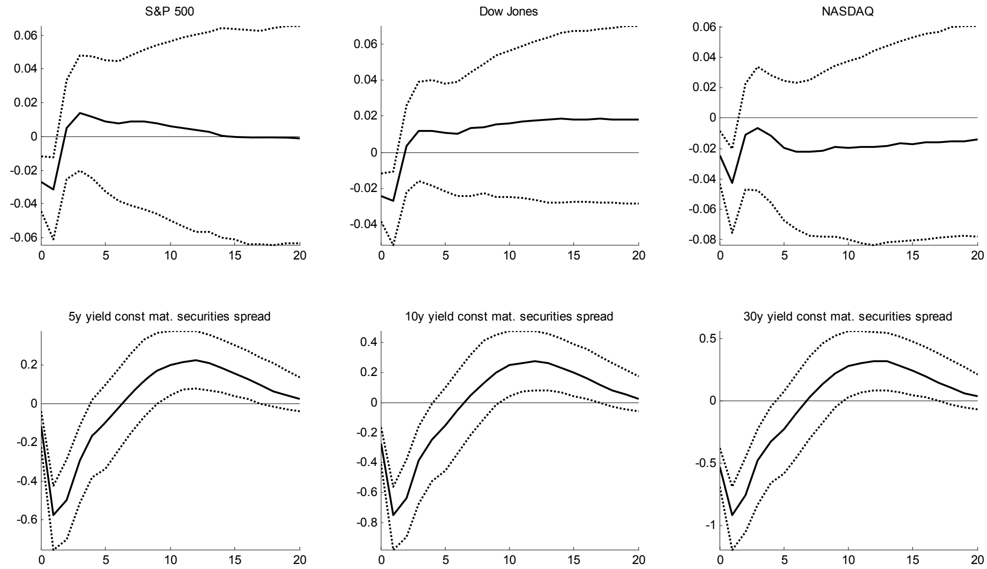

Note: The charts show the median and the 1 standard deviation confidence intervals. The sample period of the analysis is 1987Q3-2007Q4.

## Figure 4: Impulse response functions of property prices



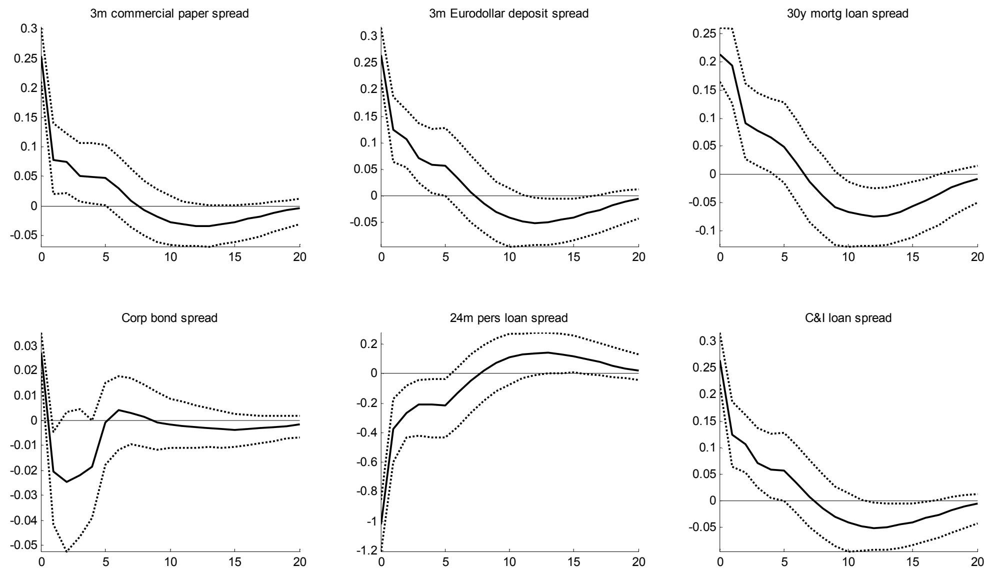

Note: same as for Figure 3.

**Figure 5: Impulse response functions of stock prices and government bond yield spreads**




Note: same as for Figure 3.

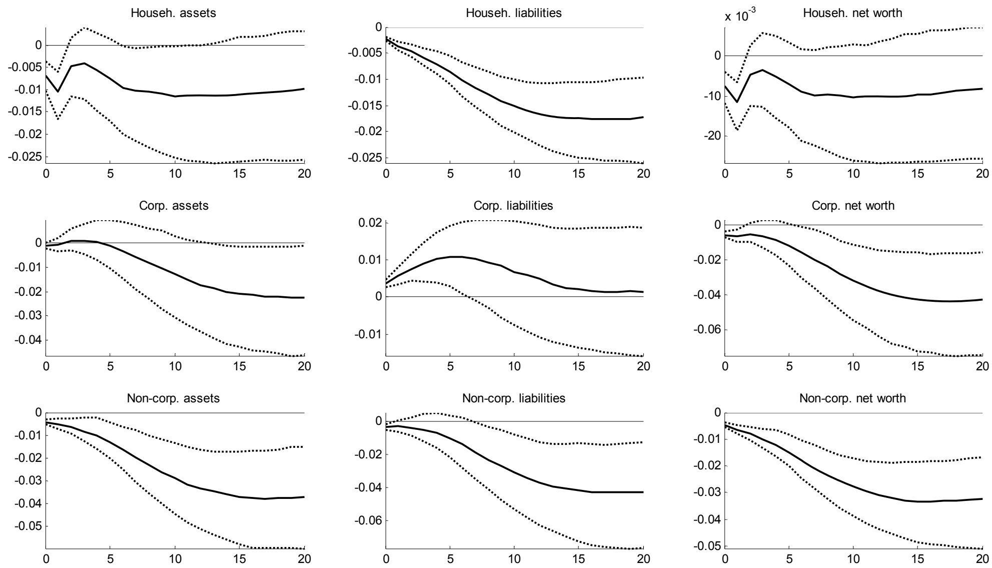
**Figure 6: Impulse response functions of credit risk spreads**



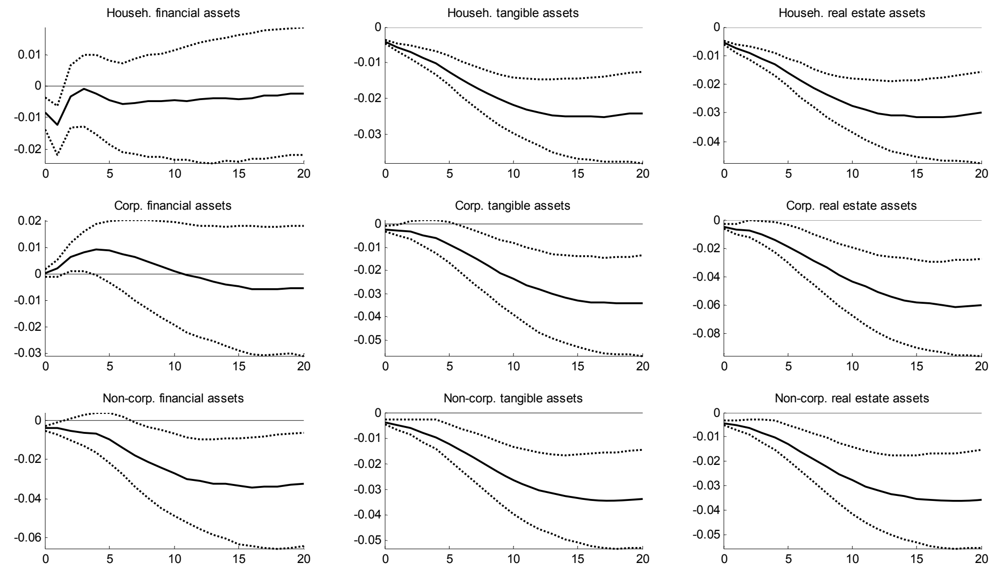

Note: same as for Figure 3.

**Figure 7: Impulse response functions of assets and liabilities of the non-financial private sector**

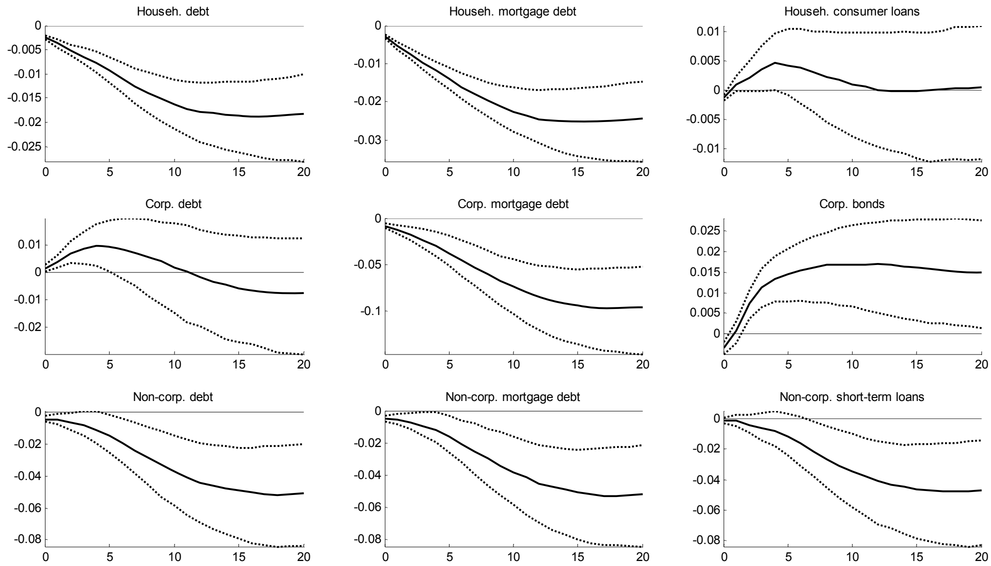
**(a) Total assets, total liabilities and net worth**




**(b) Assets**

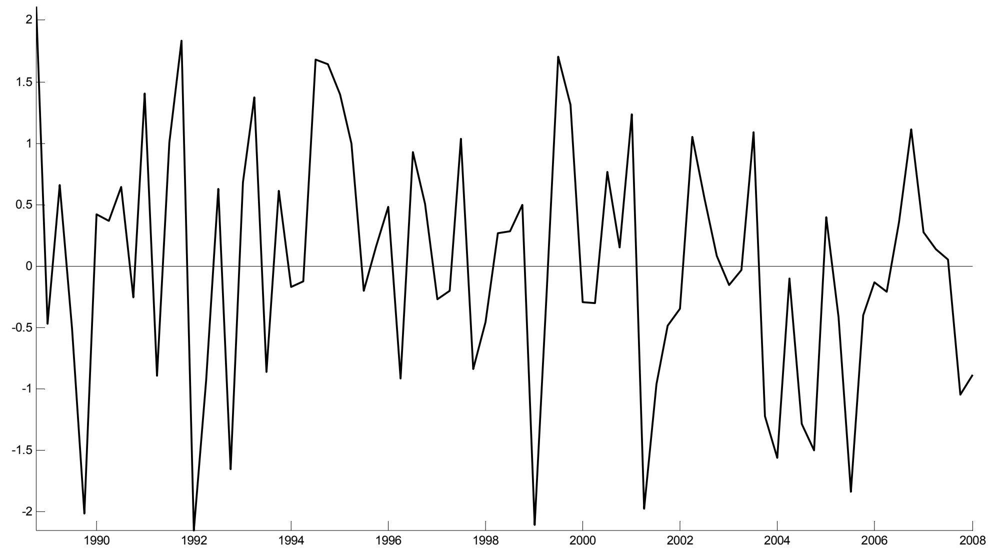


## (c) Debt




Note: same as for Figure 3.

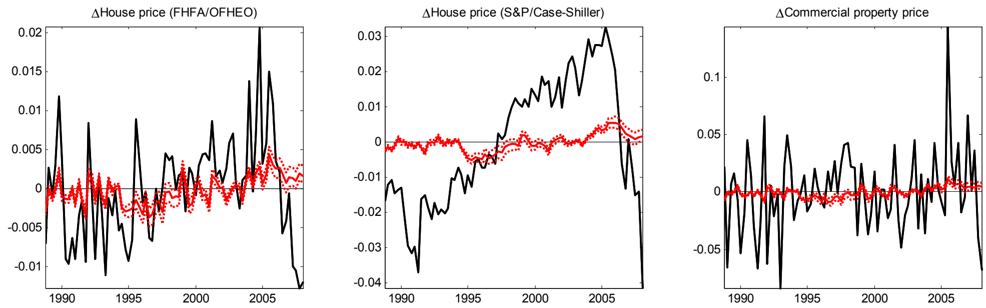
## Figure 8: Time series of the monetary policy shock



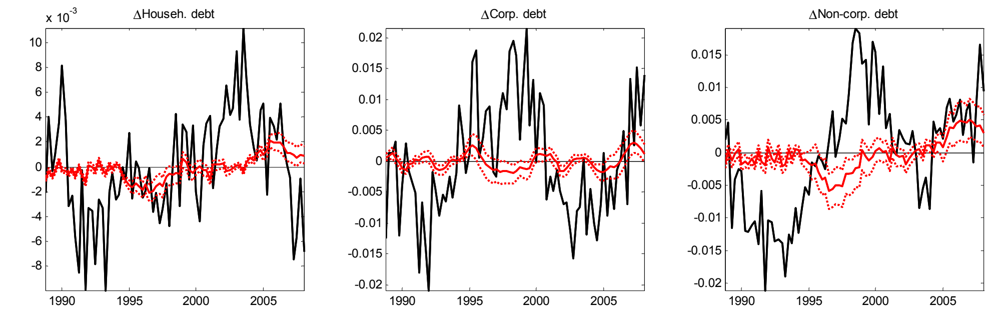

Note: The shock was scaled to have an impact of 100 basis points on the Federal Funds rate.

## Figure 9: Historical decomposition of selected financial variables

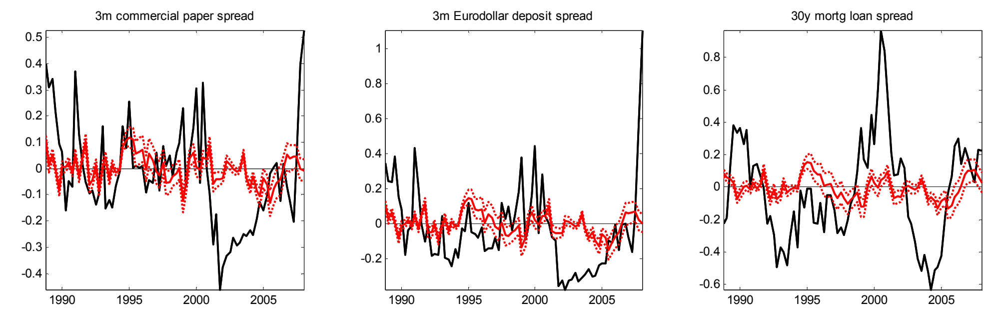
### (a) Property prices




### (b) Debt

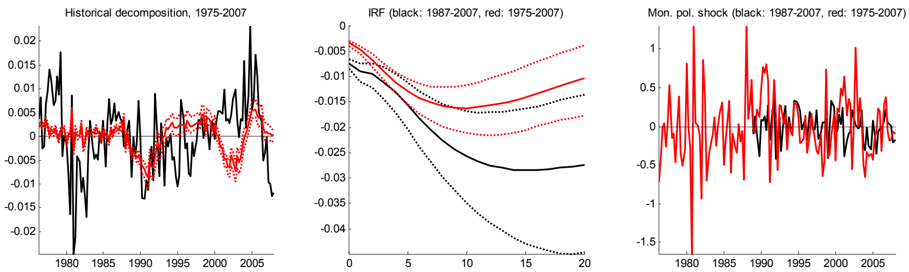



### (c) Credit risk spreads



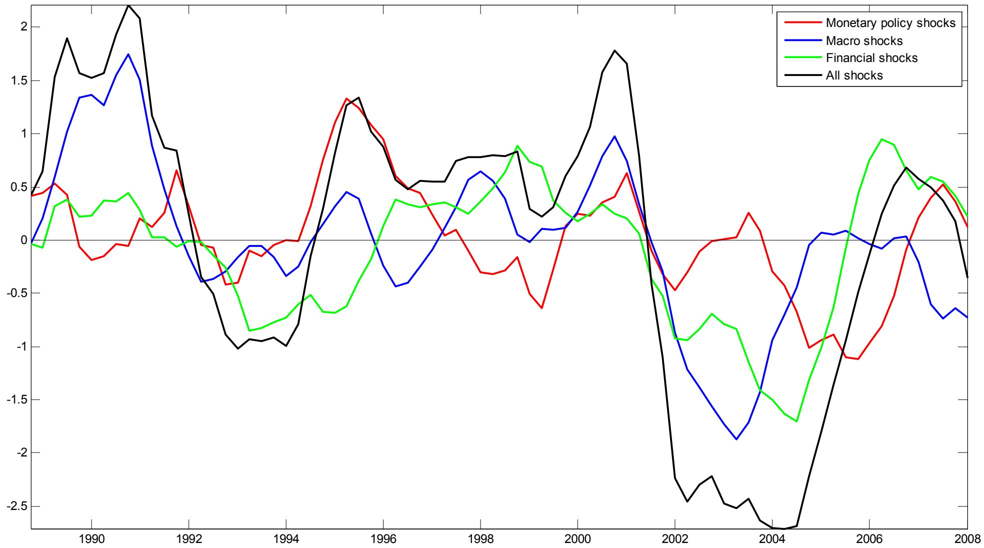

Note: The black line refers to the forecast error explained by all (common and idiosyncratic) shocks, the red line to the forecast error explained by monetary policy shocks. The forecast error explained by idiosyncratic shocks was estimated by fitting an AR(1) model to each idiosyncratic component. Historical 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 corresponding confidence bands.

## Figure 10: Contribution of monetary policy shocks to house price inflation (FHFA/OFHEO) in the long sample compared to the short sample



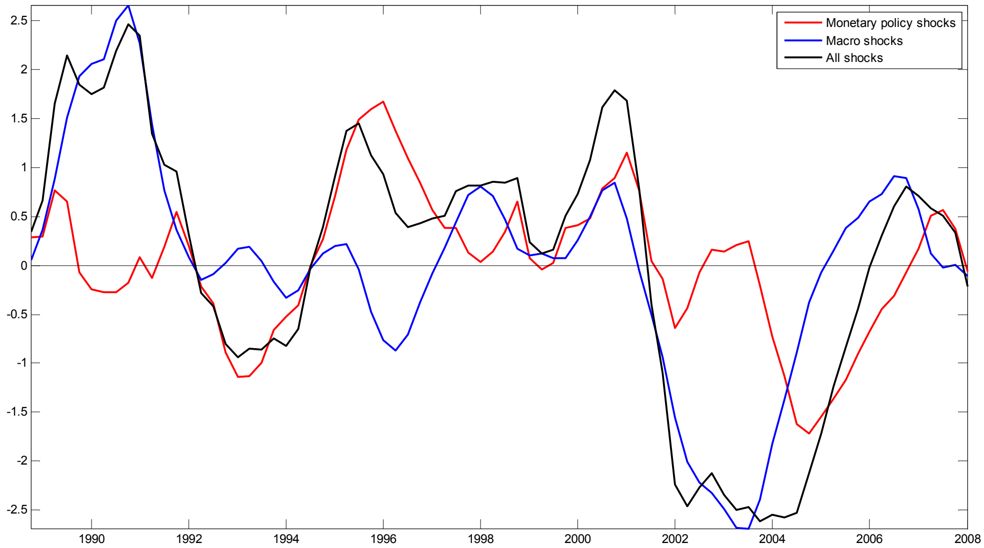

Note: The long sample spans the period 1975Q1-2007Q4. The short sample is as before 1987Q3-2007Q4. The historical decomposition refers to house price inflation, the impulse response functions to the levels of house prices. In the chart for the impulse response function and the monetary policy shock, the red line refers to the long sample and the black line to the short sample. For further details see notes below Figures 3, 8 and 9.

## Figure 11: Historical decomposition of the Federal Funds rate




Note: 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 below Figure 9.

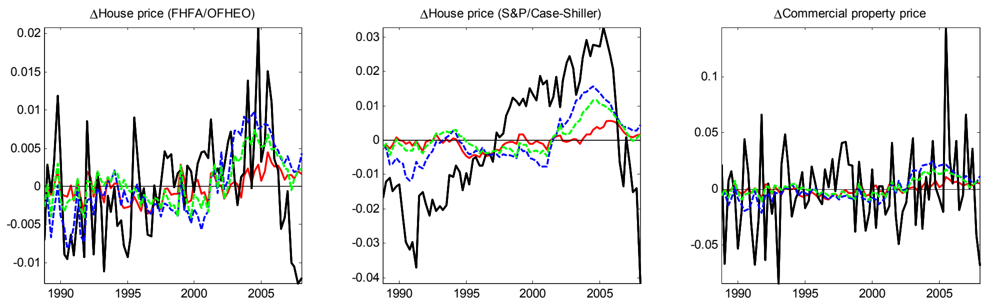
## Figure 12: Historical decomposition of the Federal Funds rate based on a VAR without financial factors



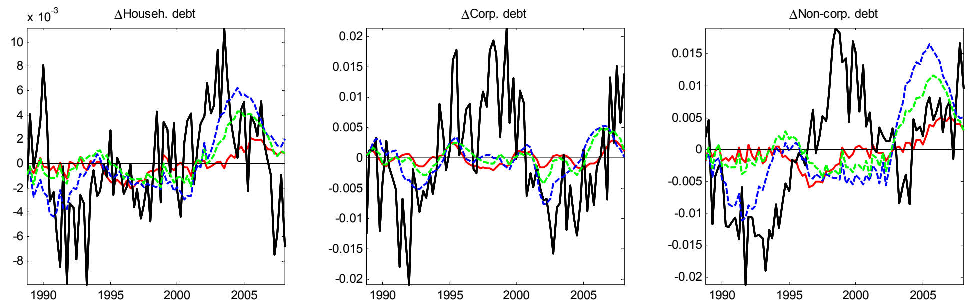

Note: The black line refers to the contribution of all (common and idiosyncratic) shocks, the other lines indicate the contribution of shocks; for more details, see note below Figure 9.

## Figure 13: Historical decompositions and counterfactual simulations – the role of monetary policy shocks and of systematic monetary policy

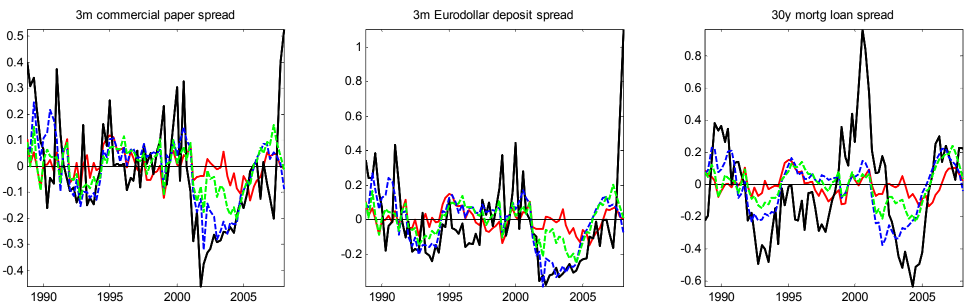
### (a) Property prices




### (b) Debt




### (c) Credit risks spreads




Note: 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 contribution 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 below Figure 9.

## Appendix 1: Verifying the validity of assumptions of the approximate factor model for our dataset

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 been taken into account in various empirical forecasting studies (see Eickmeier and Ziegler (2008) and references therein) but rarely in more structural studies.

In order to assess whether this may be an issue in our dataset, we estimate $\boldsymbol{r}$ principal components from $\mathrm{X}_t$, remove series with low commonality (e.g. here defined as a variance share explained by the common factors of $< 0.2$ and, respectively, $< 0.3$) and, alternatively, highly cross-correlated idiosyncratic components from the dataset following Rule 1 suggested in Boivin and Ng (2006). This rule involves looking at each series $\boldsymbol{i} = 1, \ldots, \boldsymbol{N}$ in $\mathrm{X}_t$ and dropping the series $j$ from the rest of the dataset 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 re-estimate factors from the reduced dataset, 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 dataset.

Table A.2 shows that the factors extracted from the entire dataset (which we use in our estimation) are almost perfectly correlated with the factors extracted from the reduced datasets. We therefore can conclude that low commonality and cross-correlated idiosyncratic errors are not problems in our dataset and that the factors we estimated from $\mathrm{X}_t$ are likely to be accurate.

## Appendix 2: 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

$$\hat{v}_t = \hat{A}\hat{u}_t, \tag{A1}$$

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

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

$$R(\theta) = \prod\nolimits_{l,n} \begin{bmatrix} 1 & 0 & \cdots & & & & \cdots & 0 \\ 0 & \ddots & & & & & & 0 \\ \vdots & & \cos(\theta) & & & -\sin(\theta) & & \vdots \\ & & & \ddots & & & & \\ & & & & 1 & & & \\ & & & & & \ddots & & \\ & & \sin(\theta) & & & \cos(\theta) & & \vdots \\ \vdots & & & & & & \ddots & 0 \\ 0 & \cdots & & & & \cdots & 0 & 1 \end{bmatrix}, \tag{A2}$$

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

It turns out that more than one $\theta$ satisfy 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) have called attention to another possible problem. They argue that the literature often presents summary measures of impulse response functions such as the medians that come from different models or, put differently, that reflect shocks which are not orthogonal. To avoid these problems, they suggest choosing, out of all $\theta$ that satisfy the sign restrictions, the $\theta$ that leads to impulse response functions which 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 $\pi$, until we have obtained $K$ $\theta$s which satisfy the restrictions. $K$ is set at 200 to keep it computationally tractable. For each $\theta$, 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 $\theta$ and some fixed horizon, we group the standardized impulse responses into a $L \times 1$ vector $\vartheta$ ($L$ is the number of restricted variables/impulse response functions). We pick the $\theta$ that minimizes $\vartheta'\vartheta$, denoted by $\theta*$. Based on $\theta*$, we compute the rotation matrix $\mathrm{R}(\theta*)$.

## Table A.1: Data

| # | Variable | Source | Treatment |
|---|---|---|---|
| 1 | FHFA/OFHEO House Price Index, U.S. | FHFA/OFHEO | 0 |
| 2 | FHFA/OFHEO House Price Index AK | FHFA/OFHEO | 0 |
| 3 | FHFA/OFHEO House Price Index AL | FHFA/OFHEO | 0 |
| 4 | FHFA/OFHEO House Price Index AR | FHFA/OFHEO | 0 |
| 5 | FHFA/OFHEO House Price Index AZ | FHFA/OFHEO | 0 |
| 6 | FHFA/OFHEO House Price Index CA | FHFA/OFHEO | 0 |
| 7 | FHFA/OFHEO House Price Index CO | FHFA/OFHEO | 0 |
| 8 | FHFA/OFHEO House Price Index CT | FHFA/OFHEO | 0 |
| 9 | FHFA/OFHEO House Price Index DC | FHFA/OFHEO | 0 |
| 10 | FHFA/OFHEO House Price Index DE | FHFA/OFHEO | 0 |
| 11 | FHFA/OFHEO House Price Index FL | FHFA/OFHEO | 0 |
| 12 | FHFA/OFHEO House Price Index GA | FHFA/OFHEO | 0 |
| 13 | FHFA/OFHEO House Price Index HI | FHFA/OFHEO | 0 |
| 14 | FHFA/OFHEO House Price Index IA | FHFA/OFHEO | 0 |
| 15 | FHFA/OFHEO House Price Index ID | FHFA/OFHEO | 0 |
| 16 | FHFA/OFHEO House Price Index IL | FHFA/OFHEO | 0 |
| 17 | FHFA/OFHEO House Price Index IN | FHFA/OFHEO | 0 |
| 18 | FHFA/OFHEO House Price Index KS | FHFA/OFHEO | 0 |
| 19 | FHFA/OFHEO House Price Index KY | FHFA/OFHEO | 0 |
| 20 | FHFA/OFHEO House Price Index LA | FHFA/OFHEO | 0 |
| 21 | FHFA/OFHEO House Price Index MA | FHFA/OFHEO | 0 |
| 22 | FHFA/OFHEO House Price Index MD | FHFA/OFHEO | 0 |
| 23 | FHFA/OFHEO House Price Index ME | FHFA/OFHEO | 0 |
| 24 | FHFA/OFHEO House Price Index MI | FHFA/OFHEO | 0 |
| 25 | FHFA/OFHEO House Price Index MN | FHFA/OFHEO | 0 |
| 26 | FHFA/OFHEO House Price Index MO | FHFA/OFHEO | 0 |
| 27 | FHFA/OFHEO House Price Index MS | FHFA/OFHEO | 0 |
| 28 | FHFA/OFHEO House Price Index MT | FHFA/OFHEO | 0 |
| 29 | FHFA/OFHEO House Price Index NC | FHFA/OFHEO | 0 |
| 30 | FHFA/OFHEO House Price Index ND | FHFA/OFHEO | 0 |
| 31 | FHFA/OFHEO House Price Index NE | FHFA/OFHEO | 0 |
| 32 | FHFA/OFHEO House Price Index NH | FHFA/OFHEO | 0 |
| 33 | FHFA/OFHEO House Price Index NJ | FHFA/OFHEO | 0 |
| 34 | FHFA/OFHEO House Price Index NM | FHFA/OFHEO | 0 |
| 35 | FHFA/OFHEO House Price Index NV | FHFA/OFHEO | 0 |
| 36 | FHFA/OFHEO House Price Index NY | FHFA/OFHEO | 0 |
| 37 | FHFA/OFHEO House Price Index OH | FHFA/OFHEO | 0 |
| 38 | FHFA/OFHEO House Price Index OK | FHFA/OFHEO | 0 |
| 39 | FHFA/OFHEO House Price Index OR | FHFA/OFHEO | 0 |
| 40 | FHFA/OFHEO House Price Index PA | FHFA/OFHEO | 0 |
| 41 | FHFA/OFHEO House Price Index RI | FHFA/OFHEO | 0 |
| 42 | FHFA/OFHEO House Price Index SC | FHFA/OFHEO | 0 |
| 43 | FHFA/OFHEO House Price Index SD | FHFA/OFHEO | 0 |
| 44 | FHFA/OFHEO House Price Index TN | FHFA/OFHEO | 0 |
| 45 | FHFA/OFHEO House Price Index TX | FHFA/OFHEO | 0 |
| 46 | FHFA/OFHEO House Price Index UT | FHFA/OFHEO | 0 |
| 47 | FHFA/OFHEO House Price Index VA | FHFA/OFHEO | 0 |
| 48 | FHFA/OFHEO House Price Index VT | FHFA/OFHEO | 0 |
| 49 | FHFA/OFHEO House Price Index WA | FHFA/OFHEO | 0 |
| 50 | FHFA/OFHEO House Price Index WI | FHFA/OFHEO | 0 |
| 51 | FHFA/OFHEO House Price Index WV | FHFA/OFHEO | 0 |
| 52 | FHFA/OFHEO House Price Index WY | FHFA/OFHEO | 0 |
| 53 | Freddie Mac Conventional Mortgage Home Price Index, United States (Q1-87=100) | Federal Home Loan Mortgage Corporation | 0 |
| 54 | Freddie Mac Conventional Mortgage Purchase-Only Home Price Index, US (Q1-87=100) | Federal Home Loan Mortgage Corporation | 0 |
| 55 | Price Index of New 1-Family Houses Sold (2005=100) | Census Bureau | 0 |
| 56 | NAR Median Sales Price: Existing 1-Family Homes, United States (Dollars) | National Association of Realtors | 0 |
| 57 | New 1-Family Houses: Median Sales Price, U.S. Total (Dollars) | Census Bureau | 0 |
| 58 | New 1-Family Houses: Median Sales Price, Northeast (Dollars) | Census Bureau | 0 |
| 59 | New 1-Family Houses: Median Sales Price, Midwest (Dollars) | Census Bureau | 0 |
| 60 | New 1-Family Houses: Median Sales Price, South (Dollars) | Census Bureau | 0 |
| 61 | New 1-Family Houses: Median Sales Price, West (Dollars) | Census Bureau | 0 |
| 62 | New 1-Family Houses: Average Sales Price, U.S. Total (Dollars) | Census Bureau | 0 |
| 63 | New 1-Family Houses: Average Sales Price, Northeast (Dollars) | Census Bureau | 0 |
| 64 | New 1-Family Houses: Average Sales Price, Midwest (Dollars) | Census Bureau | 0 |
| 65 | New 1-Family Houses: Average Sales Price, South (Dollars) | Census Bureau | 0 |
| 66 | New 1-Family Houses: Average Sales Price, West (Dollars) | Census Bureau | 0 |
| 67 | S&P/Case-Shiller Home Price Index: U.S. National (Q1-00=100) | Standard & Poor's | 0 |
| 68 | S&P/Case-Shiller Home Price Index: Composite 10 (Jan-00=100) | Standard & Poor's | 0 |
| 69 | Commercial Real Estate: Transaction-Based Price Index: All Properties (Q1-84=100) | MIT/Center for Real Estate | 0 |
| 70 | Households, Total Assets | Federal Reserve Flow of Funds Accounts | 0 |
| 71 | Households, Tangible Assets | Federal Reserve Flow of Funds Accounts | 0 |
| 72 | Households, Real Estate Assets | Federal Reserve Flow of Funds Accounts | 0 |
| 73 | Households, Consumer Durable Goods | Federal Reserve Flow of Funds Accounts | 0 |
| 74 | Households, Financial Assets | Federal Reserve Flow of Funds Accounts | 0 |
| 75 | Households, Deposits | Federal Reserve Flow of Funds Accounts | 0 |
| 76 | Households, Credit Market Instruments | Federal Reserve Flow of Funds Accounts | 0 |
| 77 | Households, Corporate Equity | Federal Reserve Flow of Funds Accounts | 0 |
| 78 | Households, Mutual Fund Shares | Federal Reserve Flow of Funds Accounts | 0 |
| 79 | Households, Life Insurance Reserves | Federal Reserve Flow of Funds Accounts | 0 |
| 80 | Households, Pension Funds Reserves | Federal Reserve Flow of Funds Accounts | 0 |

# Table A.1: Data cont.

| # | Variable | Source | Treatment |
|---|---|---|---|
| 81 | Households, Total Liabilities | Federal Reserve Flow of Funds Accounts | 0 |
| 82 | Households, Debt | Federal Reserve Flow of Funds Accounts | 0 |
| 83 | Households, Home Mortgage Debt | Federal Reserve Flow of Funds Accounts | 0 |
| 84 | Households, Consumer Credit | Federal Reserve Flow of Funds Accounts | 0 |
| 85 | Households, Net Worth | Federal Reserve Flow of Funds Accounts | 0 |
| 86 | M1 | Federal Reserve Board | 0 |
| 87 | M2 | Federal Reserve Board | 0 |
| 88 | Corporate Sector, Total Assets | Federal Reserve Flow of Funds Accounts | 0 |
| 89 | Corporate Sector, Tangible Assets | Federal Reserve Flow of Funds Accounts | 0 |
| 90 | Corporate Sector, Real Estate Assets | Federal Reserve Flow of Funds Accounts | 0 |
| 91 | Corporate Sector, Inventories | Federal Reserve Flow of Funds Accounts | 0 |
| 92 | Corporate Sector, Financial Assets | Federal Reserve Flow of Funds Accounts | 0 |
| 93 | Corporate Sector, Liabilities | Federal Reserve Flow of Funds Accounts | 0 |
| 94 | Corporate Sector, Debt | Federal Reserve Flow of Funds Accounts | 0 |
| 95 | Corporate Sector, Commercial Paper | Federal Reserve Flow of Funds Accounts | 0 |
| 96 | Corporate Sector, Mutual Fund Shares | Federal Reserve Flow of Funds Accounts | 0 |
| 97 | Corporate Sector, Corporate Bonds | Federal Reserve Flow of Funds Accounts | 0 |
| 98 | Corporate Sector, Bank Loans | Federal Reserve Flow of Funds Accounts | 0 |
| 99 | Corporate Sector, Other Loans and Advances | Federal Reserve Flow of Funds Accounts | 0 |
| 100 | Corporate Sector, Short-Term Loans | Federal Reserve Flow of Funds Accounts | 0 |
| 101 | Corporate Sector, Mortgage Loans | Federal Reserve Flow of Funds Accounts | 0 |
| 102 | Corporate Sector, Net Worth | Federal Reserve Flow of Funds Accounts | 0 |
| 103 | Corporate Sector, Loans | Federal Reserve Flow of Funds Accounts | 0 |
| 104 | Corporate Sector, Securities | Federal Reserve Flow of Funds Accounts | 0 |
| 105 | Corporate Sector, Long-Term Debt | Federal Reserve Flow of Funds Accounts | 0 |
| 106 | Corporate Sector, Short-Term Debt | Federal Reserve Flow of Funds Accounts | 0 |
| 107 | Non-corporate Sector, Total Assets | Federal Reserve Flow of Funds Accounts | 0 |
| 108 | Non-corporate Sector, Tangible Assets | Federal Reserve Flow of Funds Accounts | 0 |
| 109 | Non-corporate Sector, Real Estate Assets | Federal Reserve Flow of Funds Accounts | 0 |
| 110 | Non-corporate Sector, Equipment and Software | Federal Reserve Flow of Funds Accounts | 0 |
| 111 | Non-corporate Sector, Financial Assets | Federal Reserve Flow of Funds Accounts | 0 |
| 112 | Non-corporate Sector, Liabilities | Federal Reserve Flow of Funds Accounts | 0 |
| 113 | Non-corporate Sector, Debt | Federal Reserve Flow of Funds Accounts | 0 |
| 114 | Non-corporate Sector, Bank Loans | Federal Reserve Flow of Funds Accounts | 0 |
| 115 | Non-corporate Sector, Other Loans and Advances | Federal Reserve Flow of Funds Accounts | 0 |
| 116 | Non-corporate Sector, Mortgage Loans | Federal Reserve Flow of Funds Accounts | 0 |
| 117 | Non-corporate Sector, Net Worth | Federal Reserve Flow of Funds Accounts | 0 |
| 118 | Non-corporate Sector, Short-Term Debt | Federal Reserve Flow of Funds Accounts | 0 |
| 119 | Non-corporate Sector, Short-Term Loans | Federal Reserve Flow of Funds Accounts | 0 |
| 120 | S&P 500, Composite Price Index (w/GFD extension) | Global Financial Data | 0 |
| 121 | S&P 500, Citigroup Growth Price Index | Global Financial Data | 0 |
| 122 | S&P 500, Citigroup Value Price Index | Global Financial Data | 0 |
| 123 | Dow Jones: 30 Industrial Stocks: Average Price Close | Global Financial Data | 0 |
| 124 | Nasdaq: Composite Index, (Index Feb 05 1971=100) | Global Financial Data | 0 |
| 125 | S&P 500, Consumer Discretionary (25) | Global Financial Data | 0 |
| 126 | S&P 500, Retailing (255) | Global Financial Data | 0 |
| 127 | S&P 500, Movies and Entertainment (25413) | Global Financial Data | 0 |
| 128 | S&P 500, Automobile Manufacturers (25121) | Global Financial Data | 0 |
| 129 | S&P 500, Homebuilding (25213) | Global Financial Data | 0 |
| 130 | S&P 500, Automobiles (2512) | Global Financial Data | 0 |
| 131 | S&P Retail Composite | Global Financial Data | 0 |
| 132 | S&P 500, Restaurants (25314) | Global Financial Data | 0 |
| 133 | S&P 500, Apparel | Global Financial Data | 0 |
| 134 | S&P 500, Hotels | Global Financial Data | 0 |
| 135 | S&P 500, Apparel Retails (25541) | Global Financial Data | 0 |
| 136 | S&P 500, Leisure Products (25221) | Global Financial Data | 0 |
| 137 | S&P 500, Broadcasting and Cable TV (25412) | Global Financial Data | 0 |
| 138 | S&P 500, Footware (25232) | Global Financial Data | 0 |
| 139 | S&P 500, Household Appliances (25214) | Global Financial Data | 0 |
| 140 | S&P 500, Department Stores (25531) | Global Financial Data | 0 |
| 141 | S&P 500, Home Furnishings (25212) | Global Financial Data | 0 |
| 142 | S&P 500, Publishing (25414) | Global Financial Data | 0 |
| 143 | S&P 500, Textiles | Global Financial Data | 0 |
| 144 | S&P 500, Consumer Staples (30) | Global Financial Data | 0 |
| 145 | S&P 500, Packaged Foods & Meats (30223) | Global Financial Data | 0 |
| 146 | S&P 500, Tobacco (3023) | Global Financial Data | 0 |
| 147 | S&P 500, Household Products (3031) | Global Financial Data | 0 |
| 148 | S&P 500, Food Retail (30113) | Global Financial Data | 0 |
| 149 | S&P 500, Soft Drinks (30213) | Global Financial Data | 0 |
| 150 | S&P 500, Personal Products (3032) | Global Financial Data | 0 |
| 151 | S&P 500, Oil | Global Financial Data | 0 |
| 152 | S&P 500, Integrated Oil and Gas (10121) | Global Financial Data | 0 |
| 153 | S&P 500, Property and Casualty Insurance (40314) | Global Financial Data | 0 |
| 154 | S&P 500, Life and Health Insurance (40312) | Global Financial Data | 0 |
| 155 | S&P 500, Commercial Banks (4011) | Global Financial Data | 0 |
| 156 | S&P 500, Consumer Finance (40221) | Global Financial Data | 0 |
| 157 | S&P 500, Pharmaceuticals (3522) | Global Financial Data | 0 |
| 158 | S&P 500, Health Care Equipment (35111) | Global Financial Data | 0 |
| 159 | S&P 500, Industrials (20) | Global Financial Data | 0 |
| 160 | S&P 500, Aerospace and Defense (2011) | Global Financial Data | 0 |

## Table A.1: Data cont.

| # | Variable | Source | Treatment |
|---|---|---|---|
| 161 | S&P 500, Machinery (2016) | Global Financial Data | 0 |
| 162 | S&P 500, Building Products (2012) | Global Financial Data | 0 |
| 163 | S&P 500, Industrial Conglomerates (2015) | Global Financial Data | 0 |
| 164 | S&P 500, Capital Goods (201) | Global Financial Data | 0 |
| 165 | S&P 500, Environmental Services (20215) | Global Financial Data | 0 |
| 166 | S&P 500, Information Technology (45) | Global Financial Data | 0 |
| 167 | S&P 500, Gold (15143) | Global Financial Data | 0 |
| 168 | S&P 500, Chemicals Composite (1511) | Global Financial Data | 0 |
| 169 | S&P 500, Steel (15145) | Global Financial Data | 0 |
| 170 | S&P 500, Paper and Forest (1515) | Global Financial Data | 0 |
| 171 | S&P 500, Diversified Metals & Mining (15142) | Global Financial Data | 0 |
| 172 | S&P 500, Aluminum (15141) | Global Financial Data | 0 |
| 173 | S&P 500, Diversified Chemicals (15112) | Global Financial Data | 0 |
| 174 | S&P 500, Metal and Glass Containers (15131) | Global Financial Data | 0 |
| 175 | S&P 500, Integrated Telecommunications (50112) | Global Financial Data | 0 |
| 176 | S&P 500, Airlines (2032) | Global Financial Data | 0 |
| 177 | S&P 500, Railroads (20341) | Global Financial Data | 0 |
| 178 | S&P 500, Air Freight and Couriers (2031) | Global Financial Data | 0 |
| 179 | S&P 500, Utilities (55) | Global Financial Data | 0 |
| 180 | S&P 500, Electric Utilities (5511) | Global Financial Data | 0 |
| 181 | S&P 500, Gas Utilities (5512) | Global Financial Data | 0 |
| 182 | Interest Rates: USA 3-Month Commercial Paper | Federal Reserve Board: Selected Interest Rates (H.15) | 1 |
| 183 | Interest Rates: 3-Month Treasury Bills - Secondary Market, (% P.A.) | Federal Reserve Board: Selected Interest Rates (H.15) | 1 |
| 184 | Interest Rates: 6-Month Treasury Bills - Secondary Market, (% P.A.) | Federal Reserve Board: Selected Interest Rates (H.15) | 1 |
| 185 | Interest Rates: CDs secondary Market - 1 Month, (% P.A.) | Federal Reserve Board: Selected Interest Rates (H.15) | 1 |
| 186 | Interest Rates: CDs secondary Market - 3 Month, (% P.A.) | Federal Reserve Board: Selected Interest Rates (H.15) | 1 |
| 187 | Interest Rates: CDs secondary Market - 6 Month, (% P.A.) | Federal Reserve Board: Selected Interest Rates (H.15) | 1 |
| 188 | Interest Rates: Eurodollar Deposits; London - 1 Month, (% P.A.) | Federal Reserve Board: Selected Interest Rates (H.15) | 1 |
| 189 | Interest Rates: Eurodollar Deposits; London - 3 Month, (% P.A.) | Federal Reserve Board: Selected Interest Rates (H.15) | 1 |
| 190 | Interest Rates: Eurodollar Deposits; London - 6 Month, (% P.A.) | Federal Reserve Board: Selected Interest Rates (H.15) | 1 |
| 191 | Interest Rates: 1-Year Constant Maturity Securities, (% P.A.) | Federal Reserve Board: Selected Interest Rates (H.15) | 1 |
| 192 | Interest Rates: 3-Year Constant Maturity Securities, (% P.A.) | Federal Reserve Board: Selected Interest Rates (H.15) | 1 |
| 193 | Interest Rates: 5-Year Constant Maturity Securities, (% P.A.) | Federal Reserve Board: Selected Interest Rates (H.15) | 1 |
| 194 | Interest Rates: 10-Year Constant Maturity Securities, (% P.A.) | Federal Reserve Board: Selected Interest Rates (H.15) | 1 |
| 195 | Interest Rates: 30-Year Constant Maturity Securities, (% P.A.) | Federal Reserve Board: Selected Interest Rates (H.15) | 1 |
| 196 | Consumer Installment Credit; Commercial Banks: 48 Month New Car Loan, (%) | Federal Reserve Board: Selected Interest Rates (H.15) | 1 |
| 197 | Commercial Banks: 24 Month Personal Loan, (%) | Federal Reserve Board: Selected Interest Rates (H.15) | 1 |
| 198 | Finance Company: Interest Rate New Car Loan, (%) | Federal Reserve Board: Selected Interest Rates (H.15) | 1 |
| 199 | Finance Company: Interest Rate Used Car Loan, (%) | Federal Reserve Board: Selected Interest Rates (H.15) | 1 |
| 200 | C&I loan rate | Federal Reserve Board: Selected Interest Rates (H.15) | 1 |
| 201 | Moody's Corporate AAA Yield | Global Financial Data | 1 |
| 202 | Moody's AA Industrial Bond Yield | Global Financial Data | 1 |
| 203 | Moody's A Utility Bond Yield | Global Financial Data | 1 |
| 204 | Moody's BAA Utility Bond Yield | Global Financial Data | 1 |
| 205 | Moody's AA Utility Bond Yield | Global Financial Data | 1 |
| 206 | Moody's Corporate BAA Yield | Global Financial Data | 1 |
| 207 | Moody's Corporate A Yield | Global Financial Data | 1 |
| 208 | Moody's Corporate AA Yield | Global Financial Data | 1 |
| 209 | Moody's A Industrial Bond Yield | Global Financial Data | 1 |
| 210 | Moody's BAA Industrial Bond Yield | Global Financial Data | 1 |
| 211 | Interest Rates: Moodys AAA Seasoned, (%) | Global Financial Data | 1 |
| 212 | Interest Rates: Moodys BAA Seasoned, (%) | Global Financial Data | 1 |
| 213 | Home Mortgage Loans: Contract Interest Rate, All Loans Closed (%) | Federal Housing Finance Board | 1 |
| 214 | Purchase of New Single-Family Home: Contract Interest Rate (%) | Federal Housing Finance Board | 1 |
| 215 | Purchase of Existing Single-Family Home: Contract Interest Rate (%) | Federal Housing Finance Board | 1 |
| 216 | Home Mortgage Loans: Effective Rate, All Loans Closed (%) | Federal Housing Finance Board | 1 |
| 217 | Purchase of Newly-Built Homes: Effective Rate, All Loans (%) | Federal Housing Finance Board | 1 |
| 218 | Purchase of Previously Occupied Homes: Effective Rate, All Loans (%) | Federal Housing Finance Board | 1 |
| 219 | Contract Rates on Commitments: Conventional 30-Year Mortgages, FHLMC (%) | Federal Housing Finance Board | 1 |
| 220 | Citigroup Global Markets: Credit {Corporate} Bond Yield: AAA/AA (%) | Global Financial Data | 1 |
| 221 | Citigroup Global Markets: Credit {Corporate} Bond Yield: A (%) | Global Financial Data | 1 |
| 222 | Citigroup Global Markets: Credit {Corporate} Bond Yield: BBB (%) | Global Financial Data | 1 |
| 223 | Moody's Seasoned Corporate Bond Spread (BAA-AAA) | Own calculation | 1 |
| 224 | 3-Month Commercial Paper Rate - 3-Month Tbill Rate | Own calculation | 1 |
| 225 | CDs 3-Month Rate - 3-Month T-Bill Rate | Own calculation | 1 |
| 226 | 3-Month Eurodollar Deposit Rate - 3-Month T-Bill Rate | Own calculation | 1 |
| 227 | C&I Loan Rate - 2-Year Constant Maturity Securities | Own calculation | 1 |
| 228 | 24-Month Personal Loan Rate Loan Rate - 2-Year Zero Coupon C201 | Own calculation | 1 |
| 229 | 30-Year Mortgage Rate - 30-Year Constant Maturity Securities | Own calculation | 1 |
| 230 | Interest Rates: 5-Year Constant Maturity Securities, (% P.A.)-Federal Funds rate | Federal Reserve Board: Selected Interest Rates (H.15) | 1 |
| 231 | Interest Rates: 10-Year Constant Maturity Securities, (% P.A.)-Federal Funds rate | Federal Reserve Board: Selected Interest Rates (H.15) | 1 |
| 232 | Interest Rates: 30-Year Constant Maturity Securities, (% P.A.)-Federal Funds rate | Federal Reserve Board: Selected Interest Rates (H.15) | 1 |

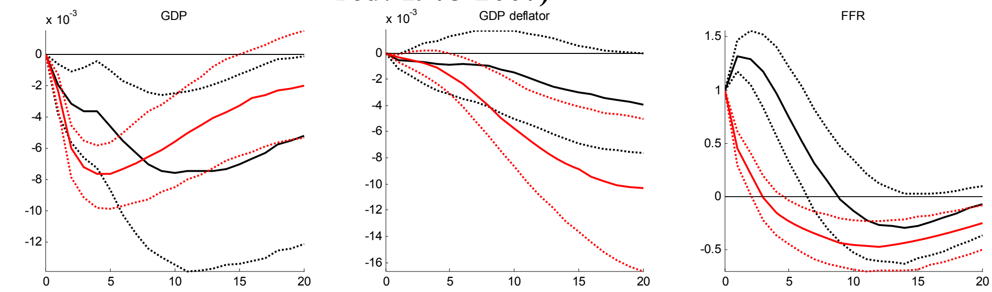
Note: Data are transformed as follows. 0: log differences, 1: levels. Property prices, stock prices, monetary aggregates and balance sheet variables are divided by the GDP deflator and enter the final dataset in real terms. See the main text for more details on the dataset.

**Table A.2: Correlation between factors extracted from the entire dataset with factors extracted from reduced datasets**

| | ex commonality < 0.2 | ex commonality < 0.3 | rule 1 (Boivin-Ng) |
|---|---|---|---|
| $\hat{\boldsymbol{h}}_{1t}$ | 1.00 | 1.00 | 0.98 |
| $\hat{\boldsymbol{h}}_{2t}$ | 1.00 | 1.00 | 0.97 |
| $\hat{\boldsymbol{h}}_{3t}$ | 1.00 | 0.99 | 0.98 |
| $N$ | 216 | 209 | 108 |

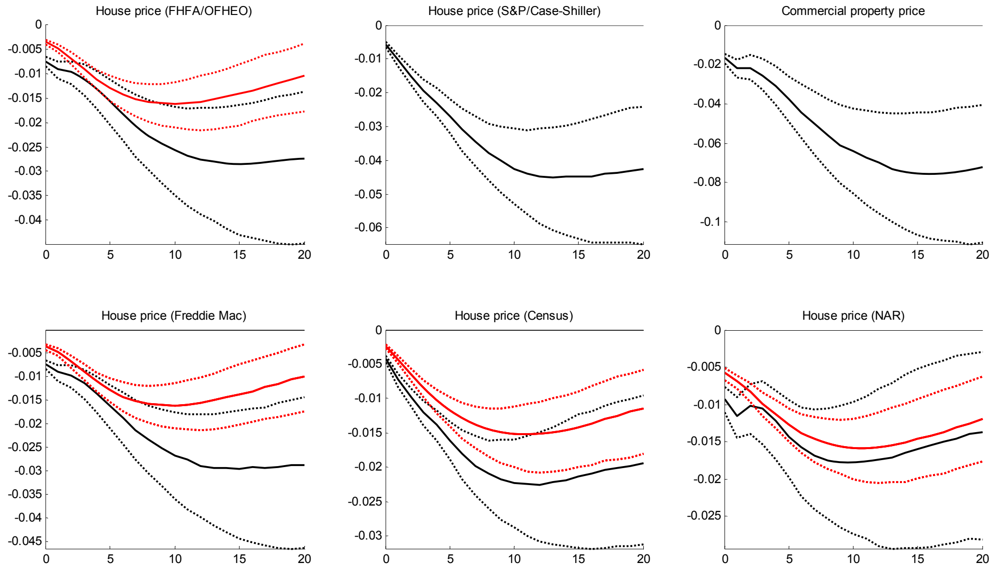
Note: ex commonality < x indicates that series with a variance share explained by the common factors of < x are dropped from the dataset; with rule 1 (Boivin-Ng) variables with highly cross-correlated idiosyncratic components are dropped as described in more details in Appendix 1 and in Boivin and Ng (2006).

**Figure A.1: Impulse response functions of macro variables (black: 1987-2007, red: 1975-2007)**



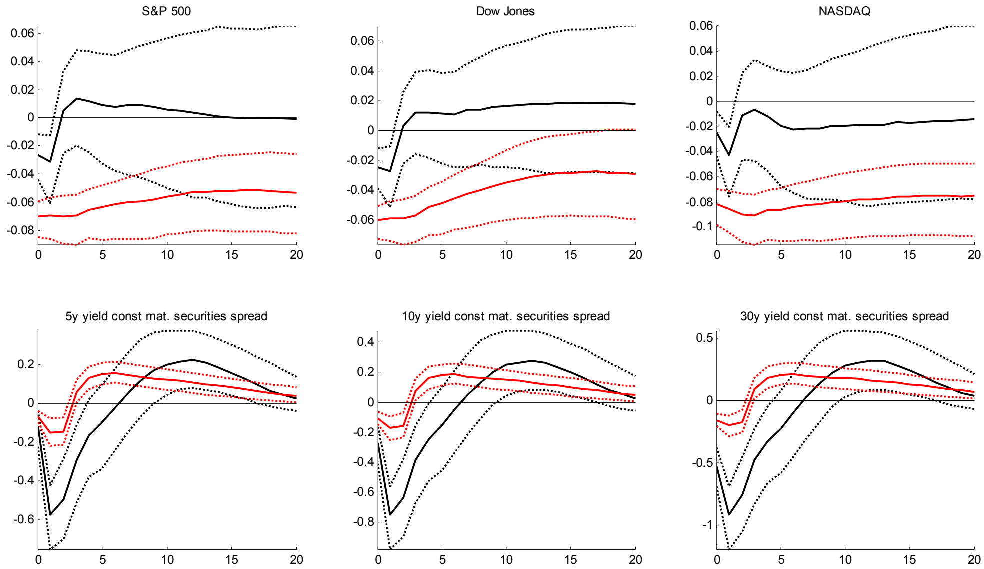

Note: same as for Figure 3.

**Figure A.2: Impulse response functions of property prices (black: 1987-2007, red: 1975-2007)**



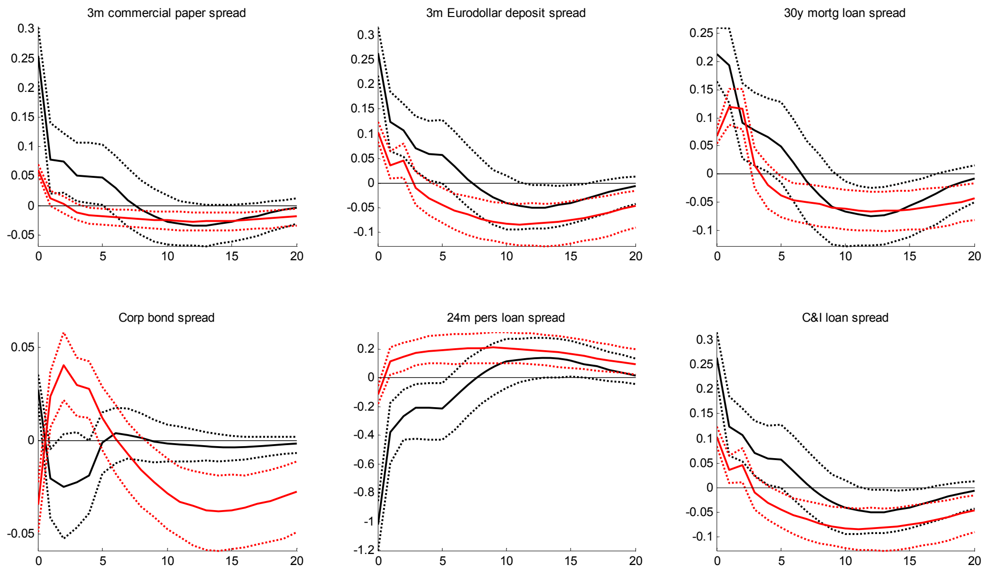

Note: same as for Figure 3.

**Figure A.3: Impulse response functions of stock prices and government bond yield spreads (black: 1987-2007, red: 1975-2007)**




Note: same as for Figure 3.

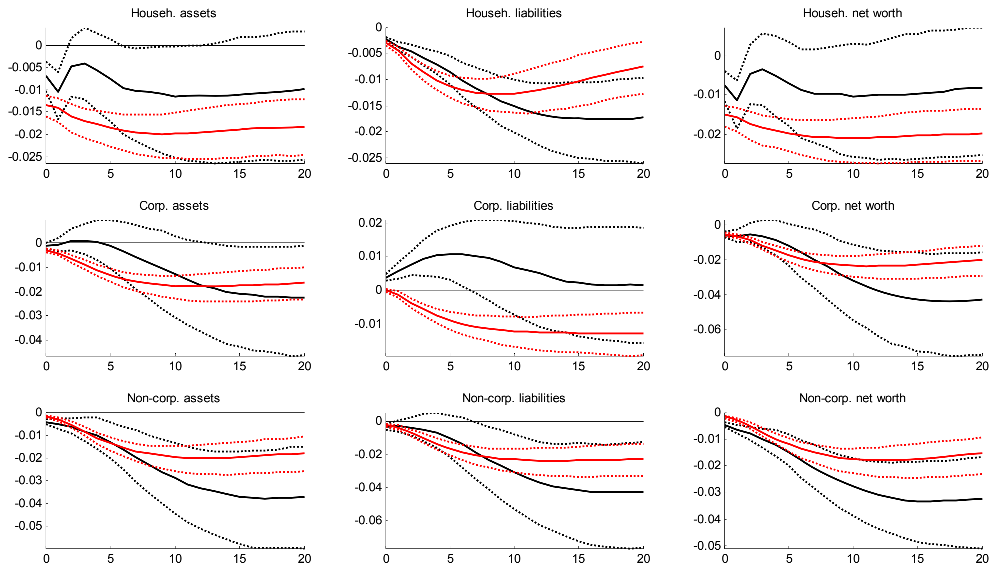
**Figure A.4: Impulse response functions of credit risk spreads (black: 1987-2007, red: 1975-2007)**



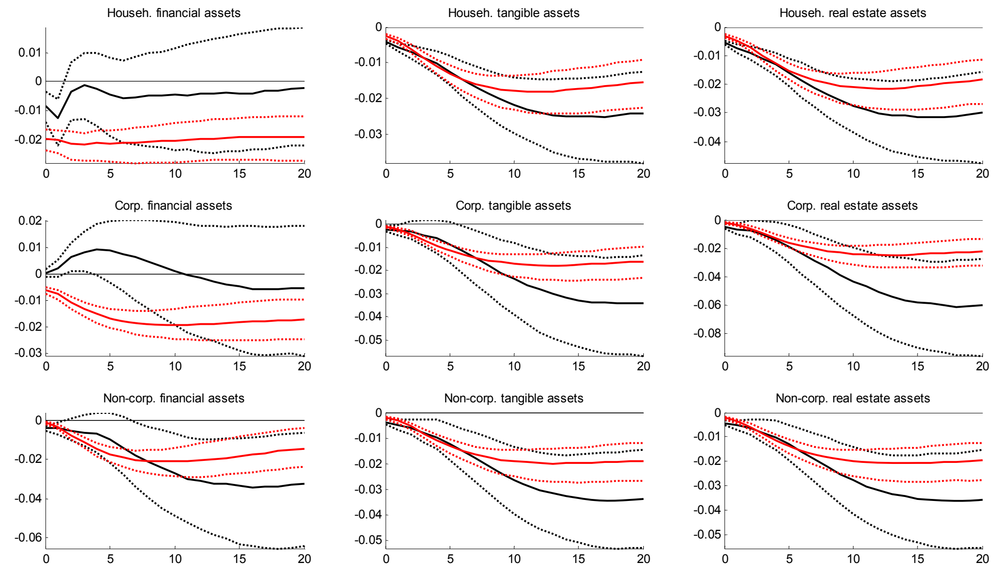

Note: same as for Figure 3.

**Figure A.5: Impulse response functions of assets and liabilities of the non-financial private sector (black: 1987-2007, red: 1975-2007)**

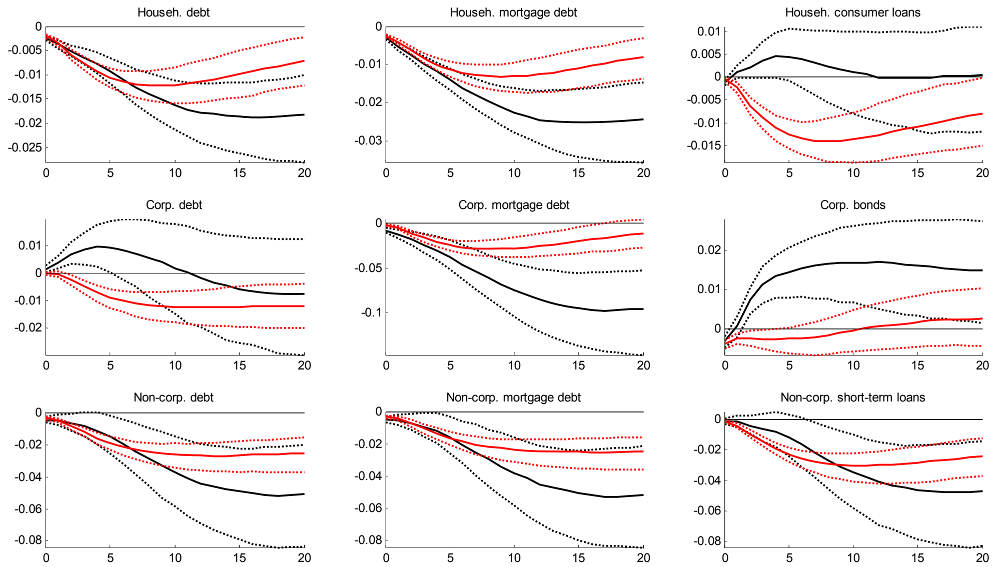
**(a) Total assets, total liabilities and net worth**




**(b) Assets**



## (c) Debt




Note: same as for Figure 3.

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