Business Cycle Implications of Mortgage Spreads*

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Abstract

What are the business cycle effects of shocks to the interest rate spread between residential mortgages and government bonds of the corresponding maturity? We start by noting that the mortgage spread (i) has substantial volatility, (ii) is countercyclical and (iii) leads GDP by 2-3 quarters. Using a structural VAR, we find that innovations to the mortgage spread reduce house prices, residential investment, consumption and GDP by both economically and statistically significant magnitudes. Furthermore, the policy interest rate reacts strongly and in an offsetting direction to mortgage spread innovations. These findings highlight the relevance of financial frictions in residential mortgage markets as an unexplored source of business cycles. In addition, we show that unconventional monetary policy which affects the mortgage spread has sizable macroeconomic impact. Our results are robust to the inclusion of a corporate spread.

Keywords: Sources of business cycles, unconventional monetary policy, credit supply, housing demand, house prices, financial frictions.

JEL codes: E21, E32, E44, E52, R21.

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1 Introduction

What are the quantitative business cycle effects of time variation in the residential mortgage interest rate spread? Surprisingly, this question is almost unexplored in the existing literature despite the substantial cyclical variation of this spread in the data. While Hubbard and Mayer (2009), Guerrieri and Lorenzoni (2011) and Hall (2011a, 2011b) have referenced the issue, none have empirically documented the relationship between mortgage spreads and macroeconomic variables. We define the mortgage spread as the difference between the average interest rate on newly issued mortgages at a given maturity and the government bond rate of the corresponding maturity. By using this definition, we separate the mortgage spread from the term premium. We restrict our analysis to the prime mortgage market. This is not because we think that subprime mortgages are unimportant, but rather because the two markets merit separate analysis.

Why might mortgage rates matter for the business cycle? Theoretically, the mortgage rate, and thus the mortgage spread – in addition to the risk-free interest rate – potentially affects the economy through several channels: i) house prices and residential investment through the user cost of housing, ii) as one relevant rate in the consumption/savings decision and iii) the post-interest disposable income of any household with a mortgage. If house prices are affected, then housing wealth and collateral values are also affected by mortgage spreads. In the presence of binding collateral constraints or, more generally, if credit extension is decreasing in household leverage, mortgage spreads will influence spending decisions through this collateral channel.

Our motivation for exploring the business cycle effects of residential mortgage spread variation – and, more specifically, innovations to this spread – is threefold. First, it is a matter of general understanding of what drives business cycles. More specifically, what is the quantitative importance of mortgage spread innovations for macroeconomic variables?[1] Second, if the mortgage spread affects macroeconomic variables, then monetary policy should take that into account. Accordingly, our analysis includes how monetary policy has historically responded to mortgage spread innovations. We thereby complement Cúrdia and Woodford's (2009) analysis which addresses how this is optimally done in a stylized model with one lending spread that applies to all types of loans. Third, our research question has bearings on unconventional monetary policy intended to affect the business cycle through the mortgage spread, such as the Federal Reserve's recent purchases of mortgage backed securities (MBS). To our knowledge, this paper is unique in that it empirically quantifies the business cycle effects of mortgage spread innovations without relying on a specific theoretical model.

Our primary country of study is the US for the sample period 1983q1-2011q4. We start by documenting the substantial time-variation in the mortgage spread and that the spread is countercyclical. Furthermore, the maximum absolute cross-correlation

[1] A closely related issue is that if mortgage spread variation have non-negligible importance, existing models that abstract from it are misspecified. This problem is probably most severe for estimated structural models on the role of housing for the business cycle, e.g. Iacoviello and Neri (2011) and Walentin (2013).

occurs when the mortgage spread leads GDP by 2-3 quarters. In other words, the spread is lowest immediately prior to GDP peaks and highest immediately prior to GDP troughs. A very similar pattern has been documented by Kydland, Rupert and Šustek (2012) for nominal mortgage rates.

Our main exercise is inspired by Gilchrist, Yankov and Zakrajšek's (2009) and Gilchrist and Zakrajšek's (2012) work on the macroeconomic effects of corporate bond spreads. We document the role of innovations to mortgage spreads for business cycles by estimating a structural vector autoregression (SVAR). Our baseline SVAR includes the following seven variables in levels: consumption, residential investment, GDP, the consumer price index, the mortgage spread, the policy interest rate, and house prices. The identifying restriction is that mortgage spread shocks do not affect macroeconomic quantities or consumer prices on impact but are allowed to contemporaneously affect the policy rate and house prices.

The mortgage spread impulse responses we obtain are consistent with the simple theoretical relationships mentioned above and an interpretation as credit supply shocks: macroeconomic quantities and house prices all decrease following a positive innovation to the spread. A mortgage shock of 100 basis points (bp) yields a decrease in the level of consumption by 1.6%, in residential investment by 6.2% and in GDP by 1.9%. These responses are gradual and reach a trough after more than one year. House prices respond faster and with a decrease of 2.6%. We find a fast and strong 183 bp offsetting response of the policy rate to the mortgage spread shock. In a second exercise, we document the effect of mortgage spread shocks in a setting where the policy rate is fixed. This is the relevant context in which to analyze recent unconventional monetary policy. In this exercise, we find that a 100 bp increase in the mortgage spread yields a decrease of 2.7% in consumption, 15.6% in residential investment, 2.4% in GDP and 6.9% in house prices. Note that residential investment and house prices are the most dramatically affected variables from holding the policy rate fixed.

Variance decomposition is another way to illustrate the dynamics implied by mortgage spread innovations. The importance of the spread innovation for macroeconomic quantities is moderate in terms of this metric. It is highest, at or above 10%, for consumption and GDP at the 8 quarter forecast horizon. The variable affected the most by mortgage spread shocks is the policy rate: one quarter of the policy rate variation at short horizons is driven by mortgage spread shocks. Finally, roughly 10% of house price variation is due to the spread shock at short horizons.

Comparing the variance decomposition results to the corporate bond spread literature, we note that the mortgage spread shock explored in this paper is as important as the excess bond premium shock documented in Gilchrist and Zakrajšek (2012) in terms of consumption and GDP, and considerably more important for the policy rate. We perform our own comparison by including a corporate spread in our exercise and find that mortgage spread shocks are substantially more important than corporate spread shocks for the macro variables.

We find similar results for the UK and Sweden. In particular, mortgage spread innovations also appear both statistically and economically important for these countries. Furthermore, they induce the same qualitative dynamics. Focusing on the differences, the mortgage spread shock matters more for macroeconomic quantities and house prices in these countries than in the U.S. and its impact is faster. This difference may be because the typical duration of mortgage contracts in the UK and Sweden is much shorter than in the US.

Our results are robust to several variations in both the SVAR specification and the sample period. In particular, we find that none of the results are sensitive to the exact lag-length of the vector autoregression (VAR). Shortening the sample period by excluding the recent financial crisis reduces the estimated importance of mortgage spread innovations. Ordering the policy rate before the mortgage spread generates even stronger effects of spread innovations on real quantities and house prices. Finally, and perhaps most importantly, we confirm that including a corporate bond spread in the VAR – ordered before the mortgage spread – does not diminish the importance of the mortgage spread innovations.

To confirm the interpretation of the mortgage spread innovations, we add the amount of outstanding mortgage debt to the VAR. We find that mortgage spread innovations drive the price and the quantity of credit in opposite directions. This corroborates other indications that mortgage spread innovations should be interpreted as credit supply disturbances.

The general lessons from this paper are that i) business cycle fluctuations are affected by financial frictions in residential mortgage markets, ii) innovations in the mortgage spread appear to capture movements in credit supply that are moderately important for business cycle variation in macroeconomic quantities and house prices, iii) the policy rate partially offsets mortgage spread innovations, and its variance is to a substantial degree driven by these, and iv) we conclude that if unconventional monetary policy in the form of asset purchases in mortgage markets succeeds in affecting the mortgage spread – which has been shown to be the case (Fuster and Willen, 2010, Hancock and Passmore, 2011, and Krishnamurthy and Vissing-Jorgensen, 2011) – then it has sizable effects on house prices, residential investment and GDP.

The paper is organized as follows. The remaining part of this section describes the related literature. Section 2 characterizes the mortgage spread. Section 3 contains the quantitative exercises and results. Robustness exercises are documented in Section 4 and Section 5 concludes.

1.1 Related literature

Although their main focus differs from ours, three papers clearly relate to the present paper as they include empirical analysis of the effects of a household borrowing spread on the macroeconomy. Both Darracq Pariès, Kok Sørensen and Rodriguez-Palenzuela (2011) and Gerali, Neri, Sessa and Signoretti (2010) estimate a DSGE model using one measure of the retail bank loan rate and another for the retail deposit rate, in addition to standard macro variables. Musso, Neri and Stracca (2011) estimate structural VAR models to compare the US' and the Euro area's monetary transmission mechanisms, with a focus on housing. They include a measure of the mortgage spread in their structural VAR models, but without matching maturities.

This paper concerns time variation in aggregate mortgage conditions in terms of prices, measured as spreads. This complements the mainly theoretical literature on time variation in the quantity dimension of mortgage credit conditions, mainly measured by the maximum loan-to-value ratio (LTV). Guerrieri and Lorenzoni (2011) explore changes in both these dimensions in a theoretical model with heterogeneous agents. An important finding in their model is that changes in the LTV only mildly affect the aggregate variables while spread changes have a major impact. The intuition is that all borrowers are affected by spread changes while mainly households close to the borrowing constraint are affected by changes in the LTV. Justiniano, Primiceri and Tambalotti (2012) find small macroeconomic effects from LTV changes, while Eggertson and Krugman (2012) report large effects in a setting with a liquidity trap.

The present paper also complements the literature addressing other non-price aspects of mortgage supply. Wilcox (2009) and Muellbauer and Williams (2011) empirically attempt to capture all non-price aspects of mortgage conditions using a latent variable approach.

Kydland, Rupert and Šustek (2012) build a theoretical model showing that the cyclical properties of mortgage rates can explain the fact that residential investment leads business investment in the US. The same mechanism explains why housing starts lead business investment both in the US and in other OECD countries. In their model, the mortgage rate enters through the first order condition for residential investment. Our approach is more empirical and we study mortgage spreads instead of mortgage rates thus not confounding the short risk-free rate, the term premium and the mortgage spread.

The literature examining the macroeconomic effects of the Federal Reserve purchases of MBS is very thin. Chung, Laforte, Reifschneider and Williams (2011) provide an estimate of the joint effect of all Large-Scale Asset Purchase (LSAP) programs by using the FRB/US model. Gambacorta, Hofmann and Peersman (2012) take a broader approach and estimate the effect of the size of central bank balance sheets on macroeconomic variables in a cross-country SVAR study. Gertler and Karadi (2012) provide a model of how LSAPs affect the macroeconomy. They focus on LSAPs as a form of financial intermediation, and find that central bank purchases of private assets (corporate bonds) are more powerful than purchases of long-term government debt. For a model of LSAPs that distinguishes between corporate debt and mortgage debt, see Dai, Dufourt and Zhang (2013).

The analogous literature addressing corporate interest rate spreads and how shocks to these affect business investment and the business cycle more generally is well developed. For structural VAR approaches, see, for example, Gertler and Lown (1999), Gilchrist, Yankov and Zakrajšek (2009), Gilchrist and Zakrajšek (2012), Meeks (2012) and Furlanetto, Ravazzolo and Sarferaz (2013). Helbling et al (2011) considers international transmission of this type of shocks. Two examples of estimated DSGE models that allow for financial shocks and use corporate spread data are Christiano, Motto and Rostagno (2013) and Christiano, Trabandt and Walentin (2011). Jermann and Quadrini (2011) and Nolan and Thoenissen (2009) also show the importance of shocks to firm financing by taking models to the data, though not specifically including spread data. A structural VAR approach without spreads that instead uses sign restrictions for identification of financial shocks is applied by Fornari and Stracca

(2013). More generally, the business cycle literature appears to be relaxing the previously prevalent assumption that one interest rate is enough to characterize the economy.

2 Data

2.1 Countries and sample periods of study

Our main country of study is the US because of the available length of mortgage and macroeconomic time series data in an environment that may be considered one regime. For the US, we use a sample period of 1983q1-2011q4. We start the sample in 1983 to avoid the Regulation Q and the Volcker disinflation periods. We also study the UK and Sweden because these two countries provide an international perspective and because they contrast the US in that they have very short duration of mortgage contracts. Data availability and the fact that these countries have active mortgage markets also factored into our decision. For the UK and Sweden, we use data beginning in 1995q1 when both countries started to systematically collect data on mortgage rates. Thus, our sample period is 1995q1-2011q4. Both countries have been inflation targeting for the entire period. The frequency of the data is quarterly due to macro data availability.

2.2 Mortgage spread definition and characteristics

As mentioned above, we analyze the average mortgage spread over the cross-section. The ideal measure of this spread would be one based on a mortgage rate that has a fixed composition in terms of the loan-to-value ratio, and the type of borrower and lender as well as one that is representative of all mortgages. Obviously, this ideal measure is unobtainable. Let us describe the mortgage data that we use and to what degree it deviates from the ideal measure.

We work with the rates of newly issued mortgages as opposed to the rates of the stock of outstanding mortgages. We think this is preferable for economic and measurement reasons. Economically, the newly issued mortgages contain new information in terms of mortgage pricing. They are also the relevant rates for house buyers. From a measurement perspective, the maturity of newly issued mortgages is well-defined, while the maturity of the stock of outstanding mortgages is harder to measure and has an additional time-varying element.

The mortgage rate data we use is based on surveys of quoted rates. Abstracting from a constant difference in levels, these correspond very well with transaction based data.[2] The residential mortgage rates obtained are for a given maturity and we compute the spread against the government bond of corresponding maturity. For

[2] Transaction based mortgage rates for narrow maturities are only available begining in 1990 for the US (from FHFA), from 2004 for the UK and from 1997 for Sweden.

the US we use the Freddie Mac mortgage rates (the Primary Mortgage Market Survey) for conventional conforming mortgages.[3] This implies that we exclude subprime mortgages and many other categories of mortgages, for example those that are too large to be conforming ("jumbo mortgages").

The surveys specify a LTV of 80% for the US and a LTV of 75% for the UK. For these countries and in the LTV dimension, we are accordingly close to the ideal measure. No LTV is specified for Sweden. We use the 30-year fixed rate for the US and the 2-year fixed rate for the UK and Sweden. See the data appendix for details on the fraction of mortgages at various maturities in the different countries that motivated this choice. US is the only country in our sample with non-negligible mortgage pre-payment activity. Accordingly, we match the other countries' mortgage rates with a government bond of the same maturity (de jure, face value). For the US, the conventional estimate is that the duration of a 30-year fixed rate mortgage is 7-8 years. We use the average of the 5-year and the 10-year Treasury bond rate, thereby assuming a mortgage duration of 7.5 years.[4] We keep this maturity matching simple and refrain from trying to model the time variation in the expected duration of 30-year fixed rate mortgages.

The US mortgage spread is plotted in Figure 1. To highlight the cyclicality, we have plotted the National Bureau of Economic Research (NBER) recession dates and the Congressional Budget Office (CBO) GDP gap in the same figure. The substantial variation as well as the countercyclicality of the spread are evident in the figure. An interesting exception from this pattern is the mid-1980's spike in mortgage spreads followed by an increase in the GDP gap, rather than a recession.

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[3] We use mortgage rates at face value and abstract from "points" in the Primary Mortgage Market Survey as the points were not measured for the full sample and changed definition in 1998.

[4] An alternative measure would be to use a swap rate instead of a Treasury bond rate, but swap rates are not available for the full sample period.

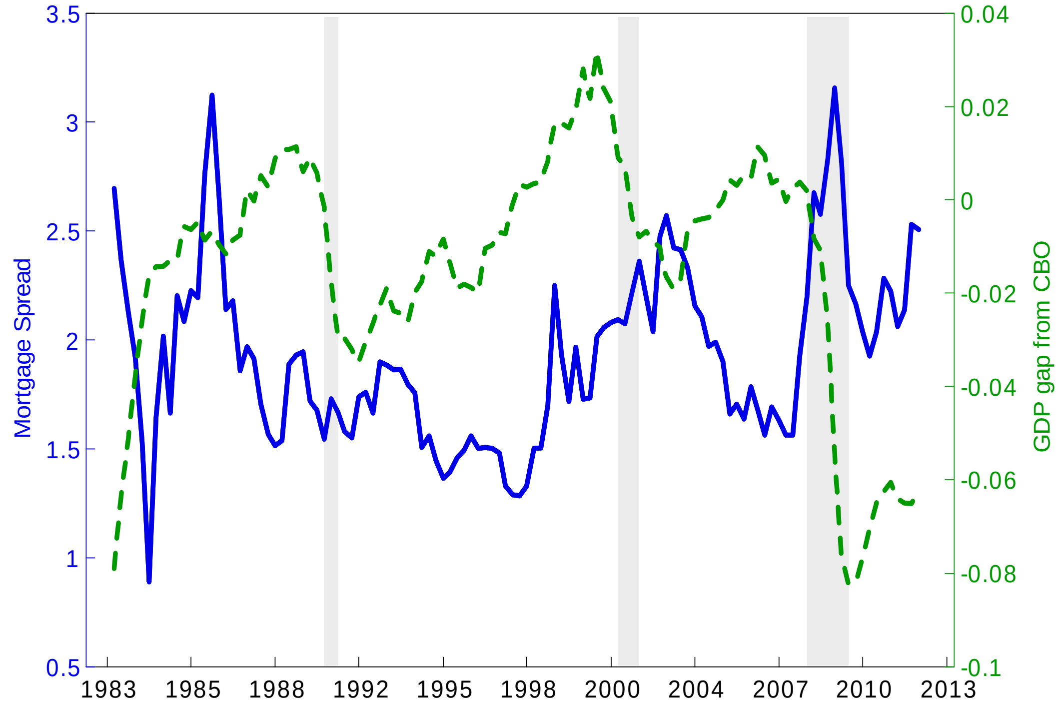

Figure 1. US 1983q1-2011q4. Mortgage spread (solid line), GDP gap (dashed line) based on Congressional Budget Office potential GDP and NBER recession dates (shaded bars). The spread is computed as the 30-year fixed rate mortgage rate minus the average of the 5-year and the 10-year Treasury bond rate.

Key moments of the mortgage rates used are documented in Table 1. For cross-correlation with GDP, we use Hodrick-Prescott (HP) filtered GDP.[5] The main take-away from Table 1 is that mortgage spreads are reasonably volatile and countercyclical.[6] In particular, they lead the business cycle by 2-3 quarters. Mortgage spreads ("mspreads") are less volatile than corporate spreads ("cspreads") though they are highly correlated, especially since 2008. There are cross-country differences in mortgage spread characteristics, but the similarities dominate. In summary, these characteristics encourage us to explore the structural role of mortgage spreads for the business cycle. For a more detailed documentation of the cyclical pattern of mortgage spreads in the US, see Table 18 in the Appendix.[7]

[5]For the US, results for GDP deviation from CBO potential GDP are very similar. In particular Corr(mspread,GDP)$= -0.34$ and the maximum cross-correlation is corr($mspread_{t+3}, GDP_t$)$= -0.42$.

[6]Time variation in the composition of borrowers, and in particular stricter requirements/screening in downturns, would make the mortgage spread lower in these periods, i.e. less countercyclical. In other words, this type of variation in the composition of borrowers – which is very plausible – would mean that the true countercyclicality of mortgage spreads is stronger than the measured one.

[7]The fact that the mortgage spread leads GDP raises the question of whether it is also a good predictor of the business cycle. That type of exercise has been performed previously using corporate spreads (Gilchrist and Zakrajšek, 2012). We did explore the predictive content of the mortgage

The US mortgage spread variation is driven in equal parts by the variation in the mortgage rate and the government bond rate. In other words, these time series have equal volatility at the quarterly frequency. There is no apparent lagging tendency in the mortgage rate compared to the Treasury bond rate.

Moment\Country	US	UK	Sweden
Mean	1.92	1.02	1.36
Standard deviation	0.41	0.98	0.42
Corr(mspread,GDP)	-0.21	-0.36	-0.15
Maximum cross-corr [lead]	-0.41 [3]	-0.43 [2]	-0.53 [3]
Standard deviation(cspread)	0.73	1.23	0.44
Corr(mspread,cspread)	0.83	0.74	0.56
Corr(mspread,cspread) -2007q4	0.86	0.24	0.30

Table 1: Characteristics of the mortgage spread. The third row shows the correlation between mortgage spreads and the GDP. The fourth row shows the maximum cross-correlation and how many quarters ahead of GDP the mortgage spread is for this maximum. The lower part of the table relates the mortgage spread to the corporate spread which is measured as the difference in the interest rates on Moody's Baa-rated corporate bonds and the 10-year Treasury bond. GDP is in terms of deviation from the Hodrick-Prescott trend.

3 Mortgage spread innovations and business cycles

3.1 Structural VAR specification

The aim of our main exercise is to quantify the effects of innovations to the mortgage spread on the rest of the economy. We do this by estimating a structural VAR and documenting the impulse response functions (IRFs) and variance decompositions as well as the historical decompositions. Based on which macroeconomic variables might plausibly be affected by (or affect) the mortgage spread, we let the VAR consist of the following variables: consumption, residential investment, GDP, the consumer price level, the mortgage spread, the (nominal) policy interest rate and house prices. All quantities and the house prices, are in real terms. Variables are expressed in natural logs where appropriate. We estimate the VAR in levels. Recall that the frequency of the data is quarterly.

The estimation is performed for each country separately. We believe that the potential differences in macroeconomic structure and housing finance characteristics are too large to warrant a pooled estimation approach.

spread compared to a benchmark where GDP, or another business cycle variable, is predicted using its own lag, the real short-term risk-free interest rate and the term premium. For the US, we found very limited predictive value of the mortgage spread. For the UK and Sweden, the predictive power is non-negligible, but moderate.

We use short-run restrictions for identification. The identifying restriction is that mortgage spread shocks do not affect real quantities or consumer prices on impact, but are allowed to contemporaneously (within the quarter) affect the policy rate and house prices.[8] In a secondary exercise, we explore monetary policy shocks, mainly as a point of comparison but also to document the role of the mortgage spread in the monetary transmission mechanism. Monetary policy shocks are only allowed to affect house prices contemporaneously. We do not identify any other shocks beyond these two and, accordingly, the ordering between the other variables does not matter. We explore alternative short-run restrictions in the robustness section below.

Lag length selection is generally difficult in this type of exercise. We therefore document that the results are robust to reasonable variation in lag length. We use four lags for the US but two lags for the UK and Sweden because of their shorter sample.[9] Statistical properties of our specification are provided in the statistical appendix. We also plot all data series used and the time series of mortgage spread shocks and historical decompositions not contained in the main text in the appendix.

We use maximum likelihood to estimate the VAR and employ a Bayesian approach with flat priors.[10] [11]

3.2 Time series of mortgage spread innovations

We plot the US time series of the mortgage spread innovations in Figure 2 to provide some indicative validation. Extreme innovations have been marked in the figure: 1984q2(-), 1986q3(+), 1990q3(-) (the beginning of Gulf War I), 1998q4(+) (following the LTCM bailout and the Russian financial crisis) and 2008q1(+) (the US housing crisis).[12]

The largest policy intervention in the mortgage market is the November 25th, 2008 announcement of the Federal Reserve's "QE1/LSAP1" program, which consisted of buying \$500 billion (extended in March 2009 to \$1.25 trillion) of MBS from January 2009 to March 2010. The first three quarters following this announcement are marked in bold red. They are all characterized by negative innovations, with the largest ones occurring in 2009q1 and 2009q2. This is suggestive of the joint hypothesis that i) the SVAR is appropriately capturing innovations to the mortgage spread and ii) that the Federal Reserve's MBS purchase program had a substantial effect on mortgage

[8] With regard to the information lag, the Freddie Mac mortgage rate survey (PMMS) is collected and disseminated very quickly. The survey is performed weekly and published with at most a 3 day delay. This makes it reasonable to assume that the mortgage spread can be incorporated in the monetary policy decision within the quarter.

[9] Residential investment, and to a lesser degree the mortgage spread, appear to need more lags than standard macroeconomic variables to be well modeled.

[10] We make 200 000 draws after burn-in and apply a thin-out frequency of 10.

[11] For Sweden, we impose stationarity of the VAR dynamics using a Gibbs sampler, as the impulse response functions otherwise are explosive for any lag length above 1.

[12] Interestingly, neither the 1992 ERM crisis in Europe nor the 1997 Asian financial crisis coincide with any extreme innovations to the mortgage spread. Yet the mortgage spread was gradually hit by innovations amounting to a total of 3 standard deviations in the three quarters of the ERM crisis, 1992q3-1993q1.

spreads.

A negative one standard deviation innovation implies an 18 bp decrease in the mortgage spread on impact. For the following quarter the effect is 12 bp and for the third quarter 7 bp (see impulse response in Figure 3 for longer horizons). Accordingly, the innovations in the three quarters 2008q4-2009q2 ($-0.3, -1.1$ and -1.0) add up to 33 bp. This contrasts with Hancock and Passmore (2011) who find a 100-150 bp effect using a very different method. However, our result is close to the event-study results of Fuster and Willen (2010).[13] We only measure total innovations, so the comparison is halting as it assumes that no other unexpected events affected mortgage spreads during these three quarters. For this reason, we think of the results in Figure 2 for 2008q4-2009q2 as more of an indicative validation of the SVAR specification, rather than providing insight into the exact effect on the mortgage spread of the MBS purchase program, QE1. Regarding the macroeconomic effects of QE1, refer to section 3.3.1 below.

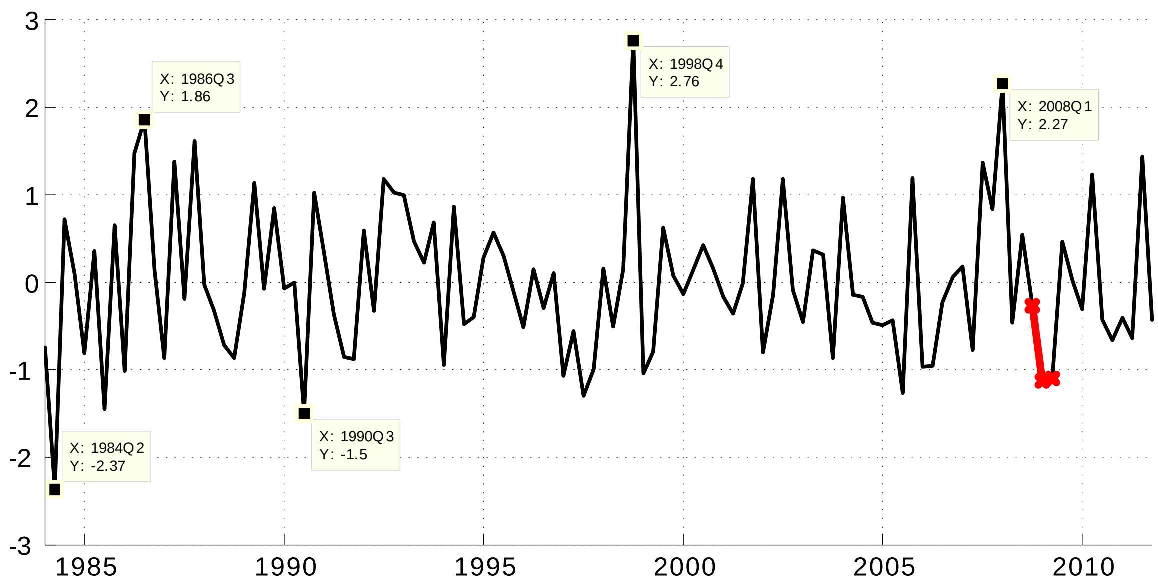

Figure 2. Mortgage spread innovations. US 1983q1-2011q4. Y-axis units are in terms of standard deviations. One standard deviation represents an 18 basis points effect on the mortgage spread at impact. The first three quarters of QE1 are marked in bold red.

[13]The time profile of the effects differ between our results and the literature. E.g. Hancock and Passmore (2011) find the majority of the effect already in 2008q4. An important reason that we do not obtain such a fast effect is that we use average mortgage rates per quarter, which limits the Q4 impact of a policy action announced on November 25th.

3.3 Dynamic effects of mortgage spread innovations

In Figure 3, we plot the US impulse response functions for a mortgage spread innovation. All our IRF plots include 68% and 90% probability intervals in addition to the median response. If not otherwise noted, all numbers reported in the text refer to the median estimate. The mortgage spread shock yields a gradual contraction in all real quantities and a fall in the policy rate and house prices. Consumer prices is the only variable that does not respond. This qualitative characterization is consistent with our hypothesis that mortgage spread innovations should be interpreted as credit supply shocks.

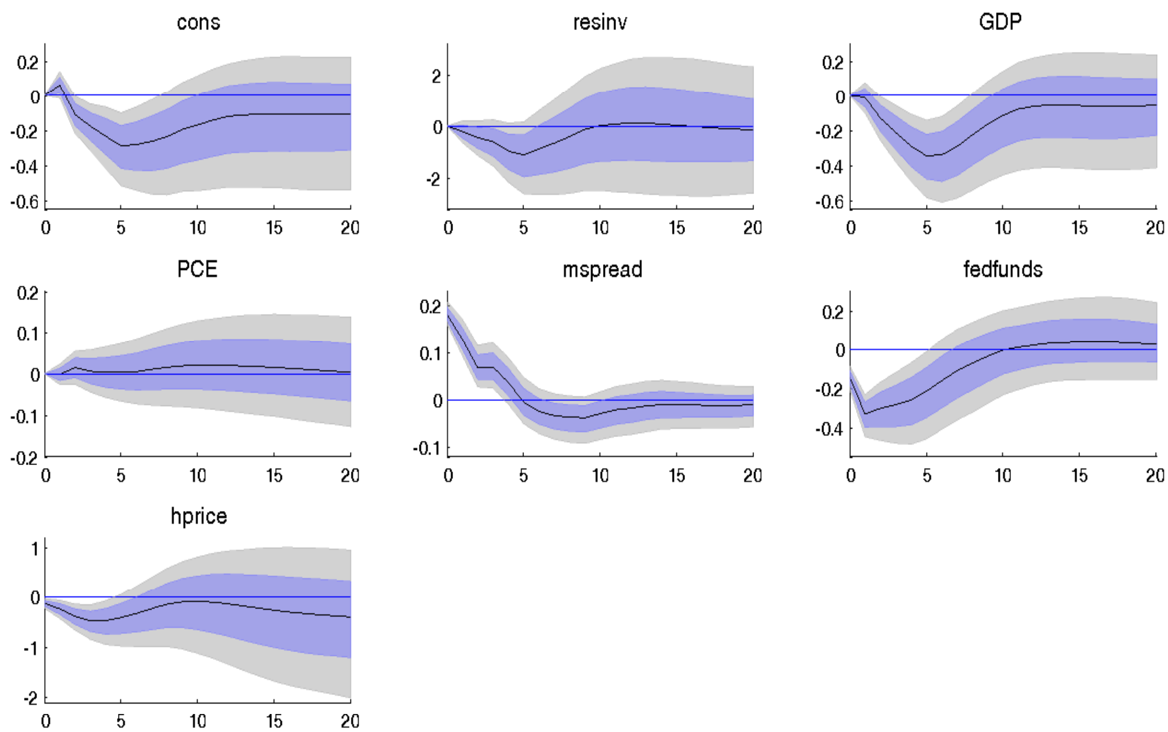

Figure 3. IRF to mortgage spread shock. US 1983q1-2011q4. Units are in percent deviation, except the two interest rates which are in terms of annual percentage rate (APR). Median, 68% and 90% probability bands.

In terms of magnitudes, a one standard deviation (18 bp) shock to the mortgage spread accrues to a decrease in consumption of 0.29%, in residential investment of 1.1%, in GDP of 0.35% and in house prices of 0.47%. Furthermore, the federal funds rate decreases by 33 bp, thereby dampening the response of other variables. One interpretation of the strong policy response is that policy makers are well aware of the contractionary effects of mortgage shocks in spite of the absence of academic literature. The largest effect on the real quantities occurs after five quarters, while the federal funds rate and house prices react more quickly. The entire 90% probability band of the responses is below zero for all these variables for some quarters, except for residential investment.

To facilitate interpretation and comparison, we document the amplitude of the response of key variables to a unit-sized shock. These "elasticities" (or sensitivities) to the mortgage spread shock are displayed in Table 2.[14] The interpretation is, for example, that a 100 bp shock to mortgage spreads reduces GDP by 1.9% and house prices by 2.6%. Consumption responds slightly less than GDP while residential investment responds three times more. The policy rate responds strongly by decreasing 184 bp. Note that it is difficult to compare changes in interest rates at such different maturities. The comparison is clouded by the fact that the mortgage rate of a contract signed in the quarter of the shock stays fixed (in expectation) for 7.5 years, while a federal funds contract is overnight. Thus, the two interest rates have very different persistence in terms of their impact on the economy. Table 2 further documents the uncertainty of the estimation in terms of 68% and 90% probability bands for the elasticities. These bands are reasonably tight, with the exception of residential investment. For example, we note that, for all variables, the elasticity to a mortgage shock is above unity (0.96 for consumption) with 84% probability.

Variable	Elasticity	68% band (84%, 16%)	90% band (95%, 5%)
Consumption	-1.61	(-0.96,-2.31)	(-0.55,-2.86)
Residential investment	-6.18	(-1.90,-10.84)	(0.88,-14.45)
GDP	-1.92	(-1.24,-2.65)	(-0.79,-3.23)
Policy rate	-1.84	(-1.50,-2.21)	(-1.29,-2.48)
House prices	-2.58	(-1.52,-3.77)	(-0.82,-4.64)

Table 2: Elasticity of variables to mortgage spread shocks. Computed as max (response of variable)/initial increase in shock variable. US 1983q1-2011q4. Median in first column, 68% probability band in second column and 90% probability band in third column.

For comparison, we plot the IRF to a monetary policy shock in Figure 4. The message we want to convey with this IRF is twofold. First, the effects on macro variables are qualitatively similar to the mortgage shock, though more delayed. Second, there is no clear effect from the monetary policy shock on the mortgage spread (note the small scale on the mortgage spread response). The second statement implies that there are no signs of either i) amplification of the monetary transmission through the mortgage spread, or ii) deceleration due to imperfect or delayed pass-through from monetary policy to mortgage rates. The former contradicts the standard version of the 'financial accelerator theory' applied to mortgages whereby the monetary policy shock would reduce collateral values of borrowers and therefore increase spreads. The latter contradicts limited pass-through to lending rates as reported in, for example, Kobayashi (2008). While unlikely, it could be that both these mechanisms are important but that they cancel each other out.

[14] When computing the amplitude, we only consider the first 12 quarters of the IRF to avoid being mislead by oscillations or extreme longer run dynamics. This limitation in terms of horizon only appears to bind when computing house price elasticities.

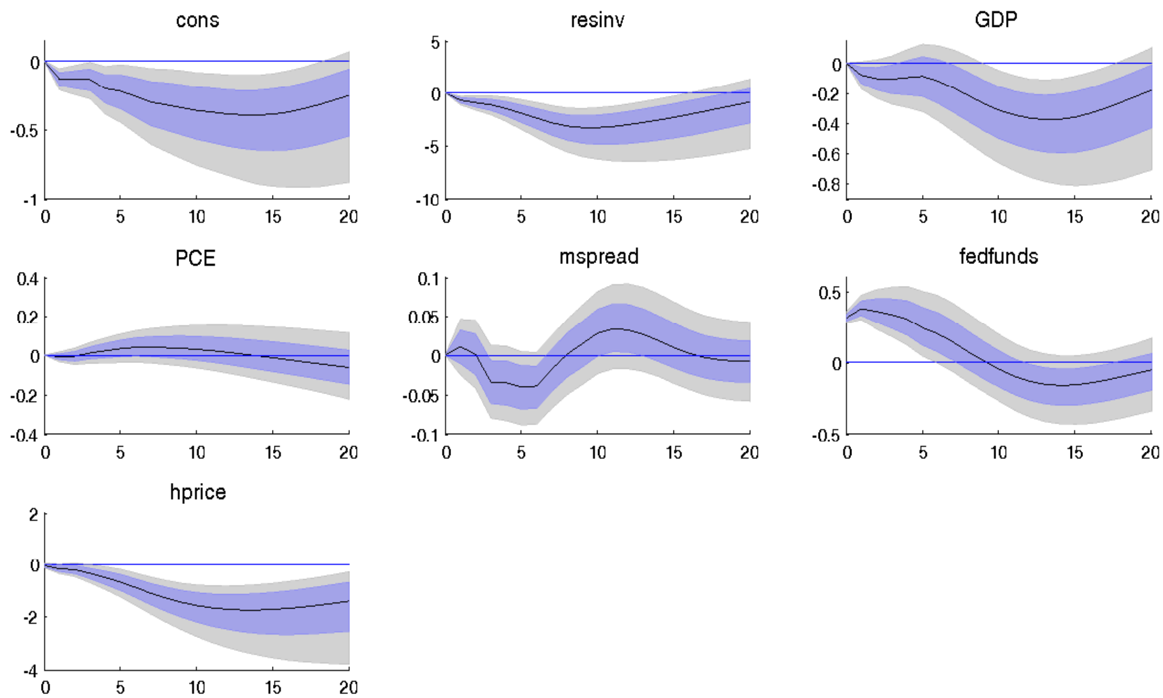

Figure 4. IRF to monetary policy shock. US 1983q1-2011q4. See Figure 3 for units etc.

To further quantify the importance of mortgage spread shocks, we provide a variance decomposition. In Table 3, we document the fraction of the variance that is attributed to the mortgage spread shock for key variables.[15] We start by noting that, according to the variance decomposition, between two-thirds (2 quarter horizon) and one-third (16 quarters horizon) of the variation in the mortgage spread is due to the mortgage shock itself. The importance for real quantities is generally moderate. The importance of the mortgage spread shock is highest for consumption and GDP at the 8 quarter horizon, at or above 10%. The policy rate is the variable most affected by the mortgage spread shock: one quarter of its variation at short horizons is driven by this type shock. Finally, roughly 10% of house price variation is due to the spread shock at 2-4 quarters horizon, but less for longer horizons.

To complement the point estimates in Table 3, Figure 5 documents the uncertainty in the variance decomposition by showing the 68% and 90% probability intervals, in addition to the median estimates.

[15] We report median values. The mean values are generally approximately 2% higher due to the asymmetry induced by the lower bound of variance decompositions at zero (except for the federal funds rate and the spread itself).

Variable \ Horizon in quarters	2	4	8	12	16
Consumption	3	7	10	7	6
Residential investment	1	3	3	3	3
GDP	2	8	14	10	9
Mortgage spread	64	57	43	35	32
Policy rate	23	20	18	16	14
House prices	8	9	4	3	3

Table 3: Variance decomposition - fraction of variance, in percent, explained by mortgage spread shock. US 1983q1-2011q4. Median.

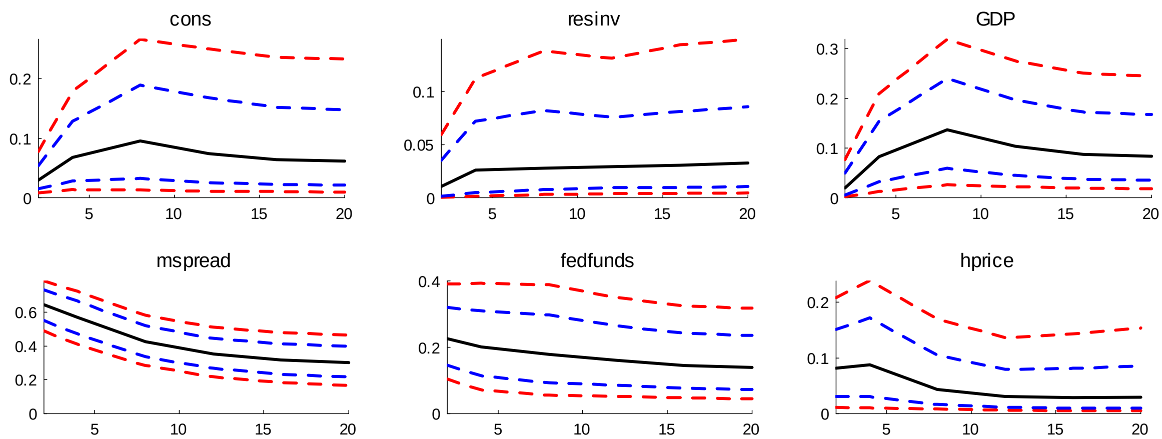

Figure 5. Variance decomposition including median, 68% and 90% probability intervals. US 1983q1-2011q4.

For comparison, we display the variance contribution of monetary policy shocks in Table 4. Compared to monetary policy shocks, mortgage spread shocks explain more of the variance in GDP for horizons up to 12 quarters, and in house prices at the shortest horizons. For the remaining real quantities and horizons, monetary policy shocks are more important.

Comparing the variance decomposition results to the existing literature, the mortgage spread shock is at least as important as the corporate excess bond premium shock documented in Gilchrist and Zakrajšek (2012) in terms of consumption and GDP, and substantially more important for the policy rate.[16]

Historical decomposition for the mortgage spread shock is documented in Figure 6. For visibility we only display results from 2001 onwards. In line with the variance decomposition, we note the moderate importance of the mortgage shock. The figure indicates that without mortgage shocks, in the 2004-2007 run-up to the crisis mortgage spreads would have been higher, GDP would have been lower and the federal funds

[16] They find that the excess (corporate) bond premium shock explains roughly 10% of consumption, 25% of business investment, and slightly more than 10% of GDP.

Variable \ Horizon in quarters	2	4	8	12	16
Consumption	6	6	10	13	16
Residential investment	5	8	17	20	20
GDP	2	3	4	10	14
Mortgage spread	1	4	6	7	8
Policy rate	37	31	26	24	23
House prices	3	6	16	22	24

Table 4: Variance decomposition - fraction of variance, in percent, explained by monetary policy shock. US 1983q1-2011q4. Median.

rate would have been lower. Conversely, in the absence of mortgage shocks, GDP would have stayed higher in the 2008-2009 downturn. A similar tendency is present in house prices, but quantitatively, the spread shock appears to have had a negligible effect on the house price boom-bust.[17] Recall that our analysis does not explicitly include subprime lending conditions, which plausibly was an important driver of the house price boom-bust. To summarize, mortgage spread shocks had a destabilizing effect during the most recent business cycle.

Figure 6. Historical decomposition for US 2001q1-2011q4 (although estimated on the full sample). Data (solid line) and counterfactual time series where mortgage spread shock is turned off (dashed line).

3.3.1 Zero lower bound dynamics and the macroeconomic effects of QE1

The purpose of this section is twofold. First, we characterize the effects of a mortgage spread innovation when the federal funds rate is held fixed. Second, we use these results to quantify the macroeconomic effects of QE1.

Impulse responses for a situation with a fixed federal funds rate are generated using the method in Sims and Zha (2006). This implies setting all coefficients for the federal funds rate equal to zero in the VAR. Unsurprisingly, the impulse responses documented in Figure 7 have greater amplitude than the impulses in our baseline specification. The maximum effects are obtained more slowly compared to the baseline specification. The elasticities are documented in Table 5 and are substantially

[17]The historical decomposition results for the UK and Sweden are very similar to the US results, and are reported in the appendix. The only notable difference is that in those countries, the mortgage spread shock was more important for house prices.

greater for all variables. The difference is most pronounced for residential investment and house prices where elasticities are more than twice as large when the policy interest rate is held fixed.[18]

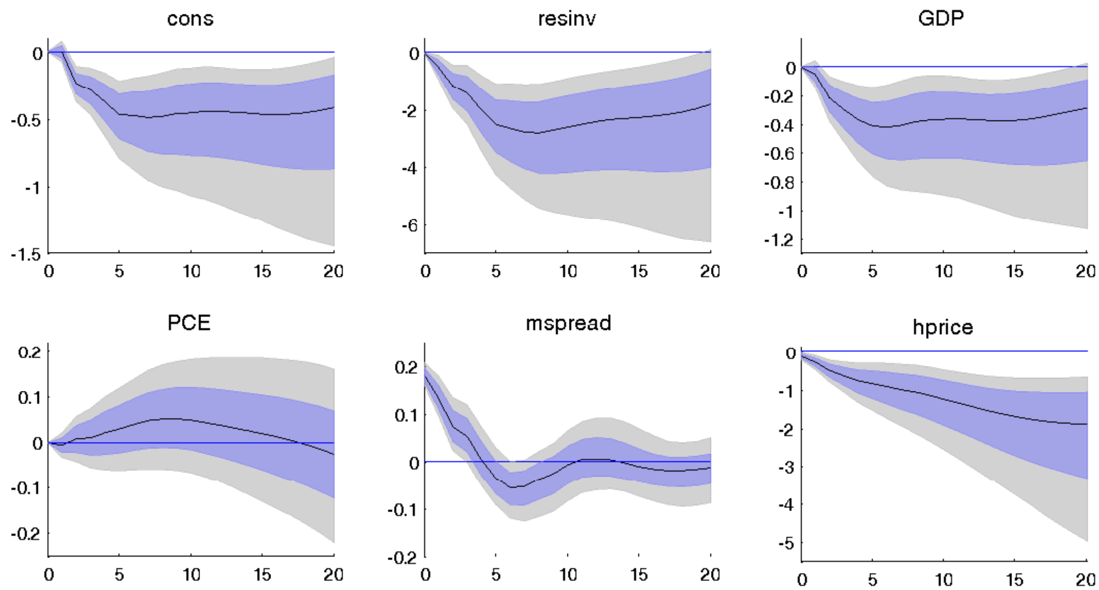

Figure 7. IRF to mortgage spread shock when the federal funds rate is held fixed. US 1983q1-2011q4. See Figure 3 for units etc.

Variable	Elasticity	68% band	90% band
Consumption	-2.73	(-1.65,-4.12)	(-1.01,-5.32)
Residential investment	-15.61	(-9.59,-23.33)	(-6.16,-30.09)
GDP	-2.35	(-1.34,-3.57)	(-0.71,-4.60)
House prices	-6.94	(-4.22,-10.73)	(-2.69,-14.25)

Table 5: Elasticity of variables to mortgage spread shock when the federal funds rate is held fixed. Computed as max (response of variable)/initial increase in shock variable. US 1983q1-2011q4. Median in first column, 68% probability band in second column and 90% probability band in third column.

We now analyze the unconventional monetary policy known as QE1. We perform this exercise under the assumption that the federal funds rate is held fixed across all horizons. Admittedly, this is merely an approximate way to handle the zero lower bound (ZLB). At some horizon, the ZLB will no longer bind and we abstract from that. We start by clarifying the interpretation of Table 5 in the context of unconventional monetary policy/LSAPs. For example, the elasticities reported in the second column of Table 5 imply that a 100 bp decrease in the mortgage spread generates an increase

[18] As noted previously, we only consider the first 12 quarters when computing elasticities. This implies that we abstract from the longer horizon decline in house prices for this specification.

in GDP of more than 2% at the peak, and an increase in house prices of 7% at the peak.

As previously mentioned, the size of the mortgage spread innovation generated by QE1 is unclear. Our estimates are ($-0.3, -1.1$ and -1.0) for 2008q4-2009q2, corresponding to a peak effect on mortgages spreads of 33 bp, and a total of 2.4 standard deviations.[19] We also present results for Hancock and Passmore's (2011) upper-end estimate of 150 bp (10.9 standard deviations). Table 6 documents both cases. Effects are large on the two housing variables and substantial for consumption and GDP, in particular for Hancock and Passmore's upper-end estimate of the unconventional policy effect on spreads.

Variable	Our estimate, 33 bp	Upper-end estimate, 150 bp
Consumption	1.18	5.36
Residential investment	6.74	30.65
GDP	1.02	4.61
House prices	3.00	13.63

Table 6: Peak effects of QE1 (percentage points).

3.3.2 Comparison of results to the previous literature

There is one empirical paper with which we can compare our mortgage spread shock results: Musso, Neri and Stracca (2011) perform a related SVAR analysis. They find a much smaller role for mortgage spread shocks. In terms of IRFs, they find that residential investment is the only variable where the 68% probability band does not include zero for the first 10 quarters. Furthermore, they obtain a negligible response of the policy rate in response to a mortgage rate shock. Finally, in terms of long horizon (24 quarters) variance decomposition, their mortgage rate shock plays no role: it explains less than 1.5% of any variable except the mortgage rate itself.[20] A plausible reason for their weaker result is that their mortgage spread confounds the term premium and the mortgage spread, as it is defined as the difference between the 30-year mortgage rate and the 3-month Treasury bill.

We can also compare our results to those obtained in theoretical models. This exercise is somewhat clouded by comparison problems related to non-linearities in these models and discrepancies between the empirically relevant 30-year fixed rate mortgage (with a prepayment option) and the debt contracts in the models. The most appropriate comparison is to an exercise in Guerrieri and Lorenzoni (2011). They analyze a large temporary shock to intermediation cost (spreads), 6% in annualized

[19] Given the persistent effect on these variables the peak effects are well approximated by multiplying the effect of one standard deviation by the sum of the innovations which amounts to 2.4. Recall that we use a linear method, so the size of the effect scales linearly in the size of the innovation.

[20] Their results for the Euro area (EA) are very different from their US results in terms of variance decomposition. For EA, Musso et al. (2011) find a substantial (>10%) role for mortgage shocks for residential investment, total mortgage debt outstanding and the 3-month interbank rate.

terms, in a model with durable and non-durable consumption while abstracting from the ZLB. In terms of 7.5-year duration mortgage rates, they find an output elasticity of 7.0 which is substantially larger than our estimated elasticity of 1.9.[21] When they include the ZLB, they instead find an output elasticity of 19.4 compared to our ZLB estimate of 2.4. An important reason for why they obtain an immediate and large effect on output is the assumption that all loan contracts are one-period, implicitly an adjustable interest rate assumption.

3.3.3 International perspective - results for the UK and Sweden

The main purpose of this section is to show the generality of the results: mortgage spread innovations also appear both statistically and economically important in other countries. Furthermore, positive mortgage spread innovations induce contractionary dynamics in line with the interpretation as credit supply shocks also in other countries. There are, however, some interesting cross-country differences.

UK In Figure 8, we plot the impulse responses for a shock to the mortgage spread in the UK. The results are similar to the corresponding IRF for the US in that we obtain a drop in all real quantities, the policy rate and house prices. The 90% probability band of the responses is below zero for some quarters for all these variables, except for consumption. The strongest responses for residential investment and GDP occur after 2-4 quarters, considerably faster than in US. On the other hand, the policy rate response is slower: it reaches its trough after 5 quarters compared to 1 quarter for the US. In this context, it is worth recalling that mortgage maturities are substantially shorter in the UK (median maturity $\approx$ 2 years) than in the US, which could explain the faster macroeconomic impact of spread shocks.

[21] The shock modeled increases the spread by 6% in annualized terms for the first quarter and then decaying by a factor 0.6. Averaging the impact over 7.5 years (30 quarters) of 0.06*0.6^(t-1) yields 50 basis points on the fixed rate mortgage. It is then trivial to compute the elasticity of output.

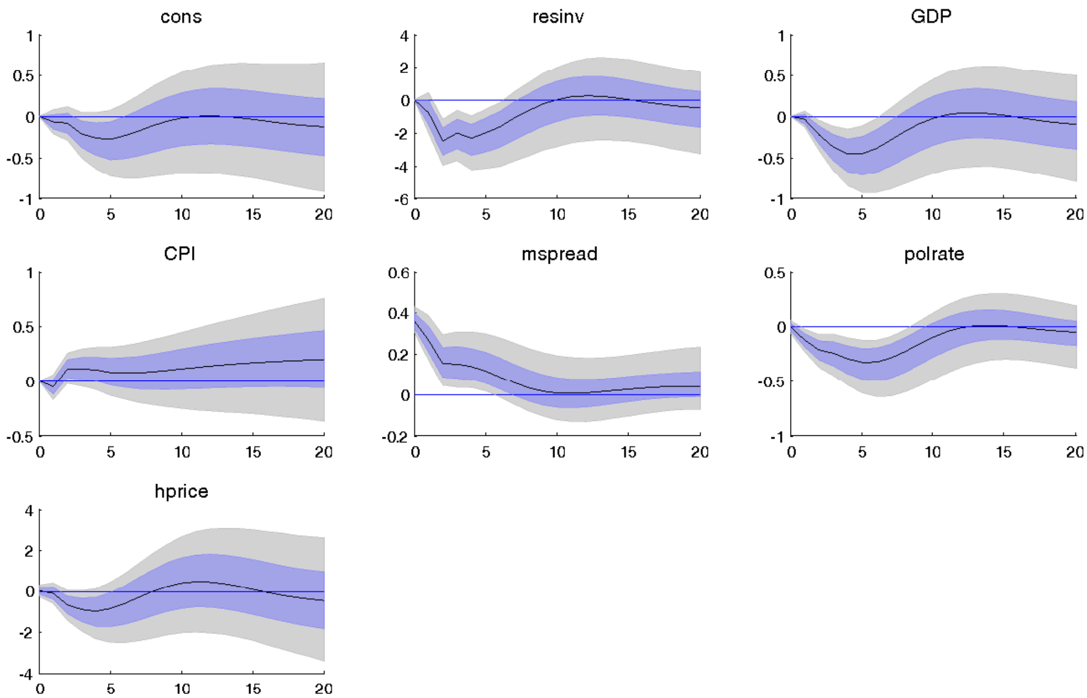

Figure 8. IRF to mortgage spread shock. UK 1995q1-2011q4. See Figure 3 for units etc.

Note that the standard deviation of the UK mortgage spread shock, 36 bp, is twice as large as in the US. This is the reason that the amplitudes of the IRFs are larger. To facilitate comparison, we ignore raw amplitudes and report elasticities of variables to the spread shock. Table 7 below documents elasticities of the variables of interest to the mortgage spread shock. Comparing the results to the US analogue, we note that the elasticity for consumption and the policy rate in the UK are lower by roughly a factor two. GDP also has a slightly lower elasticity than in the US. Residential investment and house price elasticities are similar in the US and the UK. Given the stronger policy rate response in the US, it appears that the larger US elasticities for real quantities are not due to differences in monetary policy.

Regarding the monetary policy shock (not plotted), the spread has an elasticity of 0.30 and remains positive for many years. The entire 90% probability interval is above zero for short horizons. In other words, the spread dynamics appear to amplify the monetary transmission mechanism. This is in line with a standard 'financial accelerator theory' of the mortgage spread.

In Table 8, we document the importance of the spread shock in terms of variance decomposition for the UK. We note that the shock is more important in the UK than in the US. This difference is most pronounced for residential investment. The notable exception is consumption which, in the UK, is driven by mortgage shocks to a lesser degree, consistent with the lower elasticity of UK consumption to spread shocks reported above. As in the US, the policy rate is the variable most affected

Variable	Elasticity
Consumption	-0.77
Residential investment	-6.91
GDP	-1.27
Policy rate	-0.91
House prices	-2.68

Table 7: Elasticity of variables to mortgage spread shocks. Computed as max (response of variable)/initial increase in shock variable. UK 1995q1-2011q4. Median.

by the mortgage spread shock.

To summarize the UK results, we find that mortgage spread shocks play an important role for some business cycle variables. Compared to the US, the key difference is the faster effect from the mortgage shock on residential investment and GDP. The volatility of the UK mortgage shock is higher than in the US, but the effect of a unit-sized shock on macroeconomic variables is smaller. Related to the higher volatility and the faster effect, the mortgage spread shock is more important in the UK in terms of variance decomposition.

Finally, note that although the UK had its own version of LSAP, known as the Asset Purchase Facility, announced in 2009q1, this program was overwhelmingly focused on government bonds (Gilts). Accordingly, there is no obvious reason to think that unconventional monetary policy affected the mortgage spread in the UK during our sample.[22]

Variable \ Horizon in quarters	2	4	8	12	16
Consumption	2	5	7	7	8
Residential investment	15	23	22	20	18
GDP	5	15	17	15	14
Mortgage spread	68	61	52	47	43
Policy rate	12	21	32	29	28
House prices	5	8	7	8	8

Table 8: Variance decomposition - fraction of variance, in percent, explained by mortgage spread shock. UK 1995q1-2011q4. Median.

Sweden The mortgage shock IRFs for Sweden are plotted in Figure 9. The initial increase in the mortgage spread is 19 bp. The results are quite similar to the corresponding IRF for the US and the UK. For Sweden, we also obtain a drop in all real quantities, the policy rate and house prices. The entire 90% probability band of the responses is below zero for some quarters for all these variables, except for consumption and the policy rate. The strongest responses for residential investment and GDP

[22] After our sample ends, in July 2012, the Bank of England launched its Funding for Lending Scheme which aims to reduce interest rate spreads for households and firms.

occur with roughly the same speed as in the US, that is, after approximately one year. The two notable differences in the dynamics are that the mortgage spread itself is more persistent and that the policy rate adjusts by about a third as much as in the US. Given these two characteristics, it is not surprising that all relevant variables, except consumption, respond more strongly and remain below the steady-state for a longer time.

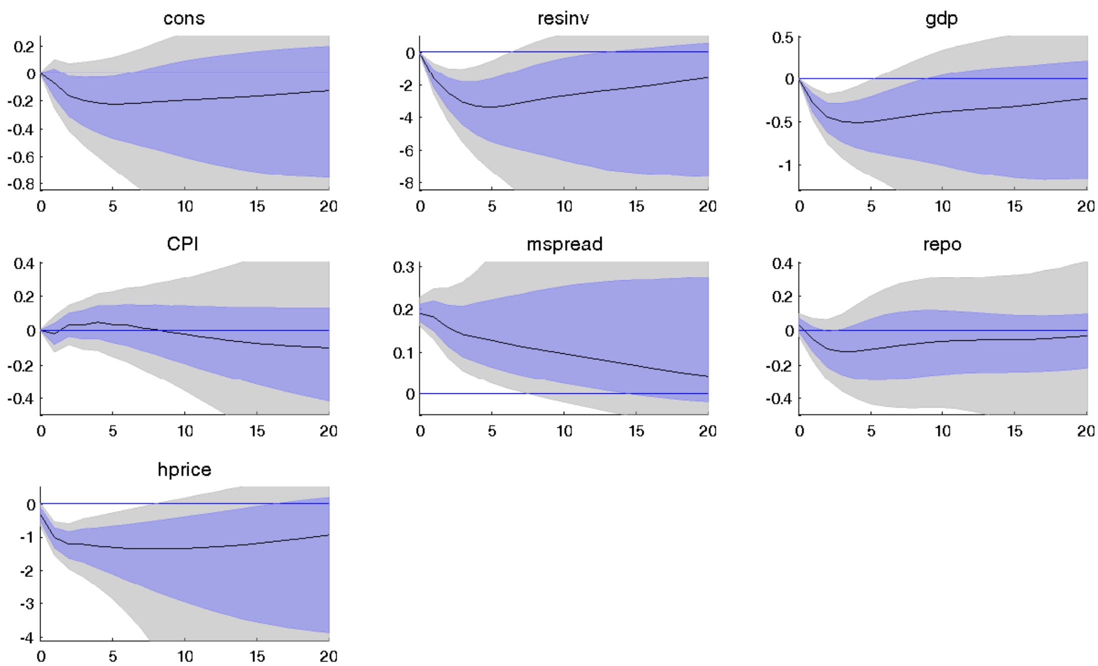

Figure 9. IRF to mortgage spread shock. Sweden 1995q1-2011q4. See Figure 3 for units etc.

Elasticities to the mortgage spread shock are reported in Table 9. Consumption and GDP have roughly similar elasticities as in the US. Compared to the US, the policy rate response is weaker while both residential investment and house prices respond almost three times as much in Sweden. Put differently, the Swedish responses are very similar to the US responses when the monetary policy rate is held fixed (see Table 5). Switching to the monetary policy shock (not plotted), the mortgage spread has an elasticity of 0.29 and is positive at all horizons, which differs from the US dynamics but is very similar to the UK's.

In Table 10, we display the variance decomposition for Sweden. Residential investment is explained by mortgage spread shocks to a higher degree than in the US, and very similarly to the UK. For GDP and house prices, the mortgage shock is more important in Sweden than in either the US or the UK. The variance decomposition of the policy rate confirms the very moderate response that we previously noted when studying the IRF.

To summarize the results for Sweden, the mortgage spread shock is more persistent and the policy rate offsets it less than in the US or in the UK. Thus, the remaining

Variable	Elasticity
Consumption	-1.21
Residential investment	-18.05
GDP	-2.71
Policy rate	-0.66
House prices	-7.16

Table 9: Elasticity of variables to mortgage spread shocks. Computed as max (response of variable)/initial increase in shock variable. Sweden 1995q1-2011q4. Median.

Variable \ Horizon in quarters	2	4	8	12	16
Consumption	3	7	10	12	14
Residential investment	13	22	25	24	25
GDP	14	21	19	18	19
Mortgage spread	55	48	42	39	38
Policy rate	3	5	10	12	14
House prices	26	29	27	26	26

Table 10: Variance decomposition - fraction of variance, in percent, explained by mortgage spread shock. Sweden 1995q1-2011q4. Median.

variables react more strongly and the effects are more long-lasting than in either the US or the UK. These differences are largest for residential investment and house prices.

4 Robustness

In terms of SVAR specification, we perform four robustness exercises. First, we change the ordering so that the monetary policy shock is allowed to affect the mortgage spread contemporaneously, but not the other way around. Second, we include a corporate bond spread. Third, we shorten the sample period to 1983q1-2008q2. Fourth, we vary the lag length.

In addition, to confirm the interpretation of the mortgage spread shock, we run an alternative SVAR specification where we add total real mortgage debt outstanding to our baseline VAR. The purpose is to find out whether the mortgage spread shock reduces mortgage amounts. That would be further indication that it should be interpreted as a credit supply shock (see Musso et al (2011)).

4.1 Allowing monetary policy shocks to affect the mortgage spread contemporaneously

It is not clear how to order the federal funds rate and the mortgage spread in the SVAR, i.e. which shock should be allowed/not allowed to affect the other variable contemporaneously. In principle, we would have preferred to allow both shocks to affect both variables contemporaneously, but this would rule out identification in a setting with only short-run restrictions. To document the sensitivity of the results to the ordering, we set up an alternative specification, reordered so that the monetary policy shock is allowed to effect the mortgage spread contemporaneously, but not the other way around.

The impulse responses for a mortgage spread shock for this specification are documented in Figure 10. All real quantities respond more strongly than in our baseline and the federal funds rate offsets the mortgage spread shock substantially less. For detailed quantification, see the elasticities in Table 11. Compared to our baseline specification, we note the largest increase in elasticity for residential investment and house prices. For GDP, the elasticity is only marginally increased. The policy rate elasticity is half as large as for the baseline specification.

We also note that the monetary policy shock IRFs for real quantities (not plotted) have a lower amplitude and are statistically weaker than in the baseline specification. Finally, the monetary policy shock effect on the mortgage spread is initially negative but of negligible size.

Finally, we note the tendency for increased importance of the mortgage spread shock in this specification also in terms of variance decomposition, as documented in Table 12. This is closely related to the decreased responsiveness of the policy rate to the mortgage spread shock.

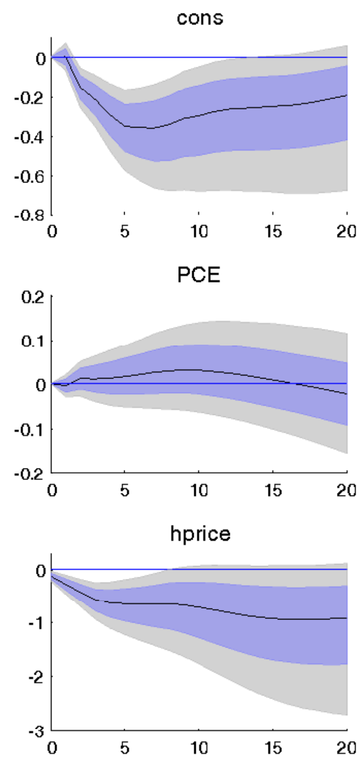

Figure 10. IRF to mortgage spread shock. US 1983q1-2011q4 in VAR specification where the federal funds rate is ordered before the mortgage spread. See Figure 3 for units etc.

Variable	Elasticity
Consumption	-2.22
Residential investment	-11.06
GDP	-2.19
Policy rate	-0.89
House prices	-4.33

Table 11: Elasticity of variables to mortgage spread shocks. Computed as max (response of variable)/initial increase in shock variable. US 1983q1-2011q4. VAR specification with the federal funds rate ordered before the mortgage spread. Median.

Variable \ Horizon in quarters	2	4	8	12	16
Consumption	4	10	16	14	13
Residential investment	3	6	9	7	6
GDP	3	10	16	14	13
Mortgage spread	54	46	36	29	26
Policy rate	4	4	5	5	5
House prices	10	13	10	8	8

Table 12: Variance decomposition - fraction of variance, in percent, explained by mortgage spread shock. US 1983q1-2011q4. VAR specification with the federal funds rate ordered before the mortgage spread. Median.

4.2 Including a corporate bond spread

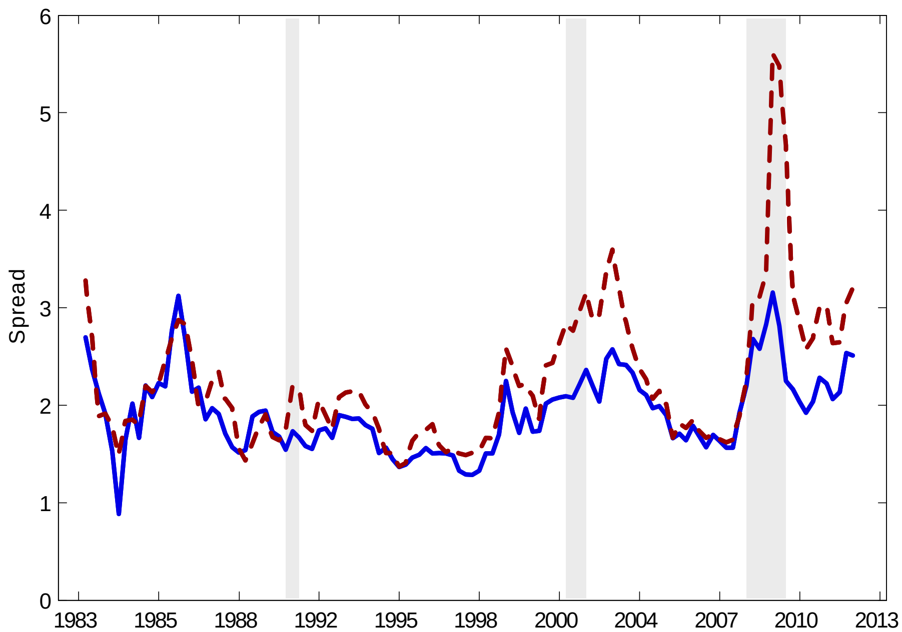

Figure 11. US 1983q1-2011q4. Mortgage spread (solid line), corporate bond spread (dashed line) and NBER recession dates (shaded bars) The corporate spread is defined as the difference in the interest rates on Moody's Baa-rated seasoned corporate bonds and the 10-year Treasury bond.

We already noted in Section 2, Table 1, that mortgage spreads and corporate bond spreads are highly correlated with a correlation coefficient of 0.83. We further document their comovement in Figure 11. This comovement motivates an alternative specification to ensure that we are capturing a causal relationship from mortgage spreads to macro variables. We add a corporate spread (difference in the interest rates on Baa-rated corporate bonds and the 10-year Treasury bond) to the VAR and order it before the mortgage spread. This implies that common contemporaneous variation in the two spreads that is orthogonal to contemporaneous movements in real quantities and inflation will be labeled a corporate spread shock. Only the remaining variation in mortgage spreads that is orthogonal to contemporaneous movements in real quantities and inflation will be filtered out as mortgage spread innovations.

Visually, the IRFs reported in Figure 12 are similar to the baseline specification except that some probability bands are wider and some magnitudes are marginally larger. Compared to the baseline specification, the standard deviation of the mortgage spread shock is marginally reduced from 18 bp to 16 bp. We report the elasticities in Table 13. Interestingly, they are slightly higher than for the baseline specification. The same tendency is present for the variance decomposition (not reported) in that there is a larger role for the mortgage spread shock than in our baseline specification. Finally, we note that the mortgage spread shock is generally substantially more important than the corporate spread shock in terms of variance decomposition (not reported), and in particular for GDP.

This exercise controls for the comovement between the two spreads as well as possible. We interpret the results as strong indicative evidence of a causal role of mortgage spread innovations for macroeconomic variables at business cycle frequencies.

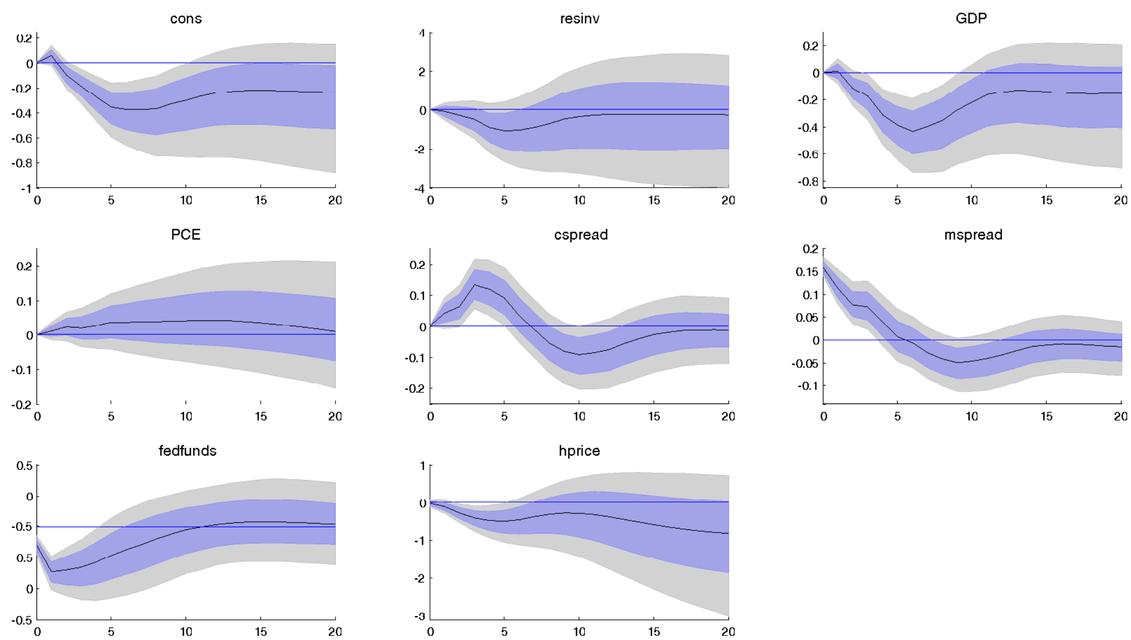

Figure 12. IRF to mortgage spread shock. US 1983q1-2011q4 in VAR specification that includes corporate spread. See Figure 3 for units etc.

Variable	Elasticity
Consumption	-2.37
Residential investment	-6.77
GDP	-2.74
Corporate spread	0.83
Policy rate	-1.83
House prices	-3.15

Table 13: Elasticity of variables to mortgage spread shocks. Computed as max (response of variable)/initial increase in shock variable. US 1983q1-2011q4. VAR specification including corporate spread. Median.

4.3 Subsample 1983q1-2008q2

In this robustness exercise, we end the sample in 2008q2 to avoid any potential econometric problems induced by the ZLB binding from the end of 2008 onwards.[23] This also means excluding the Lehman bankruptcy (September 15th, 2008) when the financial crisis became obvious. In a general sense, unconventional monetary policy such as the LSAP programs can be considered endogenous. One might therefore question our assumption of exogenous mortgage spread innovations. Yet, this problem is limited by our identification strategy as only mortgage spread movements that are orthogonal to current and lagged macroeconomic quantities are identified as mortgage spread innovations. Accordingly, we do not think that the financial crisis period should be excluded because of endogeneity issues affecting the identification. Nevertheless, we provide results for a subsample given that the end of our full sample is such an unusual period.

The impulse responses for this subsample are documented in Figure 13. The standard deviation of the mortgage spread shock is marginally lower than for the full sample; 17 bp instead of 18 bp. Importantly, the mortgage spread itself overshoots more in the subsample estimation: its response is substantially negative after four years. The responses of residential investment and house prices are noticeably reduced. The most striking difference is the decreased precision in the estimates represented by the widening of the probability bands. Even the 68% probability bands of the two housing variables overlap with zero. The federal funds rate response and its significance is basically unchanged while the 90% bands of GDP and consumption responses barely remain non-overlapping with zero. Their amplitudes are reduced by one-third compared to the full sample results. A more detailed quantification is provided in Table 14 which documents the elasticities for the subsample. Compared to the full sample results, these elasticities are generally lower and the largest reductions are obtained for residential investment and house prices.

We also analyzed robustness in terms of lag length for the subsample. We find that for lag lengths longer than 4, the affected variables have more persistent declines

[23] We also excluded the entire financial crisis period, i.e. 2007q1 onwards, and obtained very similar results.

and higher elasticities (not reported).[24]

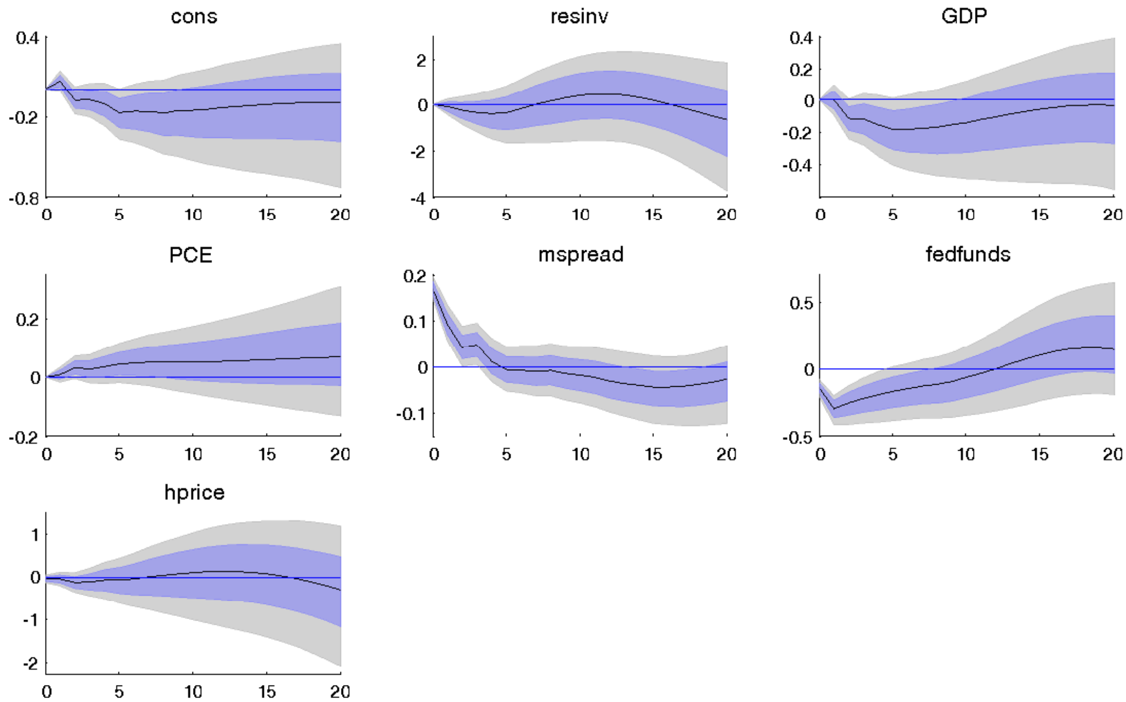

Figure 13. IRF to mortgage spread shock. US subsample 1983q1-2008q2. See Figure 3 for units etc.

Variable	Elasticity
Consumption	-1.06
Residential investment	-2.37
GDP	-1.08
Policy rate	-1.75
House prices	-0.71

Table 14: Elasticity of variables to mortgage spread shocks. Computed as max (response of variable)/initial increase in shock variable. US subsample 1983q1-2008q2. Median.

4.3.1 Subsample and corporate spread combined

We also present results for the subsample 1983q1-2008q2 in a specification where we include a corporate spread, i.e. combining two of the above robustness exercises. The

[24]Shorter lag lengths than 4 appear unsuitable as we then obtain large coefficients on the third lag and oscillating dynamics.

IRFs are reported in Figure 14 and elasticities in Table 15. In terms of elasticity point estimates, results are similar to our baseline specification and the full sample specification with a corporate spread. The key difference is that this specification has less precise estimates in that only for consumption and the federal funds rate are the 90% probability bands entirely below zero. The propagation is also slower than in the baseline specification. If we instead compare this specification to the subsample estimation without a corporate spread, we note that adding a corporate spread to the VAR yields much larger mortgage shock effects, with the exception of the policy rate response.

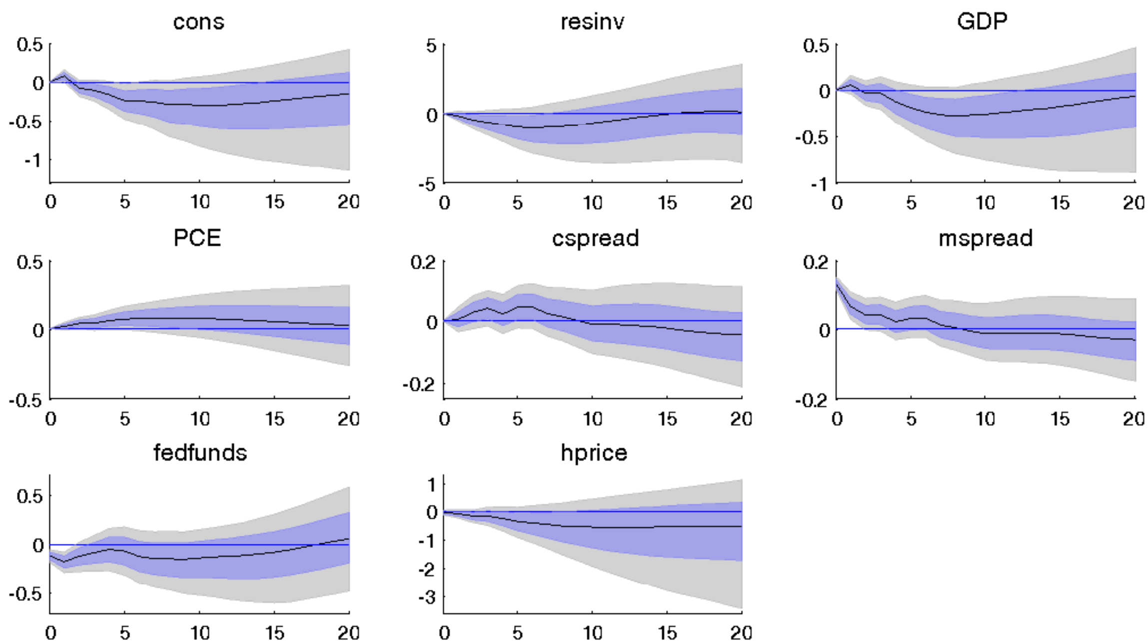

Figure 14. IRF to mortgage spread shock. US subsample 1983q1-2008q2 with corporate spread. See Figure 3 for units etc.

Variable	Elasticity
Consumption	-2.28
Residential investment	-8.22
GDP	-2.16
Corporate spread	0.34
Policy rate	-1.31
House prices	-4.12

Table 15: Elasticity of variables to mortgage spread shocks. Computed as max (response of variable)/initial increase in shock variable. US subsample 1983q1-2008q2 with corporate spread. Median.

4.4 Number of lags

As mentioned above, the appropriate lag length is unclear. It is therefore important that we demonstrate the robustness of our results to the number of lags.

The results are virtually unchanged using 5 lags. Impulse responses (not plotted) are visually identical, except that i) the GDP trough is reached after 6 quarters instead of 5 and ii) the precision in the IRF for residential investment is slightly reduced such that the decrease is only clear for the 68% probability band. We provide the elasticities for the 5-lag specification in column 2 of Table 16 to document how minor the differences are. Compared to our baseline 4-lag specification, elasticities are generally marginally larger in this specification. The size of the initial mortgage spread increase remains 18 bp.

The 6-lag specification shows the same tendency as the 5-lag specification: impulse responses (not plotted) are visually identical to the baseline specification except that the precision of estimates is slightly reduced. The 6-lag elasticities shown in column 3 of Table 16 confirm that the differences are small compared to the baseline specification. The 6-lag elasticities are in fact closer to the baseline elasticities than the 5-lag specification.

Variable	Elasticity, 5 lags	Elasticity, 6 lags
Consumption	-1.80	-1.76
Residential investment	-6.05	-5.03
GDP	-2.15	-2.05
Policy rate	-1.97	-1.84
House prices	-2.99	-3.14

Table 16: Elasticity of variables to mortgage spread shocks. Computed as max (response of variable)/initial increase in shock variable. US 1983q1-2011q4. Alternative specification with more lags. Median.

The variance decomposition for the 5-lag specification in Table 17 provides essentially the same picture. According to this specification, mortgage shocks are slightly more important than in our baseline specification. On the other hand, the 6-lag specification implies a slightly lower variance contribution (not reported) of the mortgage shock than in our baseline.

4.5 Mortgage quantities outstanding

Adding the quantity of mortgage debt outstanding to our baseline VAR yields the following system: consumption, residential investment, GDP, consumer prices, the mortgage spread, the policy interest rate, house prices and total mortgage debt outstanding. The change in specification leaves the impulse responses virtually unchanged.[25] We plot the impulses of three key variables in Figure 15. The main finding from this

[25] Elasticities are generally marginally larger in the mortgage quantity specification. In terms of variance decomposition, the specification with mortgage quantities implies that the mortgage spread shock is slightly more important than in our benchmark for all variables, except for the spread itself.

Variable \ Horizon in quarters	2	4	8	12	16
Consumption	3	7	12	10	8
Residential investment	1	2	3	3	4
GDP	2	8	16	12	10
Mortgage spread	62	53	38	32	29
Policy rate	25	21	18	16	14
House prices	10	11	6	4	4

Table 17: Variance decomposition - fraction of variance, in percent, explained by mortgage spread shock. US 1983q1-2011q4. Alternative specification with 5 lags. Median.

exercise is that mortgage debt decreases in response to a mortgage spread shock but quantitatively slightly less than house prices. The response is slightly delayed and gradual. In terms of precision, the entire 68% probability band is only below zero for quarter 5 and 6. This negative response is a further indication that the mortgage spread shock is a credit supply shock in that it increases the price and reduces the quantity of mortgages. However, from a statistical point of view, this result is quite weak.

For the UK and Sweden (not plotted), the mortgage spread shock reduces the mortgage debt outstanding for the entire 90% probability band. Relative to house prices, the decrease is more gradual and long-lasting. Adding this additional variable to the VAR does not affect the median impulse responses substantially for either country, though the precision in the estimates generally falls.

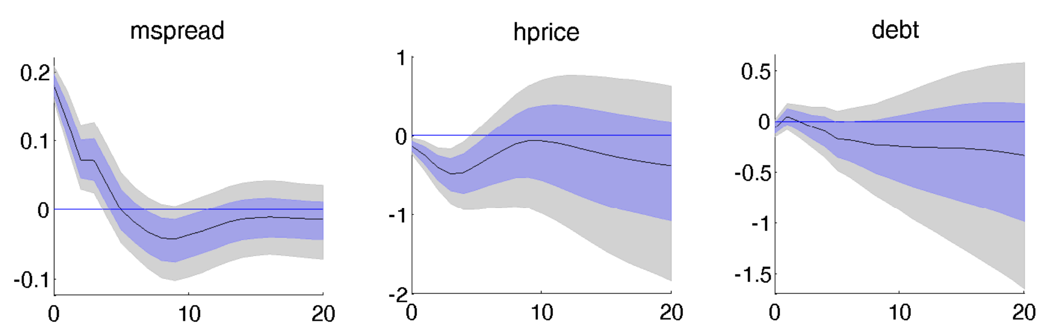

Figure 15. Impulse responses to mortgage spread shock of key variables for VAR specification with 8 variables: benchmark plus mortgage debt quantity outstanding. US 1983q1-2011q4. See Figure 3 for units etc.

4.6 Summary of robustness results

Let us now summarize the findings of the robustness exercises. Several alternative specifications have been explored. Generally, they attribute a slightly larger role to mortgage innovations for the business cycle than our baseline specification. The notable exception occurs when the sample is shortened to exclude the unconventional monetary policy period. For that specification, the effect on GDP and consumption, measured as elasticity, is reduced by one-third.

5 Interpretation and conclusions

5.1 What is a mortgage spread innovation?

We have used a SVAR with macroeconomic variables and house prices to extract exogenous innovations to the mortgage spread. We found strong indicative evidence that these innovations should be interpreted as credit supply shocks. Nevertheless, it is not obvious what the concrete underlying factors are that generate these innovations. Recall that our identification is set up so that only spread movements that are orthogonal to contemporaneous and lagged macroeconomic quantities and house prices are picked up as mortgage spread innovations. Potential underlying drivers are changes in the degree of competition in the mortgage industry, changes in banks' balance sheets (leverage) or liquidity, changes in financial regulation, changes in financial practices such as the degree of securitization, or, in the most recent years, outright government intervention in the mortgage market such as large purchases of MBS. Finally, changes in risk aversion or "risk-bearing capacity" of the financial system may generate the mortgage spread innovations

Note that only a very small fraction of the variation in mortgage spreads can be explained by variation in mortgage default risk. It is therefore a good approximation to consider the time variation in mortgage spreads studied in this paper as an "excess premium" (over and above variation in the credit risk) in the same spirit as Gilchrist and Zakrajšek (2012) or Meeks (2012). The reason that credit risk on mortgages is only marginally driving spread variation for the US is that more than 75% of the prime conforming loans we study are guaranteed against credit risk by Fannie Mae or Freddie Mac (Fuster, Goodman, Lucca, Madar, Molloy and Willen, 2012). Pricing of these guarantees is not primarily intended to capture macroeconomic variation in credit risk and has very limited (+/-5 bp) price variation within our sample period.

The UK and Sweden do not have government sponsored mortgage guarantees. However, credit losses on residential mortgages have been low in these countries and thus variation in credit losses has been limited. The details are documented in the Data Appendix. Yet, note that for Sweden, the 2007-2011 increase in the mortgage spread of more than 2% is at best marginally accounted for by increased credit risk given that the peak credit losses in the recent crisis were 0.06% of outstanding mortgages.

Quantitatively distinguishing between the driving factors mentioned above goes beyond the scope of the present paper. One step which we are considering for future research is to decompose the variation in the spread into two components: the difference between the risk free rate and the primary mortgage rate vs. the primary-secondary mortgage rate spread. Regarding the latter spread and the factors driving it (some of which are mentioned above), see Fuster et al (2012).

5.2 Concluding remarks

In this paper, we have explored the business cycle effects of innovations to the residential mortgage spread. Our approach has been to impose minimum assumptions by using a structural VAR instead of employing a fully specified model. We have confirmed that none of our key results depend on the details of the VAR specification, and that they generalize beyond the US to the UK and Sweden, countries with very different mortgage institutions.

The general lessons from this paper are the following. First, business cycle fluctuations are affected by financial frictions in residential mortgage markets. Second, innovations in the mortgage spread appear to capture movements in credit supply that are moderately important for business cycle variation in macroeconomic quantities and house prices. Third, the policy rate partially offsets mortgage spread innovations and its variance is to a substantial degree driven by these. Finally, we conclude that if unconventional monetary policy succeeds in affecting the mortgage spread then it has sizable effects on house prices, residential investment and GDP.

An interesting avenue for future research would be to build a structural model of the interaction between the macroeconomy and the mortgage spread and ideally one in which a substantial part of the mortgage spread variation is endogenous, as indicated by our VAR results. One may view this as an extension of the model in Cúrdia and Woodford (2009) but with the added complication of sector-specific spreads. One reason that a structural model would be valuable is that it would enable us to explicitly analyze normative issues. In particular, are mortgage spread shocks inefficient and should they thus be counteracted by monetary policy? The evidence presented in this paper taken at face value, as well as past policy practice, points in this direction.

Finally, it is worth recalling that the present paper does not address the subprime mortgage market. Instead, we focus exclusively on regular prime (conventional and conforming according to Freddie Mac) mortgages. This choice is to a large degree driven by our method which requires long time series with a reasonably stable composition of borrowers. To arrive at the full importance of the housing market for the business cycle, one can, in principle, add up the effects from the prime market that we have explored here with results from studies of the subprime market. In that context, our contribution can be summarized as indicating that spreads in the prime mortgage market have a role in generating business cycles.

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