Systematic Monetary Policy and the Macroeconomic Effects of Shifts in Loan-to-Value Ratios

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Abstract

What are the macroeconomic consequences of changing aggregate lending standards in residential mortgage markets, as measured by loan-to-value (LTV) ratios? Using a structural VAR, we find that GDP and business investment increase following an expansionary LTV shock. Residential investment, by contrast, falls, a result that depends on the systematic reaction of monetary policy. We show that, in our sample, the Fed tended to respond directly to expansionary LTV shocks by raising the monetary policy instrument, and, as a result, mortgage rates increase and residential investment declines. The monetary policy reaction function in the US appears to include lending standards in residential markets, a finding we confirm in Taylor rule estimations. Without the endogenous monetary policy reaction residential investment increases. House prices and household (mortgage) debt behave in a similar way. This suggests that an exogenous loosening of LTV ratios is unlikely to explain booms in residential investment and house prices, or run ups in household leverage, at least in times of conventional monetary policy.

Keywords: loan-to-value ratios, monetary policy, residential investment, structural VAR, Cholesky identification, Taylor rules.
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1 Introduction

What are the macroeconomic consequences of exogenous changes to aggregate lending standards / borrowing constraints in residential markets, as measured by loan-to-value (LTV) ratios? The most recent cycle in US housing markets saw a relaxation and subsequent tightening of borrowing conditions, leading many observers to attribute the growth in residential investment, mortgage debt, and house prices prior to the Great Recession to the loosening of lending standards.[1] In addition, recent macroprudential policy discussions include changing regulatory limits on (mortgage) LTV ratios. However, little is known empirically about the macroeconomic consequences of autonomous variations in LTV ratios; this paper is an attempt to make some headway.

Specifically, we empirically quantify the effect of exogenous shifts in LTV ratios on aggregate economic activity, in particular various investment aggregates and house prices, as well as on the development of household and firm debt. Moreover, we shed light on the systematic interaction between movements in LTV ratios and monetary policy, which provides an explanation for the effects of shocks to LTV ratios on macroeconomic activity. To measure LTV ratios, we rely on survey data from the Federal Housing Finance Agency (FHFA) among others, which polls a sample of US mortgage lenders to report terms and conditions on lending standards for conventional, newly originated mortgages within the Monthly Interest Rate Survey (MIRS).[2]

Our baseline empirical strategy consists of estimating structural vector autoregressions (VARs) to identify exogenous shocks to LTV ratios with only a few theoretical restrictions. Specifically, we isolate exogenous shifts in LTV ratios from endogenous reactions to other macroeconomic fluctuations by imposing a recursive Cholesky identification scheme. Following, among others, Lown and Morgan (2006), Gilchrist and Zakrajsek (2012), and Walentin (2014), we recover the structural VAR representation by assuming that LTV shocks affect "slow-moving" macroeconomic aggregates with a time lag of one quarter, while "fast-moving" financial variables respond to shifts in lending standards on impact.[3]

[1] See Chu (2014), Landvoigt et al. (2015), and Favilukis et al. (2016). See Kiyotaki et al. (2011) for a more sceptical, and Landvoigt (2015) and Sommer et al. (2013) for a more mixed view.

[2] We use the overall LTV ratio for conventional mortgage loans as our benchmark measure, which includes both owner occupiers and first-time buyers, but not mortgages from, e.g., the subprime category. Duca et al. (2011, 2013) stress the importance of first-time home owners as they are particularly subject to borrowing constraints. In a robustness check, we thus use an adjusted LTV series for the group of first-time home buyers only, based on the American Housing Survey (AHS), which also includes less than prime mortgages. Although the results are—due to noise in first-time home buyer data—not as clean, the qualitative evidence for first-time home buyers is very close to the results for all home owners. We also check whether our main findings are driven by cyclical composition effects along certain types of mortgages with the FHFA-provided disaggregate LTV ratio series for newly built homes, previously occupied homes, fixed-rate and adjustable-rate mortgages.

[3] In an extension, we conduct an exercise in the spirit of Bassett et al. (2014) to show that the VAR approach and the Cholesky identification are sufficient to isolate exogenous movements in aggregate residential sector lending standards. We remove influences of financial sector and macroeconomic conditions/expectations from the raw LTV series that might confound this interpretation of LTV ratios. We find that, first, the impact of such factors on the LTV ratio is rather

After an expansionary 25 basis point LTV shock, the LTV ratio rises quite persistently, and we find positive effects on real non-residential aggregate quantities, with business investment rising by 0.3 percent after a year, and GDP increasing by approximately 0.1 percent. Because of these spillovers to non-residential aggregates we view residential mortgage LTV ratios as an indicator of aggregate lending standards in a broader sense rather than just being indicative of lending standards in residential mortgage markets. We provide further evidence in the paper that this interpretation is appropriate. In particular, we show that movements in and shocks to LTV ratios are not simply mechanical reflections of movements in house prices.

The picture is different, however, for real residential investment: after a small initial increase, residential investment turns negative to minus 0.4 percent in the second year after the shock. We identify the Fed's monetary policy instrument as a potential candidate to explain the decline in residential investment after the LTV shock. The Federal Funds rate responds to looser lending standards in the residential mortgage market with a hump-shaped and rather persistent tightening of 10 basis points at the maximum, counteracting the eased *quantity* restriction on mortgage loans. In addition, the endogenous policy contraction passes through to mortgage rates—raising the *price* of mortgage loans—and, furthermore, households are aware of this increase in interest rates as data from the Michigan Survey of Consumers show. Our results thus suggest that an exogenous loosening of LTV ratios is unlikely to explain a boom in residential investment, at least under conventional monetary policy.[4] We corroborate this view through a variance decomposition and a number of historical decompositions, in particular, one showing that too lax credit standards prior to the Great Recession are unlikely to be the cause of the observed residential investment boom. By contrast, loose monetary policy appears to have had a comparatively larger influence on the housing market overdrive during that time and more generally.[5]

We analyze the systematic monetary policy response to an exogenous LTV shock along two additional dimensions. First, to answer the question what the Fed actually responds to after an LTV easing, we perform an impulse response decomposition as proposed by Kilian and Lewis (2011). This decomposition reveals which variables trigger the policy tightening. As the LTV shock causes no inflationary pressure—price inflation even slightly falls in the medium run—we find no evidence for a preemptive price stabilization motive of monetary policy. By contrast, based on the impulse response decomposition, the policy response is better characterized as a *direct* response to the altered lending conditions, rather than an *indirect* response operating through the shock propagation via other variables in the system. For short horizons at least, it is the LTV ratio that accounts for the systematic interest rate reaction almost entirely. We conjecture that aggregate lending standards, as

small and for the majority of control variables statistically insignificant; and, second, the macroeconomic consequences of shocks to the purged LTV ratio are very similar to those from specifications that use the benchmark raw LTV series.

[4]We also show that relative price inflation for residential investment decreases after a loosening of LTV ratios, just as residential investment does. Our results thus also suggest that an exogenous loosening of LTV ratios is unlikely to explain a prolonged house price boom, again, at least under conventional monetary policy.

[5]Similarly, Bhutta and Keys (2016), using a micro data approach, show the potency of interest rates to influence home equity extractions.

represented by LTV ratios, are thus part of the Fed's reaction function. This is further corroborated through estimating Taylor rules in the spirit of Coibion and Gorodnichenko (2012), where we show that even controlling for the usual inflation, output gap and output growth terms, residential LTV ratios, unlike most other financial variables, enter robustly, positively and significantly. This suggests that Taylor rules in models of the housing market with monetary policy should potentially contain residential credit market conditions.

Second, to isolate the impact of systematic monetary policy in the transmission of an LTV shock to the broader economy, we rely on the statistical decomposition proposed in Bernanke et al. (1997) and Sims and Zha (2006), and recently applied in, e.g., Kilian and Lewis (2011) and Bachmann and Sims (2012). This methodology consists of comparing the actual impulse response to an LTV shock with one for which the Fed's interest rate reaction to an LTV shock has been "zeroed out". The differences between both impulse response functions, then, identify the quantitative importance of the systematic monetary policy reaction for the transmission of LTV shocks. We find that the positive non-residential investment response is magnified in the case sans monetary policy reaction. More importantly, residential investment now exhibits a quite persistent *increase*, peaking at around 0.4 percent after a year, and it deviates, from quarter three on, statistically significantly from the impulse response with the monetary policy reaction. The systematic monetary policy response, hence, determines residential investment activity not only quantitatively, but also qualitatively. Put differently, while the reaction of non-residential investment is almost entirely driven by the aggregate lending conditions in terms of *quantities*, the dynamics of residential investment following an LTV shock are eventually dominated by an endogenous *price*, or interest rate reaction. We also show that this differential reaction is not due to different pass-through effects from the monetary policy interest rate to the relevant long-term interest rates for households and businesses, but rather the result of residential investment being substantially more interest rate sensitive than non-residential investment. Historical decompositions reveal that the systematic monetary policy reaction to LTV shocks we uncover is not simply a result that holds on average over our sample period, but rather something that can be found in a number of specific historical episodes; most clearly during the tightening-relaxation cycle of housing credit market conditions in the second half of the 1980s.

Our results without the monetary policy reaction also shed some light on the Great Recession. While our VAR is a linear model, our findings are in line with the perception that a tightening of LTV ratios may have exacerbated the downturn in housing markets during the Great Recession (see also Guerrieri and Iacoviello, 2015). The reason is the asymmetry represented by the zero lower bound on nominal interest rates. Historically, the Fed would have likely lowered interest rates in the face of the LTV tightening, however, with interest rates at zero, this cushioning mechanism was absent. According to our fixed interest rate evidence, such a situation should then be associated with a drop in residential investment, which was indeed observed during the financial crisis.

We also analyze the LTV shock propagation to measures of firm and household debt. From a theoretical perspective, collateral constraints on household borrowing represent the backbone of models that integrate durable housing goods into the dynamic stochastic general equilibrium (DSGE) framework.[6] Following the mechanism proposed in Kiyotaki and Moore (1997), household borrowing in these models is endogenously tied to a fraction of the (expected) housing value, where the down payment rate is pinned down by an exogenously fixed parameter, the LTV ratio. We find that following a loosening of lending standards for residential mortgages, which we interpret as a loosening of lending standards more broadly, *businesses* increase their debt levels, measured either by total bank loans or mortgage loans. This propensity to leverage is, perhaps surprisingly, hardly affected by the monetary policy reaction.

In contrast and resembling the evidence for residential investment, the evolution of *household* debt is contingent on the Federal Funds rate reaction. LTV shocks have a small (negative) impact on household debt even as the Federal Funds rate and mortgage rate rise. This is in line with Justiniano et al. (2015), who find in a DSGE model for the US that exogenous shifts in LTV ratios do not appear to have a strong impact on leverage.[7] Household debt, however, increases without the monetary policy reaction, making the shock transmission through the monetary policy instrument, i.e., the systematic interest rate reaction, the crucial channel of how LTV shocks affect household debt.

What do our results mean for the aforementioned macroprudential policy debate? The following quote by Stanley Fischer, during the Macroprudential Monetary Policy Conference at the Federal Reserve Bank of Boston, on October 2, 2015, attests to policymakers' interest in the effects of macroprudential policy tools: "Several other countries have used tools such as time-varying risk weights and time-varying loan-to-value (...) caps on mortgages. Indeed, international experience points to the usefulness of these tools, whereas the efficacy of new tools in the United States, such as the countercyclical capital buffer, remains untested."[8] The direct macroprudential policy applicability of our empirical results on the macroeconomic effects of LTV ratio shocks comes with the following important caveat: our Cholesky-identified LTV ratio shocks would have to be similar to LTV ratio shocks that exogenous changes in supervisory limits on LTV ratios, the way a regulator would generate them, would cause. Two issues are worth noting: firstly, is the aforementioned rather persistent effect of an LTV ratio shock on LTV ratios that we find in our VARs a good description of what would happen under macroprudential policy; secondly, how would *regulatory* changes in maximum LTV ratios translate into our VAR-identified shocks to average *de facto* LTV ratios? One possibility is that a regulator might target these de facto LTV ratios in the market. Ultimately, these are important questions, a full answer would, however, require a more structural approach.[9] We nevertheless believe

[6]See, among others, Iacoviello (2005), Monacelli (2009), and Iacoviello and Neri (2010).

[7]Similarly, Midrigan and Philippon (2016) argue that monetary policy appears to counteract shocks to household debt outside of zero lower bound episodes. In addition, Justiniano et al. (2017) make the case that the aggregate data is much better explained by changes in *lending* constraints, rather than *borrowing* constraints or lending standards.

[8]See also IMF (2011), BIS (2011), and Claessens (2014) for a summary of macroprudential tools and their implementation across different countries. In the face of the Great Recession a number of countries introduced, tightened, or at least considered the introduction of regulatory limits for LTV ratios as a macroprudential policy tool. Among them were Canada, the Netherlands, Norway, Sweden, or the United Kingdom (IMF, 2011).

[9]The following detailed history of the use of macroprudential policies in the US by Elliot et al. (2013) shows that using a simple empirical approach identifying effects directly from changes

that our results give at least some first-pass guidance to the macroprudential policy questions at hand: for instance, is the historically observed tightening monetary policy reaction counteracting an LTV ratio expansion by the Fed an optimal reaction to looser lending standards in the economy, and would the Fed do the same, if the latter was brought about by a macroprudential regulator? Furthermore, macroprudential policy measures should probably be designed in a way that coordinates with monetary policy. As for our results with a fixed interest rate monetary policy: do they mean that macroprudential policy measures are particularly effective and thus a tool of choice in times of zero lower bound episodes, or for regions that are part of a monetary union, such as member states of the European Monetary Union or US states, if coordination with monetary policy cannot be achieved?

Related Literature

Our paper is related to a recent and growing literature studying the effects of shocks to bank lending standards and financial market conditions on the macroeconomy. Perhaps most closely related is Walentin (2014), who also uses Cholesky-identified VARs to study the effects of increases in mortgage rate spreads. Unlike Walentin (2014), we focus on lending standards in terms of *quantities* (LTV ratios) rather than *prices* (spreads). His results for residential investment are somewhat more conventional than ours in that after an increase in the mortgage spread residential investment declines, albeit often without statistical significance. Walentin (2014) also finds a relaxation of monetary policy after an increase in the mortgage spread, similar to our counteracting monetary policy result, though this result does not hold for an increase in the mortgage rate, which makes the interpretation a bit more difficult. Our paper also differs in that we study the importance of the systematic monetary policy reaction for the transmission of aggregate lending shocks and that we connect our residential investment result directly to this systematic monetary policy reaction.

More broadly, Lown and Morgan (2006), Gilchrist and Zakrajsek (2012), Bassett et al. (2014), Peersman and Wagner (2015), Bassetto et al. (2016), Gambetti and Musso (2016), and López-Salido et al. (2016) study the effects of credit supply shocks (without a particular focus on residential markets) on economic activity. Many have the result that monetary policy counteracts whatever credit market shock is identified, but—with one exception in Bassetto et al. (2016)—the role of the systematic monetary policy reaction for the credit shock is not quantified, mainly

in regulation is difficult, given that the use of regulatory limits to residential LTV ratios is an anachronism from the not so recent past. The first limit on LTV ratios, 50 percent, for farm mortgages from national banks was imposed in the 1913 Federal Reserve Act, and then extended to urban real estate in 1916. The Banking Act from 1935 eased the limit to 60 percent, reflecting the government's effort to stimulate the economy in the Great Depression. The time between the Great Depression and 1950 was characterized by oscillating levels of severity of these regulations. But in 1950, with the Defense Production Act, following the outbreak of the Korean War, Congress gave the Federal Reserve for the first time a broad authority to set lending terms for residential mortgages (before Congress mandated those lending terms directly in the law). After the Korean War, mandating maximum LTV ratios fell gradually in disrepute. The 1969 Credit Control Act shifted macroprudential power to the President, because any measures had to be implemented on his request. However, President Nixon and later Fed Chairman Paul Volcker stated publicly that they did not want to use these measures. In 1982, Congress abolished all power to impose maximum LTV ratios.

because none of these papers, including Bassetto et al. (2016), feature a prima facie "counterintuitive" finding comparable to our residential investment result; instead, they usually find that their particular form of credit market tightening reduces economic activity and vice versa for expansionary shocks. By contrast, we show in this paper that when we estimate Taylor rules and run a horse race between various residential and other credit market variables, it is the residential LTV ratios and the mortgage spreads that win in the sense that monetary policy appears to systematically respond to them but not to other credit market variables. For some of these papers, that use broader, unpurged credit supply aggregates, it also might be somewhat difficult to interpret whether these credit supply shocks are driven by changing lending standards / borrowing constraints or rather changing lending constraints, recalling the important distinction suggested by Justiniano et al. (2017). By contrast, in our paper, especially after the purging exercise in the spirit of Bassett et al. (2014), we hope to have identified an aggregate borrowing constraint shock.

Lown and Morgan (2006) and Bassett et al. (2014) use Cholesky-identified VARs with the tightening variable from the Senior Loan Officer Opinion Survey (SLOOS) to identify aggregate credit supply shocks. Importantly, Bassett et al. (2014) introduce the purging exercise into the literature that we use in one of our robustness checks. Gilchrist and Zakrajsek (2012) also use Cholesky-identified VARs but with carefully computed credit spreads, that our paper also relies on for robustness checks. Peersman and Wagner (2015) and Gambetti and Musso (2016) use VARs that are sign-identified (in addition to zero restrictions in Peersman and Wagner (2015)) with lending aggregates and lending rates to identify credit supply shocks. López-Salido et al. (2016) take a longer historical perspective and use credit spreads to measure credit sentiment all the way going back to the Great Depression, not discussing, however, the endogenous reaction of monetary policy to credit supply shocks. Finally, Bassetto et al. (2016) also study, again in Cholesky-identified VARs, the endogenous monetary policy reaction to broader financial condition shocks and also show that monetary policy is important for our understanding of these shocks.

In addition to the time series literature, there is a growing cross-sectional literature that investigates the effects of credit supply shocks on economic activity. The results are somewhat mixed: while Driscoll (2004) does not find large effects, Favara and Imbs (2015) and Maggio and Kermani (2016) come out in favor of a large credit supply channel. Of course, cross-sectional, instrumental variable approaches come with a strong credibility advantage over time series methods. But one important caveat should be kept in mind: almost by construction, they cannot speak to the effects of systematic monetary policy reactions, which are always aggregate, and which, as we show, are crucial for our understanding of at least aggregate shocks to lending standards. In the end, we view, of course, both time series and cross-sectional approaches as complementary in studying the important question on how credit supply influences economic activity.

The remainder of the paper is structured as follows. Section 2 describes the data, explains the empirical strategy, and presents the core empirical findings. Section 3 uses modified and more disaggregate LTV ratio series to demonstrate the substantive robustness of our main results, while Section 4 reviews them along a few more technical robustness dimensions. Section 5 concludes the paper.

2 LTV shocks and monetary policy

This section presents the methodological framework and our main empirical findings. Section 2.1 describes the data. Section 2.2 discusses the VAR identification strategy and presents the main macroeconomic effects of LTV shocks. Section 2.3 characterizes the systematic monetary policy response to LTV shocks in detail and quantifies the macroeconomic effects of this policy reaction. Variance and historical decompositions follow. Section 2.4 analyzes the impact of LTV shocks on household and business debt.

2.1 Data

We study the effects of putatively autonomous movements in residential mortgage LTV ratios on aggregate economic, in particular, investment activity, and monetary policy. Accordingly, our parsimonious baseline model comprises four variables at the quarterly frequency: non-residential investment (i_t^{nr}), residential investment (i_t^{r}), the LTV ratio (ltv_t), and the nominal Federal Funds rate (r_t). We obtain the two quarterly investment series from the Bureau of Economic Analysis (BEA) in seasonally adjusted real terms and take the natural logarithm. The monetary policy instrument is the quarterly average of the effective Federal Funds rate. Our benchmark LTV measure is the quarterly average of the seasonally adjusted monthly national average LTV ratios on conventional mortgage loans from the Monthly Interest Rate Survey (MIRS) conducted by the Federal Housing Finance Agency (FHFA), which provides extensive data on terms and conditions of US mortgages. For instance, toward the end of our sample, the survey covers roughly 82,000 loan contracts.[10]

The sample covers the period 1973Q1 to 2008Q4, where the availability of LTV data dictates the start of the sample. We choose 2008Q4 as the end of the sample, when the Fed's policy instrument reached the zero lower bound. Since then, the Fed engaged in several unconventional policies and historical monetary policy reaction functions are likely to no longer hold (see, e.g., Kilian and Lewis, 2011; Peersman and Wagner, 2015).[11]

The FHFA survey polls a sample of mortgage lenders (savings associations, commercial banks, and mortgage companies) to report interest rates and conditions on all fully amortized single family loans closed within the last five business days of each month.[12] As part of the survey, mortgage lenders are asked to report the LTV ratios agreed upon at purchase of the properties. Importantly, focussing on newly originated mortgages guards us against house price valuation effects driving LTV

[10] See, e.g., page 6 of `www.reginfo.gov/public/do/DownloadDocument?objectID=19707402`.

[11] Incidentally, 2008Q4 is the last quarter where the FHFA survey includes adjustable-rate mortgage loans. Afterwards the entries are zero for this mortgage category. This constitutes a potential structural break in the FHFA survey and provides an additional reason for our end-of-sample choice.

[12] The survey does not comprise the following loan types: mortgages insured by the Federal Housing Administration or guaranteed by the Department of Veterans Affairs, multifamily mortgages, mortgages for mobile homes or farms, and mortgages created by refinancing existing mortgages. As discussed in Duca et al. (2011, 2013), the FHFA survey also does not include so-called Alt-A (a mortgage class between prime and subprime) nor subprime mortgages.

ratios mechanically. Also, these LTV ratios include all types of home owners, i.e., owner occupiers as well as first-time home buyers. According to Mian and Sufi (2011), existing home owners contributed substantially to the buildup in household leverage during the 2002 to 2006 house price acceleration, as about 65 percent of households already owned a property prior to the cycle.[13] The survey also includes both fixed-rate and adjustable-rate mortgage loans.

Figure 1 plots the FHFA LTV series, i.e., the national average ratio of granted mortgage loans for single family houses and the underlying property prices multiplied by 100. The shaded areas represent NBER-dated recession episodes in the US. The LTV ratio is procyclical and exhibits pronounced swings. Borrowing limits eased during the housing boom of the years 2002 to 2006, even though the LTV ratio did not reach its 1994 level. At the onset of the Great Recession the LTV ratio tightened sharply.

In addition, we augment the baseline VAR model along three dimensions:[14] first, to analyze the interest rate pass-through of the Federal Funds rate into longer-term interest rates and interest rate expectations, we add the nominal contract mortgage rate (r_t^m) on existing single family home purchases provided by the FHFA and a measure of consumers' interest rate expectations (r_t^e), which we obtain from the Michigan Survey of Consumers, to the VAR.[15] Second, to characterize the monetary policy response in detail, we allow for a more conventional monetary policy reaction function by including the natural logarithm of real GDP, y_t, and consumer price inflation, π_t, in percent. Third, to study the propagation of LTV shocks through measures of business and household debt, we either use total bank-provided loans to non-financial businesses, b_t^b, and total household debt, b_t^h, or, alternatively and more specifically, business and home mortgages, b_t^{bm} and b_t^{hm}. All debt series are stock variables (in log levels), measuring the outstanding amount of loans at the end of each quarter. We apply the GDP deflator to transform them into real quantities (see Justiniano et al., 2015).[16]

– INSERT FIGURE 1 HERE –

[13]We analyze first-time home buyer data in Section 3.2.

[14]Each extension is defined and described relative to the baseline four-variable VAR.

[15]Later, in Section 2.3.3, we also run a variant of the baseline VAR with r_t^m and Moody's BAA corporate bond yield (r_t^{baa}) for bonds with a maturity of, roughly, 30 years.

[16]We use the BEA investment and GDP series from NIPA Table 1.1.3., lines 1, 9, and 13. From the Federal Reserve Bank of St. Louis database (FRED) we obtain the quarterly Federal Funds rate (FEDFUNDS), the GDP deflator (GDPDEF), Moody's BAA corporate bond yield (WBAA), and the quarterly change of the Consumer Price Index (CPIAUCSL). The debt measures are from the Flow of Funds database with identifiers: Z1/Z1/FL144123005.Q for non-financial business loans, Z1/Z1/FL143165005.Q for non-financial business mortgages, Z1/Z1/LA153165105.Q for home mortgages, and Z1/Z1/LA153166000.Q for consumer credit of households and nonprofit organizations. The LTV series and our measure of mortgage rates are from the MIRS, Table 17 (all homes), which can be downloaded from FHFA: `http://www.fhfa.gov/DataTools/Downloads/Pages/Monthly-Interest-Rate-Data.aspx`. We apply the Census X-12 filter to seasonally adjust the LTV series and those debt series that are not seasonally adjusted in the Flow of Funds database.

2.2 Identification of LTV shocks

2.2.1 Structural VAR

To analyze the macroeconomic consequences of exogenous shifts in the LTV ratio, we rely on the vector autoregression framework. A structural representation of the variables of interest can be formulated as:

$$\boldsymbol{A_0}\boldsymbol{x}_t = \sum_{l=1}^{p} \boldsymbol{A}_l \boldsymbol{x}_{t-l} + \boldsymbol{\varepsilon}_t, \tag{1}$$

where we drop the intercept without loss of generality for notational convenience. $\boldsymbol{A}_l$ is a $n \times n$ matrix including autoregressive coefficients at lag, $l = 1, ..., p$, and $\boldsymbol{A}_0$ captures contemporaneous impact coefficients. p is the lag length, and $\boldsymbol{\varepsilon}_t$ represents mutually uncorrelated structural shocks. The $n \times 1$ vector $\boldsymbol{x}_t$ comprises the following n variables in this order, $\boldsymbol{x}_t = [i_t^{nr} \ i_t^{r} \ \Delta ltv_t \ r_t]'$.

We need to restrict elements in $\boldsymbol{A}_0$, to disentangle exogenous LTV movements from endogenous reactions to other variables in $\boldsymbol{x}_t$, i.e., to uniquely recover the structural VAR. Structural LTV shocks could arise from internal reassessments of the quality of borrowers, new business models, or shifts in the supervisory and regulatory environment under which mortgage originators operate (see Bassett et al., 2014). We follow Gilchrist and Zakrajsek (2012) and Walentin (2014) by assuming that shocks in "slow-moving" macroeconomic variables (i_t^{nr}, i_t^{r}) impact financial variables (Δltv_t, r_t) contemporaneously, whereas shocks in "fast-moving" financial variables affect the real economy with a time lag (see also Christiano et al., 1996; Peersman and Wagner, 2015). We implement the identification strategy by applying a Cholesky factorization to the variance-covariance matrix of the reduced form regression residuals, $\boldsymbol{u}_t$. Then we use the Cholesky factor for $\boldsymbol{A_0}$, which delivers the linear mapping $\boldsymbol{u}_t = \boldsymbol{A_0}^{-1}\boldsymbol{\varepsilon}_t$ and recovers the structural representation. Within the recursive identification scheme, we allow the monetary policy instrument to react on impact to LTV shocks, $\varepsilon_{L,t}$, where the subscript L is the position of Δltv_t in $\boldsymbol{x}_t$.[17]

As in Gilchrist and Zakrajsek (2012) and Bassett et al. (2014), we estimate the VAR with two lags—a lag length suggested by both the Schwarz and the Hannan-Quinn information criteria.[18] Results are, however, robust to higher lag orders (see Section 4.2). i_t^{nr} and i_t^{r} enter the VAR as natural logarithms (multiplied by 100), and we measure r_t in percent. We include ltv_t in first differences, explicitly allowing

[17] As we show in Section 2.3.2 through the estimation of Taylor rules, the Fed historically indeed appears to have reacted to housing market conditions in general, and changes in the LTV ratio in particular. Moreover, as is well-known and as we also document in Section 2.3.2, housing market variables in general, and changes in the LTV ratio in particular lead the business cycles. It is therefore plausible that the Fed not only monitors but also reacts to housing market shocks on impact. Nevertheless, results are not sensitive to a re-ordering within the block of financial variables, that is, ordering the Federal Funds rate, r_t, before Δltv_t (see Section 4.2).

[18] Ivanov and Kilian (2005) provide evidence that, for the case of quarterly observations, the Hannan-Quinn and Schwarz information criteria produce more accurately estimated impulse responses relative to alternative lag selection criteria. The Hannan-Quinn criterion also suggests two lags for the six-variable monetary policy VAR we use in Section 2.3. For all other variants and augmentations of either the four-variable or the six-variable monetary policy VAR, we fix the lag length, for compatibility reasons, at two.

for permanent movements in the LTV ratio following an LTV ratio shock.[19] To illustrate the dynamics of the LTV ratio in the VAR, we thus present cumulative impulse responses for this variable, which we can interpret as LTV ratio changes in percentage points.

2.2.2 LTV shocks: empirical evidence

Figure 2 traces out the impulse responses of the variables in $\boldsymbol{x}_t$ following an exogenous 25 basis point increase in the LTV ratio.[20] The solid lines display the point estimates of impulse response functions and the shaded areas are one standard error confidence intervals, which we obtain from 5,000 replications of the recursive-design wild bootstrap procedure of Goncalves and Kilian (2004). The LTV ratio exhibits a small and sluggish increase before levelling off at the 25 basis point level, i.e., the exogenous shock has a very persistent effect on the LTV ratio. The shock significantly affects non-residential investment, which features a hump-shaped increase with a peak around 0.3 percent after one year, and then reverts back to the pre-shock level. These spillovers to non-residential investment (and GDP, as we will show) suggest that the residential mortgage LTV ratio is also an indicator of aggregate borrowing constraints and lending standards more generally rather than just being indicative of residential mortgage markets.[21] Given the well-known leading property of housing market indicators and the hump-shaped increase in non-residential investment (and GDP), it is, however, plausible that aggregate changes in borrowing constraints and lending standards would show up first in the housing market.

In contrast, the impulse response of residential investment rises by 0.15 percent in the first quarter, but then falls significantly by 0.4 percent until it reaches its trough after two and a half years before slowly reverting back to its pre-shock level.

[19] As we show in Section 2.3.2, it is changes in ltv_t that enter Taylor rules, that is, the monetary policy reaction function. For the LTV ratio, the null hypothesis of a unit root cannot be rejected based on the augmented Dickey-Fuller test. Had we included ltv_t in levels, the event of estimating a root equal to 1.0 would have been zero probability (e.g., Born et al., 2015), thus essentially "forcing" LTV shocks to be non-permanent. In Section 4.2, we find similar results for specifications, in which all variables, including the LTV ratio, enter the VAR in levels, and in which all variables—except for interest rates—enter the VAR as first differences.

[20] We present a 25 basis point LTV shock instead of a one standard deviation shock for better comparability across specifications. Notice that this shock size is frequently used in monetary policy VARs. A one standard deviation shock to the LTV ratio would amount to 74 basis points, while a monetary policy shock has a standard deviation of 89 basis points in the six-variable monetary policy VAR. Thus the impulse of our LTV shock is of similar strength as a conventional monetary policy shock.

[21] Table A.1 in the Appendix supports this interpretation by showing how residential mortgage LTV ratios are (negatively) correlated with credit tightening measures from the Senior Loan Officer Opinion Survey (SLOOS), and (positively) correlated with LTV ratios for new car loans at auto finance companies. In addition, we find the same results in a VAR (augmented by real GDP and inflation to reflect our exercises from Section 2.3), when we replace the LTV ratio series for residential mortgages with the one for new car loans, ltv_t^{auto}; see Figure A.1 in the Appendix. A priori, it is not clear that the LTV ratio series for auto loans should have any impact on GDP, business investment, residential investment or the Federal Funds rate. That it does, supports our view that both LTV ratios, for residential mortgages and for auto loans, proxy for aggregate lending standards more broadly.

This result is perhaps surprising as it is inconsistent with the view that loose LTV ratios lead to prolonged construction booms, and, perhaps, housing bubbles.[22]

But why does a shock that eases borrowing constraints in the residential mortgage market lead to a decline in residential investment? The impulse response in the lower right panel of Figure 2 provides a candidate explanation. Monetary policy reacts to the eased lending standards by significantly and persistently raising the Federal Funds rate, by more than 10 basis points at the maximum response. The persistent contractionary shift in monetary policy seems to counteract the initial easing in mortgage markets and appears to be dominating the expansionary effects of the LTV increase, at least, for residential investment.

– INSERT FIGURE 2 HERE –

The results in Figure 2 also suggest that the LTV ratio shocks we identify here are unlikely to be other macroeconomic shocks that are spuriously picked up in our VAR (we elaborate on this issue further in Section 3.1): none of the other macroeconomic variables, residential and business investment nor the Federal Funds rate, have an impulse response function similar in shape to either Δltv_t or ltv_t (this is true also for GDP, as we shall see). Δltv_t goes back to zero quickly, and ltv_t levels off. Yet, the other variables in the VAR are hump-shaped and continue to move far beyond when Δltv_t is still changing. Had our LTV ratio shock simply picked up another macro shock, we would have expected it to behave more like the other macroeconomic variables (see, for a similar argument, DeWinne and Peersman (Fall 2016)).

We next examine the monetary policy reaction hypothesis along two further dimensions. First, we analyze whether households are plausibly aware of the endogenous interest rate hike, and, second, we study whether the shift in monetary policy passes through to interest rates that are more relevant for housing markets, i.e., mortgage rates. To do so, we add the nominal contract mortgage rate (r_t^m) on existing single family home purchases provided by the FHFA to the VAR. Furthermore, we include a measure of consumers' interest rate change expectations (r_t^e), which we obtain from the Michigan Survey of Consumers. The survey asks consumers the following question on a monthly basis: *"No one can say for sure, but what do you think will happen to interest rates for borrowing money during the next 12 months—will they go up, stay the same, or go down?"* We use a balance score, i.e., the share of consumers expecting rates to go up minus the share of consumers expecting rates to go down, plus 100. Thus the scale is qualitative and positive values indicate a less favorable expected interest rate environment. We re-estimate the VAR with these additional variables ordered as follows $\boldsymbol{x}_t = [i_t^{nr}\ i_t^r\ \Delta ltv_t\ r_t\ r_t^m\ r_t^e]'$. The recursive ordering allows the Federal Funds rate to pass through to mortgage rates contemporaneously. It also allows expectations to adjust to macroeconomic

[22] Given the initial uptick in residential investment, a first-blush explanation for this impulse response could be pure intertemporal substitution on LTV ratios: build a house now, before LTV ratios tighten again. This could lead, theoretically, to a boom-bust cycle in residential investment. However, notice that the magnitudes of the boom and the bust phase are very different, which makes it unlikely that the bust phase is just residential investment shuffled forward in time. In addition, the fact that the LTV ratio shock triggers a very persistent LTV ratio reaction makes pure intertemporal substitution on LTV ratios theoretically implausible.

and financial conditions on impact. Figure 3 presents the LTV shock propagation to the newly introduced variables in the bottom panels. We show the cumulative impulse response of interest change expectations to proxy for qualitative expectations about the *level* of interest rates.

– INSERT FIGURE 3 HERE –

The endogenous monetary policy tightening transmits significantly to mortgage rates. Thus an increase in mortgage borrowing costs (prices) counteracts the loosening of the LTV ratio on mortgage loans (quantities). The policy reaction, in addition, is reflected in consumers' qualitative expectations on borrowing interest rates, which move instantaneously and remain significantly positive for more than a year. The evidence on both variables supports the hypothesis that systematic contractionary monetary policy reactions are a candidate for explaining the decrease in residential investment after an expansionary LTV shock.

2.3 Systematic monetary policy

This section studies the systematic monetary policy reaction in detail, first, by isolating the drivers of the Federal Funds rate response, then by providing independent evidence through the estimation of Taylor rules that the Fed indeed reacts to credit conditions in the housing market. We analyze the different responses of non-residential investment and residential investment to monetary policy, and quantify the importance of the systematic monetary policy response for the reaction of the macroeconomy and the housing market to LTV shocks. Variance and historical decompositions follow.

2.3.1 What drives the monetary policy reaction?

Which variables in the VAR actually trigger the policy reaction to the change in the LTV ratio, i.e., what is the central bank responding to after an LTV shock? We answer this question by decomposing the impulse response of the Fed's policy instrument into contributions from the variables in $\boldsymbol{x}_t$, as in Kilian and Lewis (2011).[23] The rationale behind this exercise is as follows: LTV disturbances cause the Federal Funds rate to deviate from its steady state. This response can be considered as the sum of a policy reaction, first, to lags of the policy instrument itself, and, second, to deviations of other variables in $\boldsymbol{x}_t$ from their steady state values. The relative contributions of variables in $\boldsymbol{x}_t$ to the Federal Funds rate response, then, identify the forces underlying the monetary policy contraction.

It is convenient to express the structural VAR as follows:

$$\boldsymbol{x}_t = \boldsymbol{C}\boldsymbol{x}_t + \sum_{l=1}^{p} \boldsymbol{A}_l \boldsymbol{x}_{t-l} + \boldsymbol{\varepsilon}_t, \tag{2}$$

where the $n \times n$ matrix $\boldsymbol{C}$ is strictly lower triangular. Furthermore, we can compactly summarize the structural parameters as $\boldsymbol{B} = [\boldsymbol{C}\ \ \boldsymbol{A_1} \dots \boldsymbol{A_p}]$.

[23] We thank these authors for providing us with their code.

To isolate the contribution of variable j to the Federal Funds Rate response at horizon h after a time $t = 0$ shock to the LTV ratio ($\Xi_{F,j,h}$), we define:

$$\Xi_{F,j,h} = \sum_{m=0}^{\min(p,h)} \boldsymbol{B}_{F,mn+j} \boldsymbol{\Phi}_{j,L,h-m}, \tag{3}$$

with subscripts F and L denoting the position of the Federal Funds rate and LTV ratio in the system, and $h = 0, 1, 2, ..., 16$ as well as $j = 1, 2, ..., n$. $\boldsymbol{\Phi}_{j,L,h-m}$ is the $\{j, L\}$ entry of the parameter matrix of impulse reponses, $\boldsymbol{\Phi}_{h-m}$.

Given the Fed's objective of macroeconomic stabilization and taking its "dual mandate" into account, we augment the baseline for the impulse response decomposition exercise to allow for a more conventional monetary policy reaction function (e.g., Bernanke et al., 1997; Kilian and Lewis, 2011), i.e., we add real GDP, y_t, and consumer price inflation, π_t, to the VAR, and study the contributions of these variables to the policy response as well. The augmented model thus includes the following six variables in the following order $\boldsymbol{x}_t = [y_t \; i_t^{nr} \; i_t^r \; \pi_t \; \Delta ltv_t \; r_t]'$. With this identification restriction, monetary policy surprises impact other variables with a time lag of one quarter, and monetary policy reacts to realizations of macroeconomic aggregates contemporaneously, i.e., contemporaneous as well as previous realizations of all variables in $\boldsymbol{x}_t$ are reflected by the Fed's time t information set. We thus follow an established literature of recursively identified monetary policy VARs, e.g., Bernanke et al. (1997), Christiano et al. (2005), and Erceg and Levin (2006).

The upper panels of Figure 4 plot the dynamics of y_t and π_t after a 25 basis point disturbance to the LTV ratio.[24] Real GDP displays a hump-shaped rise of 0.1 percent, which peaks in quarter two and becomes insignificant from quarter eight onwards. The inflation rate is initially sticky and then increases for six quarters before moving into negative territory from quarter seven onwards. However, the inflation response is economically small and statistically insignificant over the whole forecast horizon. This suggests that the monetary policy contraction (solid lines in the lower panels of Figure 4) cannot be explained by a "leaning against the wind" towards inflationary pressure.[25]

The lower panels of Figure 4 show that in the first quarter after the shock, the LTV ratio accounts for the bulk of the Federal Funds rate response (line with nodes) and for subsequent horizons, the lags of the Federal Funds rate itself explain the Federal Funds rate response almost entirely (dashed line). The direct contributions of output, inflation, and both investment measures are negligible. Apparently, lending standards in the housing market, as reflected by residential mortgage LTV ratios, are part of the Fed's reaction function, and a contractionary reaction to more expansionary lending practices, perhaps in anticipation of the expected boom in GDP, residential and non-residential investment, drives the policy instrument following the LTV shock. The next subsection presents complementary evidence for this claim.

[24]Figure 8 shows the rest of the impulse response functions.

[25]This is an important lesson for models that study the interaction between credit conditions and monetary policy. For instance, Gambetti and Musso (2016) use a theoretical inflation-pressure argument to justify the assumption of a contractionary reaction of the Federal Funds rate to positive loan supply shocks in the sign restrictions that identify their VAR.

– INSERT FIGURE 4 HERE –

2.3.2 Does the Fed really respond to LTV ratios? A Taylor rule approach

In this section, we now directly estimate the Fed's reaction function in the spirit of Taylor (1993) and explicitly allow the monetary authority to respond to lending conditions as proxied by residential mortgage LTV ratios. We do so following the recent work by Coibion and Gorodnichenko (2012). While early estimations of Taylor rules included contemporaneous measures of economic activity and inflation, recent research favors the use of fundamentals reflecting the real-time *expectations* of the monetary authority (e.g., Orphanides, 2003; Coibion and Gorodnichenko, 2011).

We therefore characterize the Fed's *desired* policy rate, r_t^{tar}, as:

$$r_t^{tar} = c^* + \psi_\pi^* \mathbb{E}_{t-}\{\pi_{t+h_\pi}\} + \psi_{\tilde{y}}^* \mathbb{E}_{t-}\{\tilde{y}_{t+h_{\tilde{y}}}\} + \psi_{\Delta y}^* \mathbb{E}_{t-}\{\Delta y_{t+h_{\Delta y}}\} + \psi_{\Delta ltv}^* \Delta ltv_{t-1} \quad (4)$$

whereas the *realized* policy rate, r_t, can be written as:

$$r_t = r_t^{tar} + \eta_t^{TR}. \quad (5)$$

The central bank sets interest rates according to the expected realizations of the inflation rate, π_t, the output gap, $\tilde{y}_t$, and the growth rate of GDP, Δy_t. The inclusion of the latter term is motivated by empirical evidence in Ireland (2004) and subsequent studies. The reaction coefficients ψ_π^*, $\psi_{\tilde{y}}^*$, and $\psi_{\Delta y}^*$ determine to what extent the Fed changes the policy rate in response to fluctuations in the target variables. c^* is an intercept capturing time invariant target values of the central bank's objectives, and η_t^{TR} is a monetary policy disturbance. Finally, in addition to the standard Taylor rule elements, we include a term for past changes in LTV ratios, Δltv_{t-1}, with a coefficient $\psi_{\Delta ltv}^*$, to let the data tell us whether the Fed historically responded to shifts in residential mortgage lending standards.

To measure the Fed's real-time information set *prior* to official meetings of the FOMC, $\mathbb{E}_{t-}\{\cdot\}$, we follow the methodology in Coibion and Gorodnichenko (2012) and update their data set to the end of our sample, 2008Q4. Specifically, we use the forecasts conducted by the Board of Governors' staff, which are released in the so-called Greenbook with a five-year publication lag. These staff projections are exogenous to the subsequent interest setting of the Fed, so that we can estimate the Taylor rule with OLS (e.g., Coibion and Gorodnichenko, 2011, 2012). We select those meeting dates that occurred closest to a quarter's midpoint to transform the forecasts from the FOMC meetings frequency into a quarterly time series. h_π, $h_{\tilde{y}}$, and $h_{\Delta y}$ denote the forecast horizons considered.

Finally, to model the well-documented gradualism of monetary policy decisions, two leading empirical strategies exist: first, defining the current policy rate as a weighted average of the desired interest rate and past interest rate realizations—the interest rate smoothing hypothesis—or, second, allowing for serial correlation in η_t^{TR}—the persistent monetary policy shock hypothesis. To quantify their relative significance, Rudebusch (2002) formulates a nested model, allowing for both interest rate smoothing ($\rho_{r,k}$) and autocorrelated shocks ($\rho_{\eta,j}$).

We therefore specify a generalized version of this approach, i.e., one that accommodates a flexible number of lags, as follows:

$$r_t = c + \psi_\pi \mathbb{E}_{t-}\{\pi_{t+h_\pi}\} + \psi_{\tilde{y}} \mathbb{E}_{t-}\{\tilde{y}_{t+h_{\tilde{y}}}\} + \psi_{\Delta y} \mathbb{E}_{t-}\{\Delta y_{t+h_{\Delta y}}\} + \psi_{\Delta ltv} \Delta ltv_{t-1}$$
$$+ \sum_{k=1}^{K} \rho_{r,k} r_{t-k} + \eta_t^{TR}, \text{ where } \eta_t^{TR} = \sum_{j=1}^{J} \rho_{\eta,j} \eta_{t-k}^{TR} + \zeta_t. \tag{6}$$

For target variable i, the ψ_i coefficient measures the short-run response of the Fed, i.e., we define $\psi_i \equiv (1 - \sum_{k=1}^{K} \rho_{r,k})\psi_i^*$.

Coibion and Gorodnichenko (2012) provide strong empirical support for the interest rate smoothing motive relative to the serially correlated shocks hypothesis. We thus follow their specification for our benchmark Taylor rule, set $h_\pi = 1, 2$, $h_{\tilde{y}} = 0$, $h_{\Delta y} = 0$, $K = 1$, and $J = 0$, and re-estimate it for our sample period, 1973Q1 to 2008Q4, while also including changes in LTV ratios. The estimated equation is then (see Column (1) in Table 1):

$$r_t = \underset{(0.16)}{-0.72} + \underset{(0.07)}{0.35} \mathbb{E}_{t-}\{\pi_{t+1,t+2}\} + \underset{(0.02)}{0.12} \mathbb{E}_{t-}\{\tilde{y}_t\} + \underset{(0.04)}{0.17} \mathbb{E}_{t-}\{\Delta y_t\}$$
$$+ \underset{(0.11)}{0.26} \Delta ltv_{t-1} + \underset{(0.03)}{0.90} r_{t-1} + \eta_t^{TR}. \tag{7}$$

We find strong support for an interest rate smoothing motive of the Fed, with a first-order autocorrelation coefficient estimate of 0.90. The short-run inflation response coefficient is 0.35 so that the Fed satisfies the Taylor principle by reacting to inflation fluctuations significantly more than one-for-one in the long run, $\psi_\pi^{long} = \psi_\pi/(1 - \rho_{r,1}) > 1$, where $\pi_{t+1,t+2}$ is the average inflation rate over $t + 1$ and $t + 2$. The Fed adjusts policy rates to the expected contemporaneous output gap and GDP growth, with reaction coefficients of $\psi_{\tilde{y}} = 0.12$ and $\psi_{\Delta y} = 0.17$, respectively. All coefficients are highly significant, where the numbers in brackets are Newey-West standard errors. Our estimates align very closely with those in Coibion and Gorodnichenko (2012).

More importantly, we also find a significant positive response coefficient to changes in the LTV ratio, $\psi_{\Delta ltv} = 0.26$, implying an increase in the policy rate after a loosening of lending conditions.[26] This result confirms the message from the previous section that points to a direct reaction of the Fed to housing lending conditions as proxied by LTV ratios beyond any indirect effects operating through contemporaneous output or inflation. This ultimately also suggests that models that analyze the housing market and contain a meaningful monetary policy should explore the quantitative implications of such a modified Taylor rule.

Could our finding be driven by the fact that the Fed simply reacts to conditions in the housing market? Given the well-documented empirical property of housing indicators as leading the business cycle and in light of the view that "Housing (RE-

[26]This result (and really most estimated coefficients in the Taylor rule) remains stable across a number of variations in the econometric model specification. In particular, $\psi_{\Delta ltv}$ stays stable and highly significant, when we, e.g., allow for higher-order autocorrelation terms of the policy instrument and/or autocorrelated shocks, or estimate the equation on different data samples; in particular one with the same start date as Coibion and Gorodnichenko (2012), 1987Q4. Table A.2 in the Appendix shows these results.

ALLY) IS the Business Cycle" (Leamer, 2007, 2015), it is, at the very least, plausible that the Fed would make use of housing market indicators even beyond the Greenbook estimates for inflation, the output gap, and the output growth rate. Two such leading indicators are housing starts, $start_t$, and housing permits, $perm_t$. Their cyclical components—based on an Hodrick-Prescott filter with $\lambda = 1,600$—lead the cyclical real GDP component with a maximum cross-correlation at a horizon of two quarters at 0.71 and 0.73, respectively. Financial housing market indicators like mortgage rate spreads, spr_t^m, also display this property: they lead, countercyclically, the business cycle by one quarter and a cross-correlation of -0.35. Also the LTV ratio leads real GDP by one quarter and a positive cross-correlation of 0.51.[27]

Columns (2) to (4) from Table 1 present regression results for the Taylor rule from Equation (6), where we replace the LTV ratio against the three aforementioned housing market indicators, one at a time. All three indicators are significant, just as the LTV ratio. Estimating Equation (6) with all leading housing market indicators simultaneously in Column (5), only the LTV ratio and the mortgage rate spread stay statistically significant. This evidence supports the notion that US monetary policy reacts to developments in housing markets. Furthermore, among different housing market indicators, the Fed apparently puts an emphasis on *financial* relative to *real* housing variables.[28]

– INSERT TABLE 1 HERE –

2.3.3 Monetary policy and the interest sensitivity of sectoral investment

After having characterized the underlying driver(s) of the Federal Funds rate reaction following an LTV shock, we now, in the following two sections, analyze in more detail what the quantitative effect of this *endogenous* monetary policy tightening is, and ask in particular whether it can explain the seemingly paradoxical negative reaction of residential investment after an easing of lending standards. As a first step, it is, however, informative to inspect the VAR dynamics triggered by an *exogenous* monetary policy surprise (see Figure 5).

– INSERT FIGURE 5 HERE –

An identified contractionary monetary policy shock in the monetary policy VAR features negative hump-shaped responses of y_t, i_t^{nr}, and i_t^r. ltv_t significantly and sluggishly falls after a contractionary monetary policy disturbance suggesting a "risk-taking channel" (on the part of lenders) of monetary policy, that is, after a monetary

[27] We find similar correlations based on quarterly growth rates. We obtain the total housing starts of new privately owned housing units (HOUST) and the new private housing units authorized by building permits (PERMIT), each measured in thousands of units at a seasonally adjusted annual rate, from the FRED database. The mortgage rate spread is the difference between r_t^m and the 10-year treasury yield, r_t^{10}, from Gilchrist and Zakrajsek (2012).

[28] This finding is housing-specific and cannot be generalized for non-housing-related financial market indicators. Table A.3 presents estimates for Taylor rules, where we replace Δltv_{t-1} with changes in several non-housing-related financial market indicators, in particular, corporate bond spreads. We find no significant policy response to any of these indicators (see Section 3.1 for a description of the controls), which is in line with similar findings in Coibion and Gorodnichenko (2012).

contraction, fewer or less risky mortgage loans are granted. π_t reacts positively for four quarters (price puzzle) before turning negative. In terms of persistence, residential investment absorbs the policy shock more quickly than the non-residential counterpart, bottoming six quarters after the occurrence of the monetary policy innovation, whereas the latter reaches its trough in quarter ten. In terms of magnitude, the response of i_t^r is roughly three times as strong as that of i_t^{nr}, i.e., residential investment appears to be significantly more interest sensitive than non-residential investment.[29] This finding is consistent with the strong sensitivity of the housing sector to monetary policy shocks documented in, e.g., Erceg and Levin (2006), Monacelli (2009), and Calza et al. (2013).[30]

A natural question that arises from this finding is: is residential investment indeed more interest rate sensitive, or is the pass-through from the monetary policy interest rate to the relevant longer-term interest rates different? The next two Figures 6 and 7 show that it is the former. We replace the interest rate expectations series in Figure 3 with a measure of corporate bond yields, r_t^{baa}, to proxy for business sector lending rates, and thus analyze the transmission of the LTV shock via the monetary policy instrument into mortgage and non-mortgage interest rates.[31] Ignoring the dashed lines for now, Figure 6 reveals that the different behavior of i_t^{nr} and i_t^r is not driven by differences in interest rate pass-through as corporate bond yields have a very similar impulse response to that of mortgage interest rates in terms of persistence, statistical significance, and magnitude.[32]

– INSERT FIGURE 6 HERE –

Finally, given an almost identical pass-through of the endogenous monetary policy tightening to mortgage and non-mortgage interest rates, Figure 7 closes the argument by tracing out the impact of a 25 basis point innovation to corporate bond yields and mortgage rates on, respectively, non-residential and residential investment in two bi-variate VARs. We maintain the recursive identification scheme, i.e., the interest rate innovations transmit to the investment series with a time lag of one quarter. After four quarters (the trough of the residential investment reaction), the same-sized shock in the relevant interest rate induces an almost order of magnitude larger decline in residential versus non-residential investment (-3.51% versus -0.62%). That is, the interest sensitivity in both sectors of the economy is very different.

– INSERT FIGURE 7 HERE –

[29] The magnitudes also line up: in Figure 2, a roughly 10 basis point *endogenous* monetary policy tightening produces a minus 0.4 percentage points reaction of residential investment, and, in Figure 5, a 25 basis point *exogenous* monetary policy tightening produces a minus 1 percentage point reaction.

[30] Note that these papers document a larger monetary policy sensitivity of durable consumption expenditures, including residential investment, compared to nondurable consumption. We add to this literature the finding that residential investment is also more sensitive to monetary policy than non-residential investment.

[31] We are not aware of any consistent series of bank business loan interest rates and thus resort to corporate bond yields as a proxy. Specifically, we use Moody's BAA corporate bond yields, r_t^{baa}, for bonds with a remaining maturity of roughly 30 years. The results are almost identical for specifications using the AAA corporate bond yield series, r_t^{aaa}.

[32] This result arises also in the case of an exogenous monetary policy shock.

2.3.4 Quantifying the effect of the systematic monetary policy response

To flesh out the quantitative importance of the Federal Funds rate reaction in the transmission of the LTV shock more directly, we follow the methodology in Bernanke et al. (1997) and Sims and Zha (2006), and recently applied in, e.g., Kilian and Lewis (2011) and Bachmann and Sims (2012), to statistically decompose the effects of a given shock into those stemming from the endogenous reaction of another variable in the VAR, say a policy variable, and those holding the latter variable constant. To do so, we generate hypothetical sequences of monetary policy shocks that "zero out" the Federal Funds rate response after the LTV shock.

We can recursively calculate the monetary policy shocks required to force the policy response to zero over the whole forecast horizon as follows:

$$\boldsymbol{\varepsilon}_{F,h} = -\sum_{j=1}^{n} \boldsymbol{B}_{F,j}\boldsymbol{y}_{j,F} - \sum_{m=1}^{\min(p,h)} \sum_{j=1}^{n} \boldsymbol{B}_{F,mn+j}\boldsymbol{z}_{j,h-m}. \tag{8}$$

$\boldsymbol{y}_{j,0}$ is the time $t = 0$ impact of the LTV disturbance on variable j in the six-variable monetary policy VAR, whereas the same impact without the endogenous monetary policy reaction is given by:

$$\boldsymbol{z}_{j,0} = \boldsymbol{y}_{j,0} + \frac{\boldsymbol{\Phi}_{j,F,0}\boldsymbol{\varepsilon}_{F,0}}{\sigma_F}. \tag{9}$$

The standard deviation of the monetary policy disturbance is σ_F. For horizons beyond the impact period, $h > 0$, we calculate:

$$\boldsymbol{y}_{j,h} = \sum_{m=1}^{\min(p,h)} \sum_{i=1}^{n} \boldsymbol{B}_{j,mn+i}\boldsymbol{z}_{j,h-m} + \sum_{i<j}^{n} \boldsymbol{B}_{j,i}\boldsymbol{y}_{i,h} \text{ and } \boldsymbol{z}_{j,h} = \boldsymbol{y}_{j,h} + \frac{\boldsymbol{\Phi}_{j,F,0}\boldsymbol{\varepsilon}_{F,h}}{\sigma_F}. \tag{10}$$

The solid lines in Figure 8 show, for the six-variable monetary policy VAR, the impulse responses of the variables in $\boldsymbol{x}_t$ after an LTV shock together with one standard error confidence intervals (shaded area). The dashed lines represent the impulse response functions when monetary policy does not respond to the dynamics triggered by the LTV shock at any horizon. By construction, the impulse response of r_t is zero over the whole time horizon in the decomposition experiment, and, as a consequence of passive monetary policy, ltv_t features a slightly stronger and more persistent increase compared to the impulse response with the monetary policy reaction. In a statistical sense, however, the two impulse responses of ltv_t are not different. GDP, y_t, and non-residential investment, i_t^{nr}, both increase more strongly and more persistently in the absence of the policy tightening, while the response of the inflation rate, π_t, remains rather flat.[33]

The dynamics of residential investment, i_t^r, however, are most affected when monetary policy does not react: i_t^r still displays the initial surge, but then continues to increases in a hump-shaped manner to almost 0.4 percent after one year. The

[33] The monetary policy shocks necessary to zero out the Federal Funds rate are small and ordinary, below 10 basis points, which mitigates a potential Lucas critique to this exercise.

response then remains strictly positive over the whole forecast horizon, whereas, with the systematic monetary policy reaction, i_t^r turns significantly negative after one year. Statistically, the effect of the LTV shock on residential investment thus crucially depends on the endogenous reaction of monetary policy, both in a quantitative and qualitative sense. Put differently, while the reaction of non-residential investment is almost entirely driven by the lending conditions in terms of quantities, the dynamic response of residential investment following an LTV shock is eventually overwhelmed and ultimately determined by an endogenous price, or interest rate, reaction.[34]

Our results thus suggest that an exogenous loosening of LTV ratios is unlikely to explain a boom in residential investment, at least under conventional monetary policy. From a macroprudential policy perspective more generally, the efficacy of such policy measures appears to be contingent on the reaction function of monetary policy; macroprudential policy measures in the housing market, therefore, should be designed to take into account interactions with monetary policy and perhaps even coordinate with it.

– INSERT FIGURE 8 HERE –

We conclude this section by analyzing the response of real sectoral price inflation to an LTV shock. Specifically, we add the rates of change of the non-residential and residential investment real price deflators, π_t^{nr} and π_t^r, to our monetary policy VAR,[35] and show the results in Figure 9. The real price of non-residential investment is hardly affected in a statistically significant way, though the point estimate is negative. It remains roughly the same without the endogenous monetary policy reaction. This means that the combination of the LTV shock and the monetary policy tightening has little effect on the user costs of non-residential capital over and above the increase in the interest rate.

The picture is different for residential investment real price inflation: here the reaction is negative and remains persistently so, paralleling the decline in the quantity of residential investment. This adds an additional drag on residential investment (an

[34]The exercise in Figure 6 also illustrates that turning off the systematic monetary policy reaction basically shuts down the interest rate pass-through to longer-term rates such as the mortgage rate and corporate bond yields. We also note that the difference between non-residential investment (mostly quantity-driven) and residential investment (mostly price-driven) is unlikely due to differences in the type of investment good, which might mean, for example, differences in depreciation rates and thus intertemporal substitutability. An LTV shock has very similar effects on non-residential equipment investment and non-residential structures investment, which are themselves very similar to the effect on non-residential overall investment shown in Figure 8, as it regards both the actual and the sans monetary policy reaction impulse response. The detailed results are available on request. We therefore surmise that the different interest sensitivity in non-residential versus residential investment must stem from the difference in who is undertaking the investment rather than their physical characteristics. For instance, with customer markets, firms are likely to be much less reactive to fluctuations in the interest rate and will be willing to accommodate increased aggregate demand after looser lending conditions. In contrast, households, can always rent to ride out periods of higher interest rates.

[35]We use the seasonally adjusted BEA implicit price deflator series for non-residential and residential investment from NIPA Table 1.1.9., lines 9 and 13, and divide them with the GDP deflator (NIPA Table 1.1.9., line 1) before transforming both variables into growth rates.

effect that is reversed without the monetary policy reaction) through an increase in the user costs of housing due to an expected prolonged decline in its relative price. Our results, thus, also support some skepticism toward the view that the lowering of lending standards can generate (new) house price booms, again, at least in times of conventional monetary policy.[36]

At the same time, Figure 9 also shows that our results for macroeconomic quantities are robust to controlling for house price inflation, which means that changes of (and shocks to) the LTV ratio and their macroeconomic consequences are unlikely to be merely mechanical effects caused by changes in the denominator of LTV ratios, that is, house values; we discuss this further in Section 3.1.

– INSERT FIGURE 9 HERE –

2.3.5 Variance and historical decompositions

To assess the quantitative relevance of LTV shocks for macroeconomic and housing market fluctuations, we now turn to a forecast error variance decomposition. For the six-variable monetary policy VAR, introduced in Section 2.3.1, the upper panel of Table 2 shows the percentage contribution of LTV shocks to variations in real GDP, non-residential and residential investment, as well as inflation and the Federal Funds rate, at different horizons. While accounting for the majority of fluctuations in the LTV ratio itself, LTV shocks explain only small fractions of the variances of the k-step-ahead forecast errors in the block of macroeconomic variables: between 3.4 and 7.4 percent of the forecast error variance of GDP, between 4.5 and 6.2 percent for non-residential investment, and, most notably, less than 3 percent of the fluctuations in residential investment. This finding casts again doubt on the hypothesis that shifts in LTV ratios represent a substantial autonomous driver of housing markets. By contrast, the evidence in Table 2 confirms our principal finding that monetary policy reacts systematically to movements in LTV ratios, with LTV surprises accounting for up to 8.4 percent of variations in the Federal Funds rate after 2 years.[37] Turning now to the power of monetary policy, the lower panel of Table 2 reveals the comparatively rather substantial contributions of monetary policy shocks toward explaining GDP and in particular residential investment fluctuations, which amount to 30 percent.[38]

– INSERT TABLE 2 HERE –

The on average (over the entire sample) rather muted macroeconomic consequences of LTV shocks indicated by the variance decomposition, however, do not

[36]The result is essentially the same had we used the inflation rate of the Case-Shiller real house price index, which also includes existing and not just newly-built houses. The results are available on request.

[37]This number is economically relevant. For example, it exceeds the share of fluctuations in r_t accounted for by disturbances to the inflation equation error term in the recursive VAR. The latter account for up to 6.7 percent of the forecast error variance in r_t and may be thought of as reduced-form aggregate supply shocks.

[38]These findings are the same for mortgages of first-time buyers, including those with subprime mortgages, as Table A.4 in the Appendix shows. For the details on this data, see Section 3.2.

necessarily mean that LTV shocks also have little relevance in particular historical episodes. We therefore now turn to a historical decomposition for three periods that were characterized by major swings in LTV ratios (see Figure 1).

For the period from 1984 to 1990, Figure 10 plots the evolution of the LTV ratio in the top panel. In 1984 the LTV ratio experienced a historical high, that is, it was the laxest since the start of our data, and then experienced a rapid decline over three years before rebounding somewhat. Each of the remaining four panels displays, respectively, y_t, i_t^{nr}, i_t^r, and r_t as a solid line together with two counterfactual scenarios: the data without the contribution of, respectively, (i) LTV shocks (dashed line), and (ii) monetary policy shocks (solid line with asterisks). Confirming the results of the variance decomposition, the main take-away is: absent LTV shocks, the macroeconomy would have evolved fairly similarly to the historical experience (the dashed lines tend to be close to the solid lines), even in periods of major shifts in LTV ratios.

By contrast, shocks to monetary policy play a larger role, just as in the variance decomposition, especially for residential investment, as the monetary policy counterfactuals in Figure 10 show (solid line with asterisks). The differences between the data and the monetary policy counterfactuals are in general much larger than the differences between the data and the LTV ratio counterfactuals. Also, we can see that the autonomous component of monetary policy was expansionary until the end of 1986 and contractionary afterwards. Residential investment would have been lower from 1984 to 1987, and afterwards higher, without monetary policy shocks.

Nevertheless, the particular historical experience in the second half of the 1980s illustrates the conditional mechanisms at the heart of this paper, especially how monetary policy reacts systematically to credit conditions in the housing market. A high LTV ratio during 1984 and 1985 (suggesting expansionary LTV shocks) contributed positively to non-housing related quantities. In particular, non-residential investment would have been lower absent the positive LTV contribution (the dashed line lies below the solid line in the i_t^{nr}-panel until 1986). By contrast, and consistent with the finding that lending standards are part of the Fed's reaction function, the high LTV ratio induced a tightening of the policy instrument, i.e., the Federal Funds rate in the counterfactual scenario with LTV shocks switched off (dashed line) lies below the historical evolution of the Federal Funds rate (solid line) until the mid of 1986. In addition, the contractionary Federal Funds rate reaction dominated the impact on housing markets, i.e., residential investment would have been higher without the loose LTV ratios during 1984 and 1986. Quantitatively, it is thus not only the case that the contributions of the *autonomous* component of monetary policy to both residential investment activity and the policy instrument are stronger than the contributions of LTV shocks, but also, at least for the housing market, that the *systematic* movements of monetary policy dominate the effects of the LTV ratio movements that triggered them in the first place. The effects are largely inverted from 1986 on. Reflecting the gradual decline in the LTV ratio that reached a trough during 1986 and the subsequent lower levels of LTV, the contribution of LTV shocks to the policy instrument inverts toward the end of 1985, i.e., the Federal Funds rate would then have been tighter in the absence of the low LTV, which in turn influenced positively residential investment activity with a slight transmission lag from the end of 1986 on (the dashed line now lies above the solid line in the i_t^{nr}-panel).

– INSERT FIGURE 10 HERE –

Figure 11 displays the historical decomposition for the period 1991 to 2000, which started out with relatively strict lending standards that were relaxed to then unprecedented heights by 1995. A relatively low level of LTV ratios at the beginning of the sample led, at least when viewed through the lens of our VAR, the Federal Funds rate, r_t, to be lower than it would have been until the end of 1993, which in turn contributed positively to residential investment until 1995. From 1994 to 1996, the increased LTV ratio then apparently exerted a contractionary influence on the Federal Funds rate, which in turn depressed residential investment (with a slight lag) until mid-1997.[39] Perhaps interestingly, the systematic (conditional on LTV shocks) and autonomous components of monetary policy seemed to be reinforcing each other during most of this particular episode, unlike in the mid to late 1980s.

– INSERT FIGURE 11 HERE –

Figure 12 presents the historical decomposition for the episode starting in 2001 and leading to the onset of the Great Recession in 2007. The LTV ratio did not start taking off until the second quarter of 2003, i.e., the initial subsample period was characterized by a low and declining LTV ratio. From 2002 to 2004 this rather restrictive LTV environment translated, again, when viewed through the lens of our VAR, into a looser monetary policy, which by itself lead to a mild, lagged boost for residential investment from mid 2003 until the end of 2005. Starting in late 2004, the loosening of LTV ratios might have eventually induced monetary policy to be a bit tighter relative to an environment without LTV shocks. This monetary policy reaction to LTV shocks, from 2006 on, undid the initially positive extra effect on residential investment. In sum, LTV shocks—propagated through monetary policy—exerted a destabilizing effect in this episode, making the Federal Funds rate "too low" during the buildup of the housing cycle and "too high" when housing markets started declining. However, the popular narrative that too lax credit conditions in the housing market caused the housing boom leading up to the Great Recession is not supported by our historical decomposition. By contrast, this time period saw an autonomous expansionary movement in monetary policy. The Federal Funds rate would have been tighter in the absence of monetary policy surprises until the end of 2006, and these expansionary monetary policy shocks substantially contributed to the surge of residential investment—a contribution that is much larger than the indirect one from LTV shocks.[40]

– INSERT FIGURE 12 HERE –

[39] Recall Figure 4, which shows that the negative response of residential investment to an expansionary LTV shock only manifests itself after approximately one year.

[40] This—and our variance decomposition—is a *relative statement*, and does not necessarily contradict the results in Del Negro and Otrok (2007) and Luciani (2015), who argue that monetary policy only had a small contribution to the housing boom in the early 2000s. Glaeser et al. (2013) are also in line with our results: some small influence of interest rates, no discernible impact of LTV ratios.

2.4 Household and Firm Debt

We next analyze the implications of looser collateral requirements on mortgage loans for the leverage of households and businesses. We do this against the backdrop of the most recent US housing cycle of the years 2002 to 2006, where borrowing of households and businesses increased substantially. In real terms, household debt rose by more than 70 percent and bank-provided loans to non-financial businesses by 50 percent during this period. The unprecedented surge of private debt led to a number of theoretical contributions studying the interaction between leverage and the broader economy (see, e.g., Eggertsson and Krugman, 2012; Justiniano et al., 2015, 2017; Midrigan and Philippon, 2016). By using data on LTV ratios, the approach taken here adds a time series perspective on the role of changes in collateral requirements as a potential driver of leverage cycles to this literature, taking into explicit account the role of monetary policy.

We follow Monacelli (2009) and use the natural logarithm (multiplied by 100) of real household debt, b_t^h, which consists of home mortgage loans and consumer credit provided by banks. For businesses, we focus on bank-provided loans to non-financial businesses, b_t^b. We estimate a VAR including the following variables in this order $\boldsymbol{x}_t = [i_t^{nr}\ i_t^r\ \Delta ltv_t\ b_t^b\ b_t^h\ r_t]'$. According to the maintained Cholesky identification strategy, LTV shocks move the newly introduced debt measures contemporaneously, and we allow monetary policy to respond to all financial variables on impact (see Gilchrist and Zakrajsek, 2012).

Figure 13 plots the impulse responses of the debt-augmented model (solid line with confidence bands), including the impulse responses sans monetary policy reaction (dashed line). The impulse responses of i_t^{nr}, i_t^r, ltv_t, and r_t are hardly affected by the introduction of business loans and household debt, compared to the baseline four-variable VAR (or the six-variable monetary policy VAR). Bank loans to the non-financial business sector display a pronounced increase, which is significant over the whole forecast horizon, i.e., businesses quickly and persistently take advantage of the loosened availability of loans. When the Fed remains passive after the LTV shock (dashed line), no stark differences emerge for the evolution of business loans. Thus the *price* of loans—indirectly influenced by the systematic monetary policy tightening—appears to be of second order for businesses' propensity to borrow from banks, whereas the relaxation of the *quantity* restriction on loans, i.e., the LTV ratio, when interpreted as a broader indicator of aggregate lending standards, emerges as the dominating factor.

By contrast, the impulse response function of household debt is slightly negative in the impact quarter and otherwise barely reacts to the shock. Without the monetary policy tightening, however, the debt position of the household sector is crucially altered. Household debt is now slowly building up after an initial dip, and, from the second year on, is statistically different from the impulse response with the monetary policy tightening.

Restricting the analysis only to *mortgage* loans of households, b_t^{hm}, and businesses, b_t^{bm}, as illustrated in Figure 14, reveals similar results, i.e., following a loosening of borrowing constraints, businesses increase mortgage loans independently of the monetary policy response, whereas households reduce their mortgages with monetary policy tightening, and increase their mortgage leverage without it. The strong interest rate sensitivity of household debt is consistent with the dependence of the impulse responses for residential investment on monetary policy, which display the same qualitative behavior as household debt and mortgage dynamics.

Lastly, while our VAR is a linear model and we exclude the Great Recession quarters from our analysis, and while we find no significant role for changes in the LTV ratio as a driver of residential investment and household debt—including the housing cycle from 2002 to 2006—, our results support the view that a tightening of LTV ratios may have exacerbated the downturn in housing markets during the Great Recession. The reason is that the zero lower bound on nominal interest rates represents an asymmetry. Historically, the Fed would have likely lowered interest rates in the face of the LTV tightening; however, with interest rates bounded at zero, this cushioning mechanism was absent. According to our fixed interest rate results, such a situation should then be associated with a drop in residential investment and with deleveraging, which was indeed observed during the financial crisis.

– INSERT FIGURES 13 AND 14 HERE –

3 A closer look at LTV ratios

In this section, we check whether our results hold for different LTV ratio series. Three concerns with our benchmark LTV series might arise: first, have we really isolated exogenous changes in borrowing constraints / lending standards in our VAR? Second, have we used the "right" LTV ratio series when it does not contain, for example, the now notorious subprime mortgages? What, more generally, about cyclical composition effects in the aggregate LTV ratio series? The following three subsections address each of these concerns in turn: in Section 3.1, we attempt to purify the LTV ratio series from many macroeconomic, expectational and financial market influences before using it in the VAR. Section 3.2 analyzes the effects of an LTV shock restricted to the group of first-time home buyers, but now including mortgages to lower-quality borrowers. In Section 3.3, we check whether the result for the aggregate FHFA mortgage rate series also holds for more disaggregate series, that is, mortgages for newly built homes, previously built homes, fixed-rate mortgages and adjustable-rate mortgages.

3.1 The LTV ratio: an aggregate lending standards indicator?

Thus far, we have interpreted Cholesky-identified shifts in the LTV ratio as an indicator of exogenous changes in aggregate lending standards. And to a certain extent the VAR is meant to condition on macroeconomic variables that might drive the LTV ratio because of, for example, loan demand changes. But other confounding effects might exist: general financial conditions, such as the ability of banks to lend or a changing risk aversion in financial markets, expectations about macroeconomic and financial conditions, etc. Motivated by similar concerns, Bassett et al. (2014) propose a procedure to purge their lending standard measure—banks' lending standards from the Fed's Senior Loan Officer Opinion Survey (SLOOS)—from influences that, on the one hand, drive lending standards, but on the other hand, might also reflect changes in loan demand or lending ability. We apply their methodology to the raw LTV series and remove the effects of variables capturing (a) the current state of the economy, (b) the economic outlook, (c) a number of financial sector condition variables, and (d) house price developments. We then re-run our six-variable VAR from Section 2.3 with the so adjusted LTV measure.

Specifically, to control for changes in LTV ratios that are reflective of the *current state of the economy*, we follow Bassett et al. (2014) and account for the quarterly percentage change of real GDP, Δy_t, the quarterly change in the unemployment rate, Δu_t, and the quarterly change in the real Federal Funds rate, Δrr_t.

Next, we turn to variables capturing the *outlook about the future evolution of the economy*. We purge the LTV series from the one-year ahead expectations on the growth rate of real GDP, $\mathbb{E}_{t-1}\{y_{t+4} - y_t\}$, and the expected change in the unemployment rate, $\mathbb{E}_{t-1}\{u_{t+4} - u_t\}$. Both expectation measures are available from the Survey of Professional Forecasters. Furthermore, we include the change in the term spread, Δspr_t^t, which we measure as the spread between three-month and ten-year Treasury yields, that is the slope of the yield curve. This spread controls for financial market expectations about the future evolution of policy rates. In addition, we account for changes in households' interest rate expectations by including their qualitative interest rate change expectations from the Michigan Survey of Consumers, i.e., r_t^e. Controlling for interest rate expectations, guards us against the following reverse causality story: households expect the Fed to tighten and take out more loans while they are cheap, thus perhaps mechanically increasing the LTV ratio on mortgages.

We also control for the following indicators reflecting *financial sector conditions*. First, we include the change in the credit spread index, Δspr_t^c, developed by Gilchrist and Zakrajsek (2012), which represents a corporate bond spread calculated on the basis of secondary market (individual) bond prices. The index serves as an indicator of tensions in financial markets as well as perceived default risks. Second, we use changes in the excess bond premium, Δebp_t, also proposed in Gilchrist and Zakrajsek (2012), to address potential movements in financial sector risk aversion, and, third, we include the percentage change in private depository institutions' net worth, Δnw_t, to account for the influence of banks' capital position on lending policies, capturing an ability-to-lend component on the part of the banks. Fourth and finally, we add changes in the S&P Composite Stock Price Index, $\Delta stocks_t$, and the Index of Consumer Sentiment, $\Delta sent_t$, as surveyed by the Michigan Survey of Consumers, to the regression to take into account movements in financial market sentiment.

Finally, we deal with the following more mechanical concern: suppose agents have a certain amount set aside as down payment for their home purchase and they are not credit constrained; in this case, LTV ratios would mechanically positively comove with house prices, and shocks to the aggregate LTV ratio could simply reflect movements in house prices. To exclude such spurious shocks to the LTV ratio, we also purge for contemporaneous house price inflation, $\breve{\pi}_t^r$, and its first lag, $\breve{\pi}_{t-1}^r$.[41]

[41] In Equation (12), we use the BEA implicit price deflator for residential investment, but all the results in this section are robust to using the Case-Shiller house price index or the house value

In an intermediate step, we run a regression of Δltv_t only on the first set of variables controlling for the current state of the economy. Here and in the second, richer specification, we perform the estimation by ordinary least squares and report Newey-West standard errors in parentheses. The results of the intermediate-step regression are given by:

$$\Delta ltv_t = \underset{(0.08)}{-0.02} + \underset{(0.07)}{0.03}\Delta y_t - \underset{(0.29)}{0.51}\Delta u_t - \underset{(0.04)}{0.05}\Delta rr_t + \tilde{\varepsilon}_t^{ltv}, \tag{11}$$

where the residuals, $\tilde{\varepsilon}_t^{ltv}$, denote the LTV series purged from macro variables. Only changes in the unemployment rate have a significant (negative) impact on LTV ratios. With an adjusted R^2 of 0.024 the overall explanatory power of the regressors is, however, weak.

Next, we additionally purge Δltv_t from variables proxying for the economic outlook, for financial market conditions, and aggregate house price developments.[42] The resulting regression equation is given by:

$$\begin{aligned}\Delta ltv_t = &\underset{(0.46)}{-0.80} - \underset{(8.08)}{0.46}\mathbb{E}_{t-1}\{y_{t+4} - y_t\} - \underset{(0.23)}{0.49}\mathbb{E}_{t-1}\{u_{t+4} - u_t\} - \underset{(0.04)}{0.09}\Delta y_t \\ &- \underset{(0.33)}{0.16}\Delta u_t + \underset{(0.09)}{0.02}\Delta rr_t - \underset{(0.22)}{0.15}\Delta spr_t^t + \underset{(0.002)}{0.007}r_t^e - \underset{(1.08)}{0.17}\Delta ebp_t \\ &+ \underset{(0.0005)}{0.0005}\Delta nw_t - \underset{(0.72)}{0.37}\Delta spr_t^c - \underset{(0.001)}{0.002}\Delta stocks_t + \underset{(0.01)}{0.02}\Delta sent_t \\ &- \underset{(0.09)}{0.03}\breve{\pi}_t^r - \underset{(0.09)}{0.03}\breve{\pi}_{t-1}^r + \varepsilon_t^{ltv},\end{aligned} \tag{12}$$

with the residuals of this regression, ε_t^{ltv}, representing the more extensively purged LTV series. Only the expected unemployment rate, GDP growth (which was not significant in Equation (11)), and households' qualitative interest change expectations are significant at conventional levels, and the adjusted R^2 increases only slightly to 0.107. Overall, both regressions support the notion that the raw LTV series is a fairly clean measure of movements in aggregate lending standards. This support can also be seen in Figure 15, which plots the more extensively purged LTV ratio, ε_t^{ltv}, over time, and compares it to the change in the raw LTV series. Both are

data from the MIRS. They are also robust to not using the first lag of house price inflation in the purging regression. They are, finally, robust to not using house price inflation at all; after all, it could be argued that purging LTV ratios from house prices is "too much." Also, notice that both coefficients on $\breve{\pi}_t^r$ and $\breve{\pi}_{t-1}^r$, albeit insignificantly so, have negative signs, which means there is no prima facie evidence for the above-described mechanical effect. This is also confirmed by the raw correlations between Δltv_t and the three house price inflation measures, which are all statistically insignificant, and, if anything, come with a negative sign contemporaneously as well as at the first lag and first lead.

[42]We use the following data sources: from the FRED database, we obtain u_t (identifier: UNRATE) and from the Flow of Funds database, we obtain nw_t (identifier: Z1/Z1/FL702090095.Q). For spr_t^c, ebp_t, rr_t, and spr_t^t, we draw on the data set of Gilchrist and Zakrajsek (2012), which is provided on `https://www.aeaweb.org/articles.php?doi=10.1257/aer.102.4.1692`, while the historical Survey of Professional Forecasters data can be downloaded from `https://www.philadelphiafed.org/research-and-data/real-time-center/`. The S&P Index, $stocks_t$, is from Robert Shiller's homepage `http://www.econ.yale.edu/ shiller/data.htm`. To compute house price inflation, we use the seasonally adjusted BEA implicit price deflator series for residential investment from NIPA Table 1.1.9., line 13.

highly correlated at 0.9, which means that the latter is unlikely to be driven by other macroeconomic or financial conditions, or anticipation effects.

Next, we use both adjusted LTV ratios, i.e., ε_t^{ltv} and $\tilde{\varepsilon}_t^{ltv}$, to re-run the six-variable VAR from Section 2.3 and study the transmission of the LTV shock for these new LTV series. Figure 16 traces out the corresponding impulse response functions. Our core results are hardly affected. As before, the LTV shock exhibits fairly persistent effects on the LTV ratio itself and raises non-residential investment in a hump-shaped manner. Residential investment displays a small initial surge before falling significantly, and monetary policy responds to the shock with an interest rate hike of more than 10 basis points. Without the monetary policy reaction we see a somewhat stronger reaction of non-residential investment, but qualitative changes in the dynamics of residential investment. The latter rises now sluggishly in a way similar to its non-residential counterpart. In summary, the main findings of this paper are not affected by a purging exercise in the spirit of Bassett et al. (2014). We therefore conclude that shifts in the raw LTV ratio series are a good measure of exogenous changes in aggregate lending standards / borrowing constraints.

– INSERT FIGURES 15 AND 16 HERE –

3.2 LTV shocks and first-time home owners

In this section, we study the macroeconomic effects of an LTV shock for an alternative, more focussed type of borrowers. Duca et al. (2011, 2013), using confidential data from the American Housing Survey (AHS), emphasize the role of *first-time home owners* for mortgage markets, because a large share of this group of home buyers should be subject to borrowing constraints, which gives us an alternative way of extracting "more purified" shocks to aggregate lending conditions.[43] Replacing our benchmark LTV ratio from the FHFA with their first-time buyer LTV ratio series, ltv_t^{first}, in the VAR also allows us to identify, whether and to what extent potentially different trends in LTV ratios of first-time owners and former owner occupiers—both included in the FHFA survey—affect our results. For example, the FHFA LTV ratio may underestimate the increase of first-time owner LTV ratios at the beginning of the 2000s as the survey does not include so-called Alt A nor subprime mortgages, whereas the AHS contains such mortgage loans.

In the spirit of Bassett et al. (2014), Duca et al. (2011, 2013) also adjust their raw first-time buyer LTV ratio series for certain cyclical factors, such as, e.g., the unemployment rate, seasonal factors, and some exceptional events. Figure 17 plots the adjusted median LTV ratio for first-time home buyers provided to us by Duca et al. (2011, 2013).[44] The sample starts in 1978Q4, because the AHS data is available

[43]Nevertheless, the fact, described in the previous section, that the more comprehensive LTV ratio series does not seem to significantly positively comove with house prices reassures us that it too reflects largely aggregate lending conditions.

[44]We kindly thank Duca et al. (2011, 2013) for providing us with their data. As our FHFA LTV series, their first-time home buyer series does not include mortgages that are insured by the Federal Housing Administration or guaranteed by the Department of Veterans Affairs. Duca et al. (2011, 2013) add back in the Hodrick-Prescott trend which they had removed from their data time series before the purging procedure, which is why this data can be interpreted as a fraction and is directly comparable to the LTV ratio series for all home owners displayed in Figure 1.

only from then on. The first-time home buyer LTV series is noisier than the overall LTV ratio series because the number of first-time buyers in any AHS quarter is small. The series exhibits a range of variation of about 20 percentage points, which is about twice as large as for the benchmark FHFA LTV ratio. Furthermore, the average value over time of first-time home buyer LTV ratios in the sample amounts to 90 percent, whereas the counterpart for all home buyers is only slightly above 75 percent. The series fluctuates around a mean of about 85 percent in the 1980s. Then first-time home buyer LTV ratios steadily increase before declining again at the onset of the Great Recession.

– INSERT FIGURE 17 HERE –

In Figure 18, we show the effects of innovations to the first-time home buyer LTV ratio in our six-variable monetary policy VAR. All the effects are less pronounced both in terms of magnitude and statistical significance, presumably reflecting the smaller number of first-time home buyers in the data.[45] Yet, the qualitative behavior of the impulse response functions is consistent with the VAR that uses the benchmark LTV ratio, despite the aforementioned fact that, unconditionally, the LTV ratio for first-time home owners exhibits a noticeably different time series behavior than the one for all home owners. Again, a surprise loosening of the LTV ratio triggers a fairly persistent movement in the LTV ratio. Non-residential investment increases, residential investment declines. The Federal Funds rate increases. Given the somewhat weaker tightening of monetary policy, the differences between the original impulse response functions and those without the endogenous monetary policy reaction are somewhat less pronounced. However, the passive monetary policy experiment still predicts more expansionary effects for non-residential investment and an increase of residential investment following the LTV shock.

– INSERT FIGURE 18 HERE –

3.3 LTV ratio heterogeneity: more evidence

Our overall LTV ratio series could exhibit time series fluctuations that are merely driven by cyclical changes in the composition of the type of mortgages entering the series. We already addressed one particular incarnation of such a potential composition-bias concern in the previous subsection about first-time buyer LTV ratios, using an alternative data source built on the AHS. But the FHFA-MIRS also provides separate LTV ratio series for the following subgroups of mortgage contracts that allows us to address further potential composition effects: *newly built homes* versus *previously occupied homes*, and *fixed-rate mortgage loans* versus *mortgages with adjustable-rates.* Calza et al. (2013) emphasize the relevance of this latter distinction, in particular, for the transmission of monetary policy into housing markets. For a sample of industrialized countries, they find a stronger responsiveness

[45] Also, the quantitative importance—as measured by the forecast error variance decomposition in Table A.4—of shocks to the first-time buyer LTV ratio series is for most variables smaller compared to the FHFA LTV ratio, contradicting the notion that the borrowing conditions for borrowing-constrained home buyers drive aggregate dynamics.

of residential investment activity to monetary policy surprises in countries with variable-rate mortgage designs.

In Figure 19, we re-estimate the six-variable monetary policy VAR, i.e., $\boldsymbol{x}_t = [y_t \; i_t^{nr} \; i_t^r \; \pi_t \; \Delta ltv_t^j \; r_t]'$, where ltv_t^j denotes one of the four aforementioned subgroup LTV ratio series. We only plot the point estimate impulse responses for the four different LTV ratios and compare them with the confidence interval for the LTV shock to the overall LTV ratio, ltv_t. The impulse response patterns are very similar to those for the overall LTV ratio, with point estimates almost never going outside the shaded confidence interval. The only exception are the impulse response functions for variable-rate mortgage LTV ratios (dotted line). In this case, the increase of LTV ratios is somewhat weaker and so are the surges in GDP and non-residential investment. However, and in line with Calza et al. (2013), the impact of the LTV shock—propagated through monetary policy—on the housing sector appears to be stronger, with the decline in residential investment even exceeding the confidence band of the declining overall LTV ratio.[46]

– INSERT FIGURE 19 HERE –

4 Robustness

In this section, we scrutinize our main findings further. Section 4.1 presents the results when we use the Kilian and Lewis (2011) procedure (in lieu of the one by Bernanke et al. (1997) and Sims and Zha (2006)) to quantify the importance of the endogenous monetary policy reaction. Section 4.2 presents robustness checks on the VAR specification and identification.

4.1 Quantifying the endogenous monetary policy reaction: an alternative procedure

Kilian and Lewis (2011), in an application to oil price shocks, propose an alternative procedure to quantify the effects of an endogenous monetary policy response, compared to the framework in Bernanke et al. (1997) and Sims and Zha (2006) that we have used in Section 2.3.4. Recall that there the counteracting monetary policy surprises completely offset the endogenous interest rate response. This decomposition assumed that the Fed does not react to the impact of the LTV loosening *at all*, i.e., the Federal Funds rate remained constant at any horizon. Following the approach pioneered by Kilian and Lewis (2011), we now study the case when we only zero out the *direct* impact of the LTV shock with counteracting monetary policy shocks, but allow the Fed to respond to the *indirect* effects of the LTV shock operating through its propagation to other variables in the VAR system.

Using the definitions of $\boldsymbol{z}_{j,h}$ and $\boldsymbol{y}_{j,h}$ from Equation (10), we can recursively calculate the sequence of monetary policy shocks required to remove the direct influence

[46]Tables A.2 to A.5 in the Appendix show that the results sans monetary policy reaction are also essentially the same as for the overall LTV ratio.

of the LTV shock from the Fed's reaction as follows:

$$\boldsymbol{\varepsilon}_{F,h} = -\boldsymbol{B}_{F,L}\boldsymbol{y}_{L,h} - \sum_{m=1}^{\min(p,h)} \boldsymbol{B}_{F,mn+L}\boldsymbol{z}_{L,h-m}, \tag{13}$$

where the subscript L represents the position of the LTV ratio in the structural VAR.

Figure 20 traces out the impulse responses in the six-variable monetary policy VAR used in Section 2.3 as originally estimated (solid lines), the Kilian and Lewis (2011) decomposition (dashed lines), and the decomposition with a constant Federal Funds rate (lines with nodes). The experiment of removing only the direct effect of the LTV shock from the Fed's reaction (dashed lines) still predicts a surge in the policy instrument. Yet, the response is more sluggish and less pronounced compared to the actual reaction. The direct reaction to the LTV shock accounts for roughly one third of the observed policy tightening after an expansionary LTV shock. Due to the still contractionary, albeit less so, interest rate environment in this experiment, the role of the systematic reaction of monetary policy is less pronounced compared to the Bernanke et al. (1997) and Sims and Zha (2006) procedure. In fact, almost all responses in the Kilian and Lewis (2011) case lie in between the actual impulse responses and the case of no interest rate reaction. Regarding the impact on residential investment, we find an increasing impulse response in the Kilian and Lewis (2011) case for one and a half years, which subsequently abates more like the actual impulse response. The initial surge in residential investment peaks at almost 0.3 percent, however, which is not too far away from the close to 0.4 percent peak in the Bernanke et al. (1997) and Sims and Zha (2006) case.

– INSERT FIGURE 20 HERE –

4.2 Sensitivity Analyses

Finally, we assess whether our main findings remain valid in a battery of additional robustness checks concerning (i) the VAR specification, (ii) the data sample, and (iii) the ordering of the variables.

First, we re-run the six-variable monetary policy VAR by allowing for higher lag orders of $p = 3, 4$, and 6 quarters. We also estimate the VAR with LTV entering in levels, and with all variables—except for the Federal Funds rate—entering in differences. Finally, we estimate the VAR after dividing y_t, i_t^{nr}, and i_t^{r} by the civilian non-institutional population (FRED identifier: CNP16OV).[47]

Second, we check the robustness of our results with respect to the sample choice. Motivated by relatively low US inflation rates and modest output fluctuations since the 1980s, Clarida et al. (2000), among others, document a significant shift in the conduct of monetary policy for post 1979 data. Beginning with the appointment of

[47]In addition, we estimate the debt VARs from Section 2.4 with population-normalized data. The results from this exercise are almost identical compared to the non-normalized versions and available from the authors upon request.

Paul Volcker as the Fed's chairman, their estimated monetary policy reaction function changes considerably toward a more proactive attitude of controlling the inflation rate (expectations). Following Clarida et al. (2000), we therefore re-estimate the VAR by excluding the pre-Volcker era and starting the sample in 1979Q3 (see also Lubik and Schorfheide, 2004; Boivin and Giannoni, 2006, who use the same break date).[48] In addition, aggregate lending standards eased considerably in the buildup phase to the most recent US housing cycle, which suggests large lending shocks during this episode (see Figures 1 and 15). To study whether our results are driven by this perhaps extraordinary period, we exclude it from the sample and re-estimate the VAR in yet another specification with data ending in 1999Q4.

Third, we analyze the sensitivity of our results to the ordering of the variables in the recursive identification scheme. Thus far, we have assumed that LTV shocks affect monetary policy on impact, yet, exogenous shifts in monetary policy propagate to lending standards with a time lag of one quarter. We have implemented this notion by ordering Δltv_t before r_t within the block of financial variables. Now, we assume that LTV shocks propagate to all other variables with a delay of one quarter, but monetary policy surprises are allowed to influence lending standards in the impact quarter.

In Figures 21 and 22 we summarize the results of these robustness exercises for the monetary policy VAR, i.e., $\boldsymbol{x}_t = [y_t \; i_t^{nr} \; i_t^{r} \; \pi_t \; \Delta ltv_t \; r_t]'$, where we display the baseline subset of variables in columns and the different specifications in rows.[49] While the magnitudes differ somewhat across specifications, the qualitative patterns of the actual impulse responses and those sans endogenous monetary policy reaction are unaffected by these sensitivity analyses.

– INSERT FIGURES 21 AND 22 HERE –

5 Conclusion

This paper studies the macroeconomic consequences of shifts in housing-related aggregate lending standards as measured by residential mortgage LTV ratios. Using LTV data from the Federal Housing Finance Agency, we find that exogenous expansionary LTV shocks feature positive spillovers to non-residential sectors, giving residential LTV ratios the interpretation of a general indicator of aggregate lending standards / borrowing constraints. Perhaps surprisingly, however, we also find that surprise shifts in the LTV ratio are not likely to be a substantial driver of residential investment, real house price inflation and household debt in the conventionally assumed way. The reason behind this result is a systematic monetary policy response, which tightens as a reaction to a looser LTV ratio. We confirm this result by estimating Taylor rules that include changes in the LTV ratio. As a result, residential investment, real house price inflation and household debt decline (or at least

[48]The sample start in 1979Q3, moreover, is known to reduce the price puzzle in monetary policy VARs (Hanson, 2004; Castelnuovo and Surico, 2010).

[49]The dynamics for the complete set of variables are fully in line with the evidence in Section 2.3. We omit the impulses for y_t and π_t to save space. Results are available from the authors.

do not increase) after an increase in the LTV ratio. A variance decomposition and a number of historical decompositions corroborate the conclusions drawn from the impulse response analysis. In particular, we find that too loose credit standards prior to the Great Recession are unlikely to be the cause of the observed residential investment boom, contradicting certain popular narratives about this boom. Lax monetary policy seems to have had a comparatively larger influence on the housing market overdrive during that time and more generally.

Furthermore, how can we interpret the events during the Great Recession through the lens of our results? While our VAR is a linear model and we exclude deliberately the Great Recession quarters from our analysis, and while we find no significant role for surprise changes in the LTV ratio as a driver of residential investment,—including the housing cycle from 2002 to 2006—our results are in line with the perception that a tightening of LTV ratios may have exacerbated the downturn in housing markets during the Great Recession. The reason is the asymmetry represented by the zero lower bound on nominal interest rates. Historically, the Fed would have likely lowered interest rates in the face of the LTV tightening; however, with interest rates bounded at zero, this cushioning mechanism was absent. According to our fixed interest rate results, such a situation would then be associated with a drop in residential investment and a household sector deleveraging, which was indeed observed during the financial crisis.

Finally, with respect to the macroprudential debate on LTV ratios, our results raise important questions: can exogenous changes in regulatory limits on LTV ratios, the way a regulator would generate them, be identified by exogenous shocks to actual LTV ratios in VARs? Is the historically observed tightening monetary policy reaction by the Fed, counteracting an LTV ratio expansion, an optimal reaction to looser lending standards in the economy, and would the Fed do the same, if the latter was brought about by a macroprudential regulator? Should macroprudential policy measures be designed in a way that coordinates with monetary policy? As for our results with a fixed interest rate monetary policy: do they mean that macroprudential policy measures are particularly effective and thus a tool of choice in times of zero lower bound episodes, or for regions that are part of a monetary union, such as member states of the European Monetary Union or US states, if coordination with monetary policy cannot be achieved?

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Tables

Table 1: Taylor rules incorporating housing market indicators

	(1)	(2)	(3)	(4)	(5)
$\psi_{\pi} : \mathbb{E}_{t-}\{\pi_{t+1,t+2}\}$	0.35^{***} (0.07)	0.33^{***} (0.07)	0.36^{***} (0.07)	0.36^{***} (0.07)	0.35^{***} (0.06)
$\psi_{\tilde{y}} : \mathbb{E}_{t-}\{\tilde{y}_t\}$	0.12^{***} (0.02)	0.11^{***} (0.02)	0.14^{***} (0.02)	0.14^{***} (0.02)	0.13^{***} (0.02)
$\psi_{\Delta y} : \mathbb{E}_{t-}\{\Delta y_t\}$	0.17^{***} (0.04)	0.15^{***} (0.03)	0.14^{***} (0.03)	0.13^{***} (0.03)	0.10^{***} (0.03)
$\rho_{r,1} : r_{t-1}$	0.90^{***} (0.03)	0.90^{***} (0.03)	0.91^{***} (0.03)	0.91^{***} (0.03)	0.91^{***} (0.03)
$\psi_{\Delta ltv} : \Delta ltv_{t-1}$	0.26^{**} (0.11)				0.13^{**} (0.07)
$\psi^m_{\Delta spr} : \Delta spr^m_{t-1}$		-0.57^{**} (0.25)			-0.42^{**} (0.21)
$\psi_{\Delta start} : \Delta start_{t-1}$			0.03^{**} (0.02)		0.01 (0.01)
$\psi_{\Delta perm} : \Delta perm_{t-1}$				0.04^{**} (0.02)	0.02 (0.02)
$\tilde{R}^2$	0.95	0.95	0.95	0.95	0.95
$s.e.e.$	0.81	0.79	0.80	0.79	0.76

Notes: The table shows ordinary least squares estimates for the interest rate rule from Equation (6). ψ_{π} denotes the central bank reaction to inflation expectations, $\psi_{\tilde{y}}$ is the response to the expected output gap, and $\psi_{\Delta y}$ is the coefficient for expected output growth. $\rho_{r,1}$ measures the degree of AR(1) interest rate smoothing. We perform all estimations using data from 1973Q1 to 2008Q4 and present Newey-West standard errors in parentheses. In columns (2) to (4), we replace Δltv_{t-1} with reaction coefficient $\psi_{\Delta ltv}$ with changes in mortgage interest rate spreads, Δspr^m_{t-1}, the growth rate of new housing starts, $\Delta start_{t-1}$, and the growth rate of new housing permits, $\Delta perm_{t-1}$, where the reaction coefficients are $\psi^m_{\Delta spr}$, $\psi_{\Delta start}$, and $\psi_{\Delta perm}$, respectively. Column (5) includes all housing market indicators at the same time. $\tilde{R}^2$ denotes the adjusted R^2 and $s.e.e.$ stands for the standard error of the corresponding equation.

*** Significant at the 1 percent level.
** Significant at the 5 percent level.
* Significant at the 10 percent level.

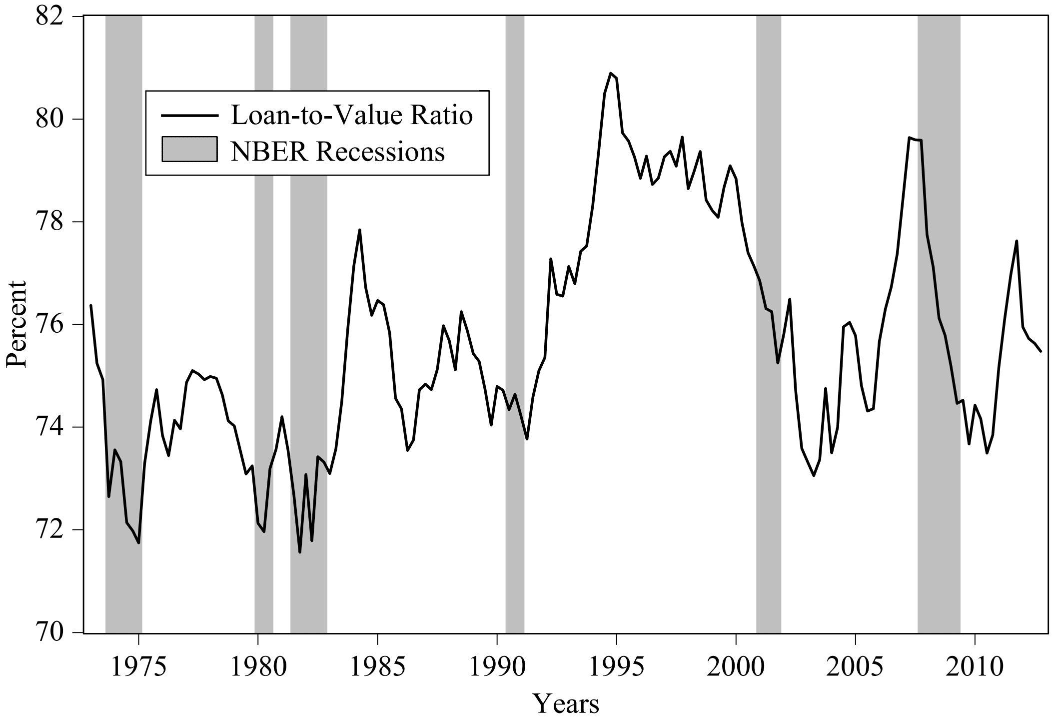
Table 2: Variance decompositions: FHFA LTV ratio

LTV Shocks	y_t	i_t^{nr}	i_t^r	π_t	Δltv_t	r_t
Impact	0.0	0.0	0.0	0.0	98.4	0.1
1 Year	7.4	4.5	0.4	0.3	87.6	7.1
2 Years	5.5	6.2	1.3	0.5	85.8	8.4
4 Years	3.4	4.6	2.9	1.5	83.9	7.3
FFR Shocks	y_t	i_t^{nr}	i_t^r	π_t	Δltv_t	r_t
Impact	0.0	0.0	0.0	0.0	0.0	89.7
1 Year	6.1	0.4	18.3	4.8	5.0	46.7
2 Years	15.4	3.5	30.1	5.0	5.0	31.0
4 Years	19.1	9.4	28.9	9.8	5.6	24.0

Notes: The table displays the fraction of the forecast error variance (in percent) for the variables in $\boldsymbol{x}_t = [y_t\ i_t^{nr}\ i_t^r\ \pi_t\ \Delta ltv_t\ r_t]'$, that is, the six-variable monetary policy VAR, that is explained by LTV shocks (upper panel) / Federal Funds rate shocks (lower panel) at different horizons.

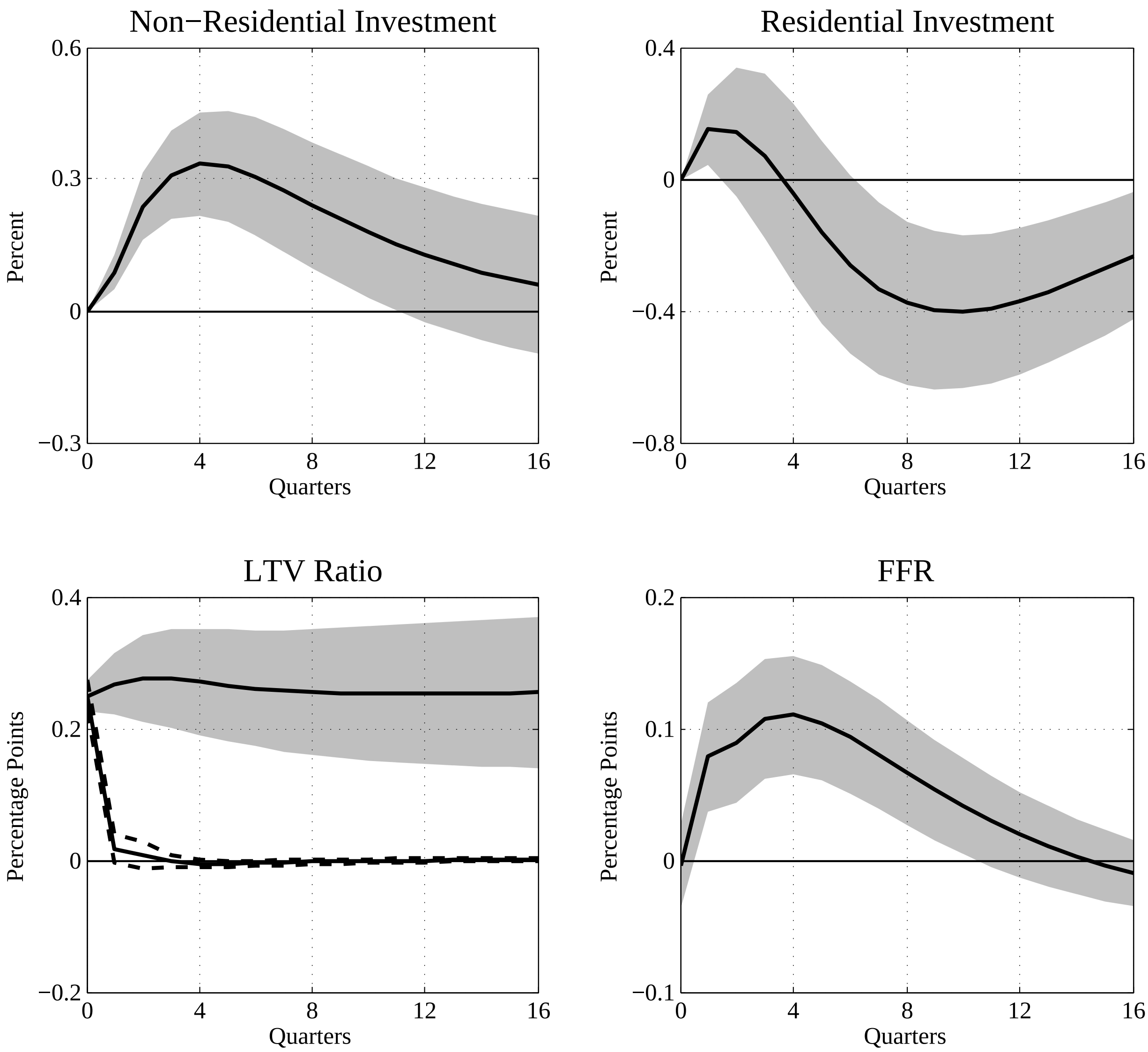
Figures

Figure 1: Loan-to-value ratio of residential mortgage loans



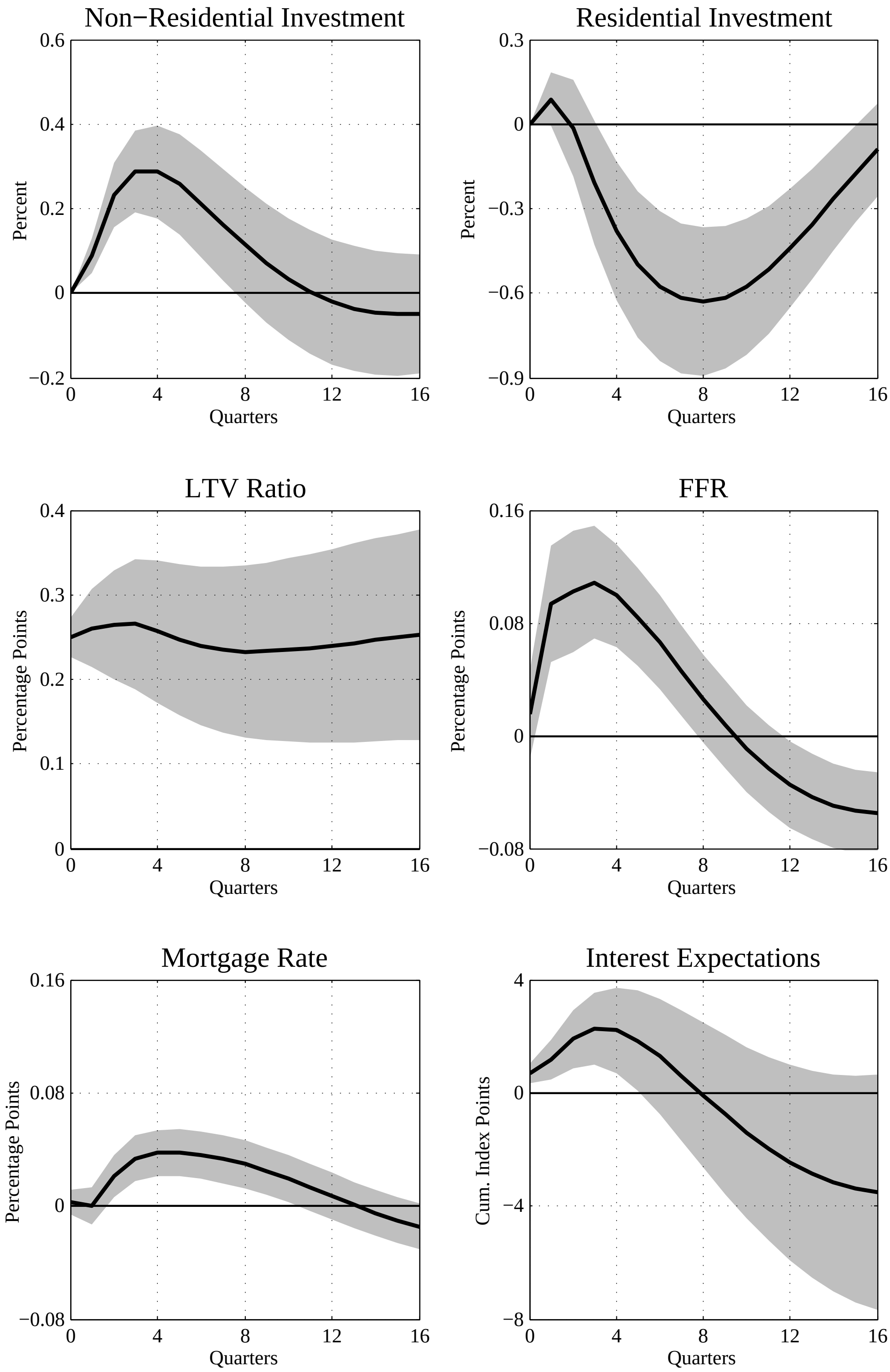
Notes: The figure displays the seasonally adjusted average loan-to-value ratio on conventional single family mortgage loans, which we obtain from the Federal Housing Finance Agency. Data are at the quarterly frequency, and we express them in percent, i.e., as a ratio of the granted mortgage loan and the underlying house price multiplied by 100. The shaded areas represent NBER-dated recession episodes in the US.

Figure 2: Loan-to-value ratio shock in the benchmark 4-variable VAR



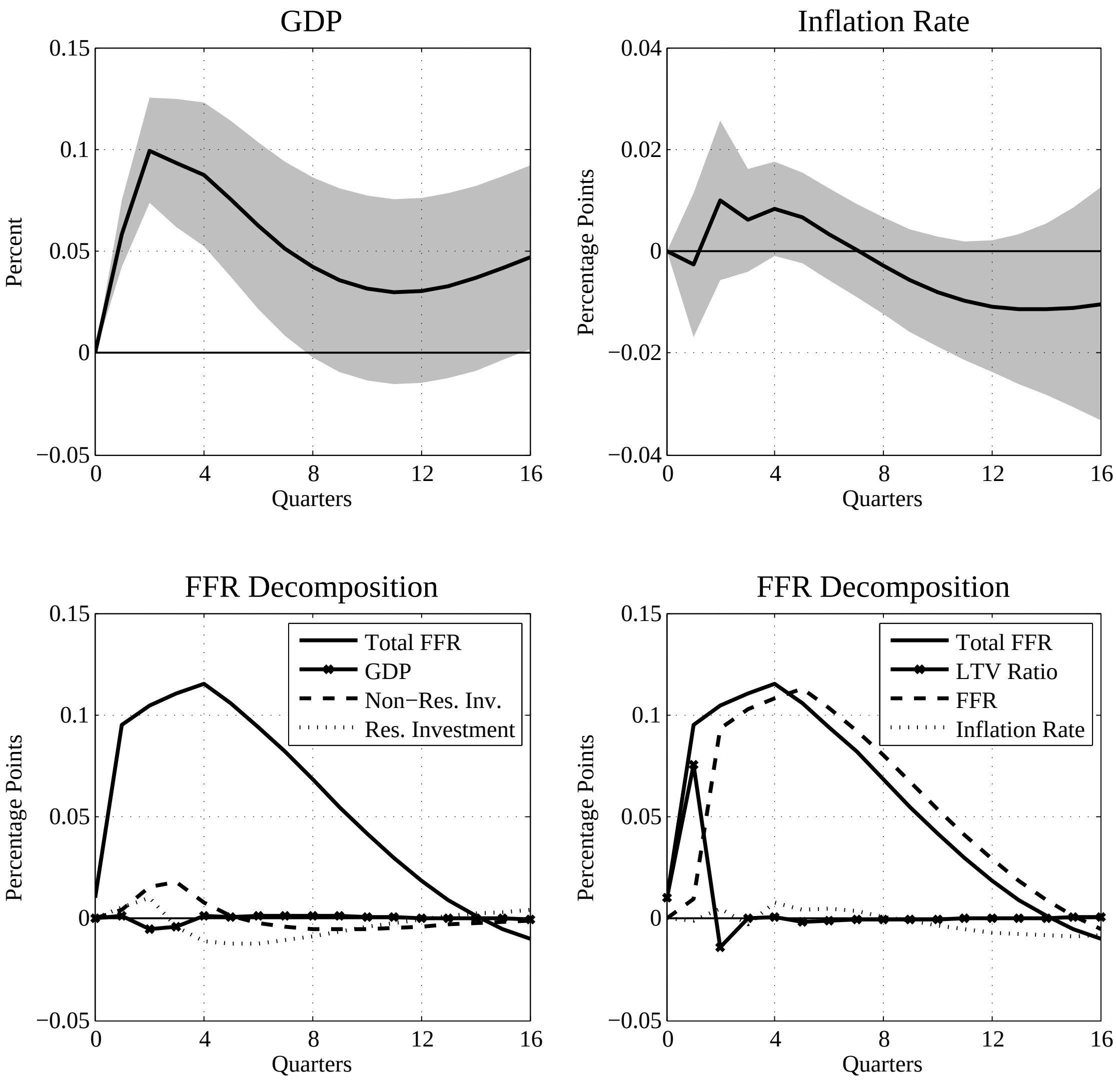
Notes: The x-axis represents time in quarters. The solid lines represent point estimates of impulse response functions for the VAR, using $\boldsymbol{x}_t = [i_t^{nr} \; i_t^{r} \; \Delta ltv_t \; r_t]'$ (the impulse response function for the LTV ratio is cumulated from the one for Δltv_t; we also show the uncumulated impulse response function for Δltv_t together with confidence bands in dashed lines). Shaded areas display one standard deviations confidence intervals, which we obtain from 5,000 replications of the recursive-design wild bootstrap procedure of Goncalves and Kilian (2004).

Figure 3: Mortgage rate and interest expectations following an LTV shock



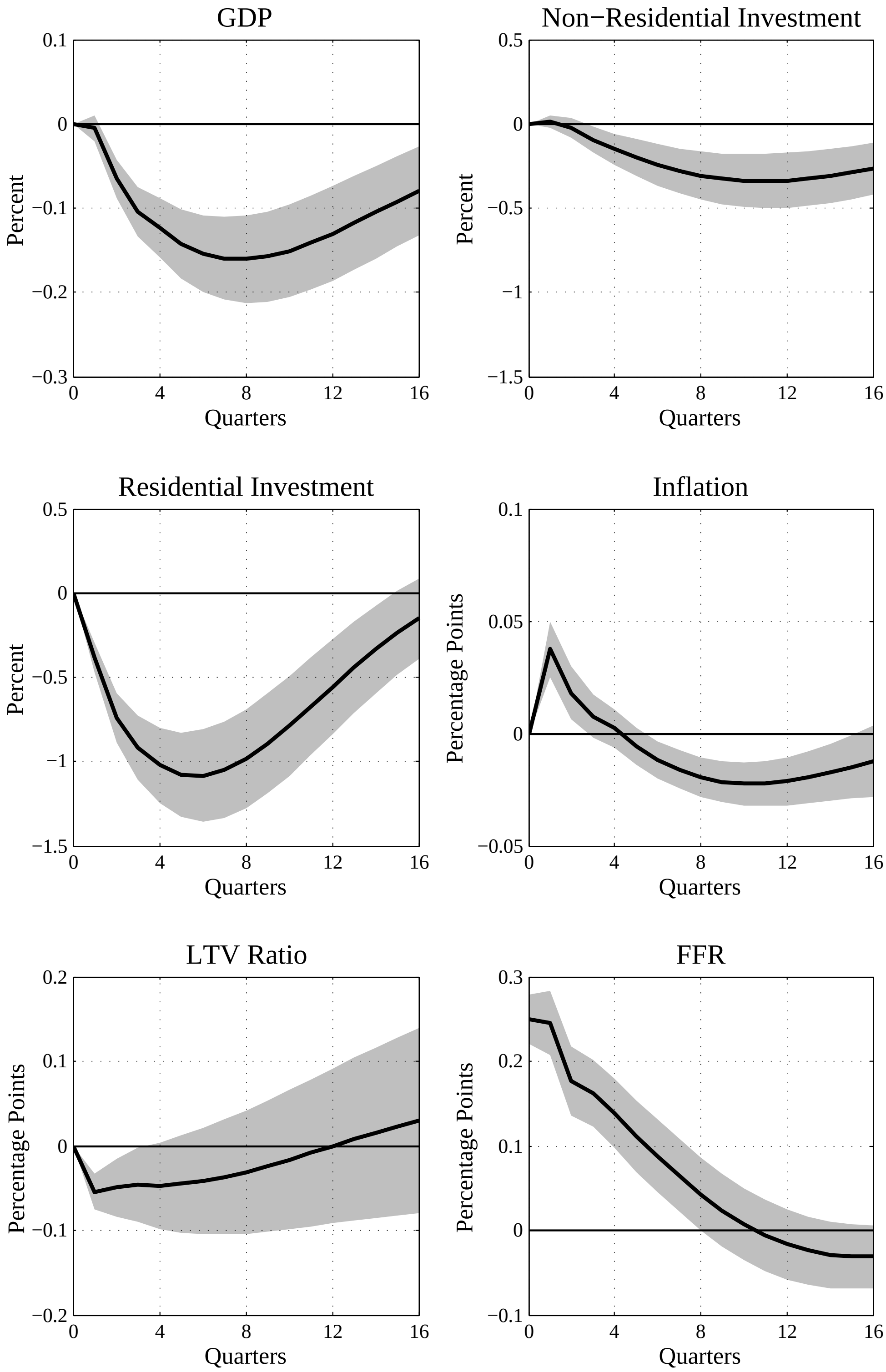
Notes: The x-axis represents time in quarters. The solid lines represent point estimates of impulse response functions for the VAR, using $\boldsymbol{x}_t = [i_t^{nr} \; i_t^r \; \Delta ltv_t \; r_t \; r_t^m \; r_t^e]'$ (the impulse response function for the LTV ratio is cumulated from the one for Δltv_t). Shaded areas display one standard deviations confidence intervals, which we obtain from 5,000 replications of the recursive-design wild bootstrap procedure of Goncalves and Kilian (2004).

Figure 4: Decomposition of the Federal Funds rate response following an LTV shock



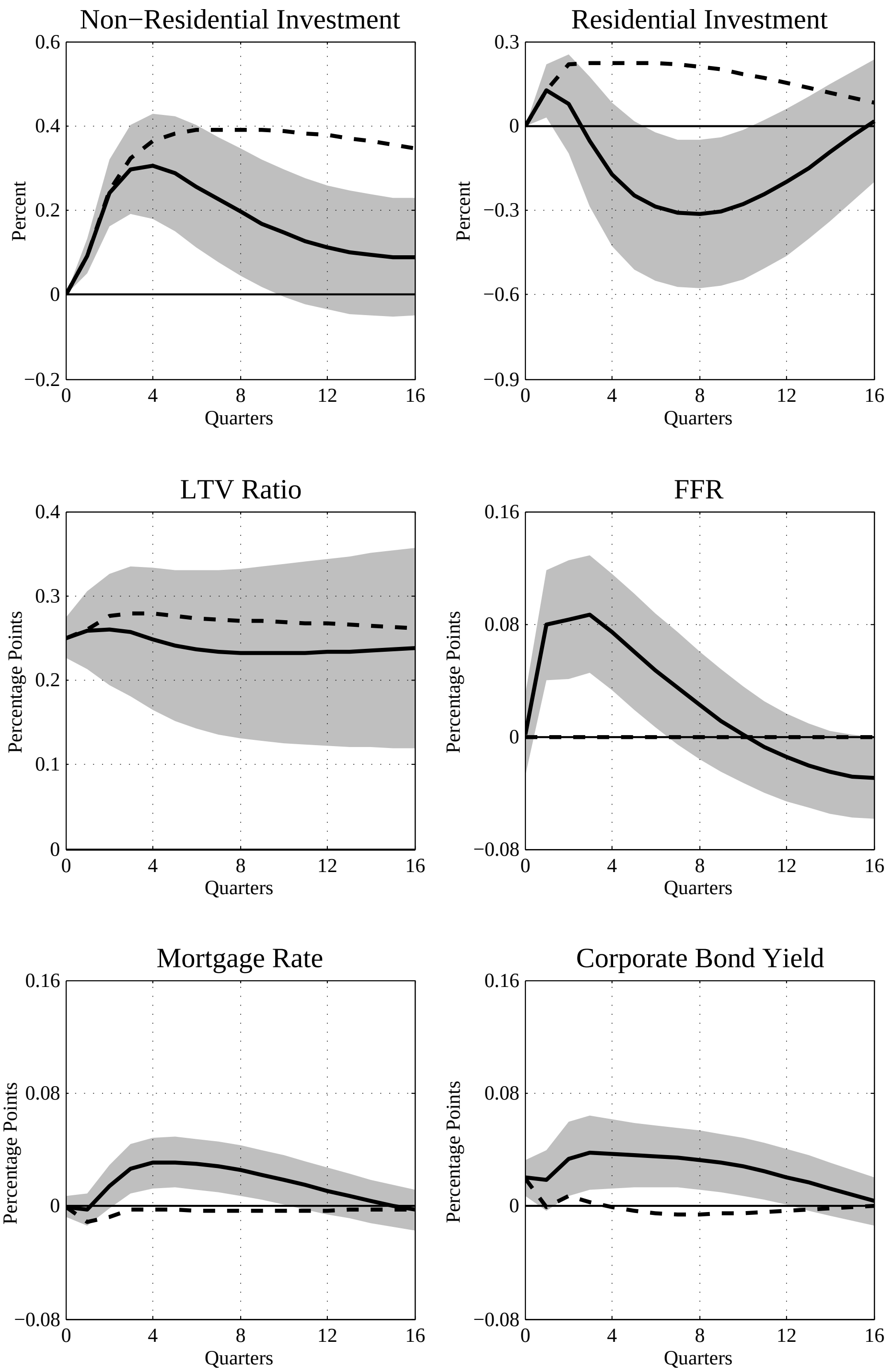
Notes: The x-axis represents time in quarters. In the upper panels, the solid lines represent point estimates of impulse response functions for y_t and π_t from the VAR with $\boldsymbol{x}_t = [y_t\ i_t^{nr}\ i_t^{r}\ \pi_t\ \Delta ltv_t\ r_t]'$, and shaded areas display one standard deviations confidence intervals, which we obtain from 5,000 replications of the recursive-design wild bootstrap procedure of Goncalves and Kilian (2004). The solid lines in the lower panels are the point estimate of the Federal Funds rate impulse response function after an LTV shock. The dashed, dotted, and lines with nodes represent the contribution of the respective variable to the reaction of the Fed's policy instrument.

Figure 5: Monetary policy shock in the monetary VAR model



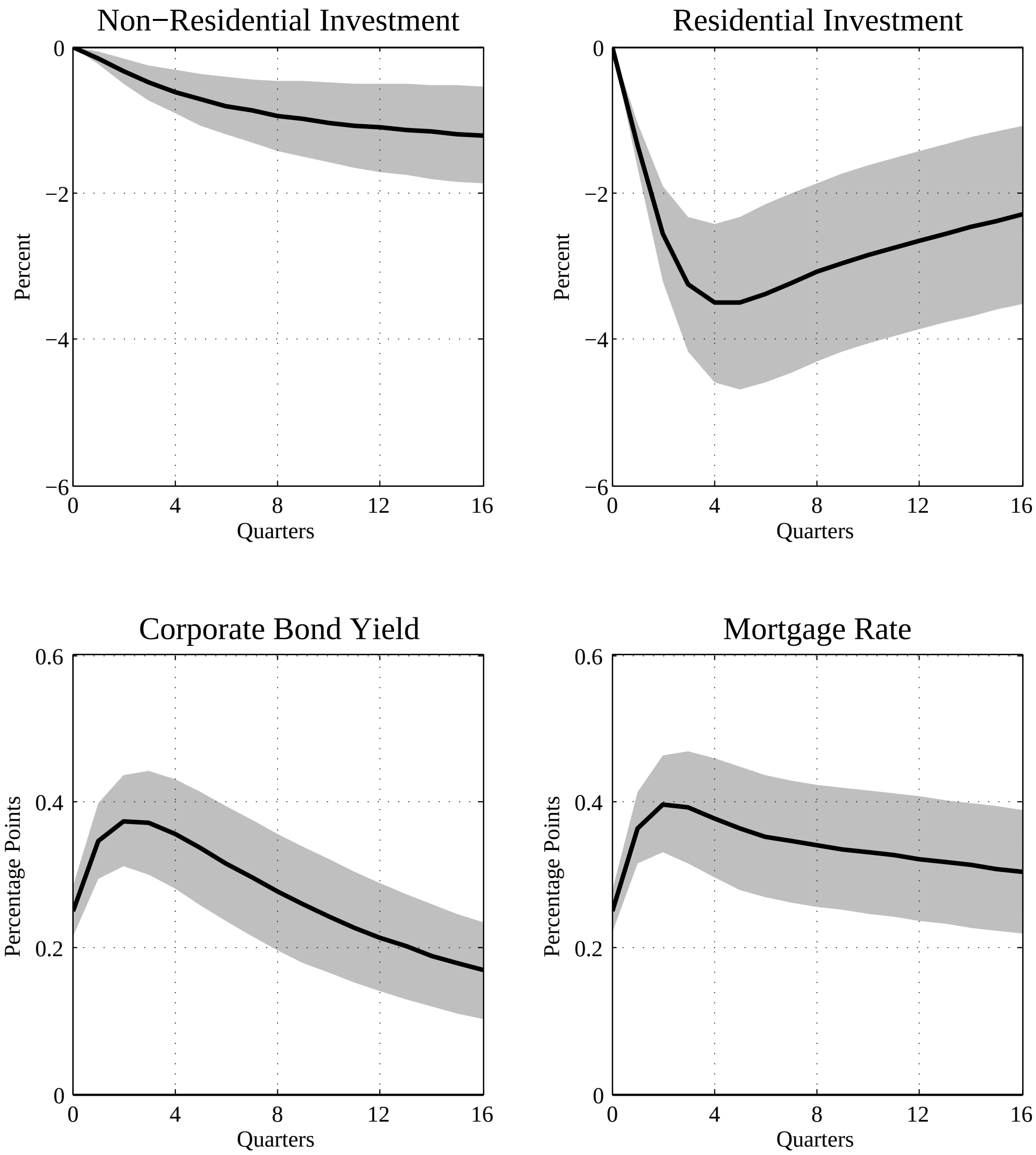
Notes: The x-axis represents time in quarters. The solid lines represent point estimates of impulse response functions for the VAR, using $\boldsymbol{x}_t = [y_t \; i_t^{nr} \; i_t^{r} \; \pi_t \; \Delta ltv_t \; r_t]'$ (the impulse response function for the LTV ratio is cumulated from the one for Δltv_t). Shaded areas display one standard deviations confidence intervals, which we obtain from 5,000 replications of the recursive-design wild bootstrap procedure of Goncalves and Kilian (2004).

Figure 6: LTV shock and interest rate pass-through



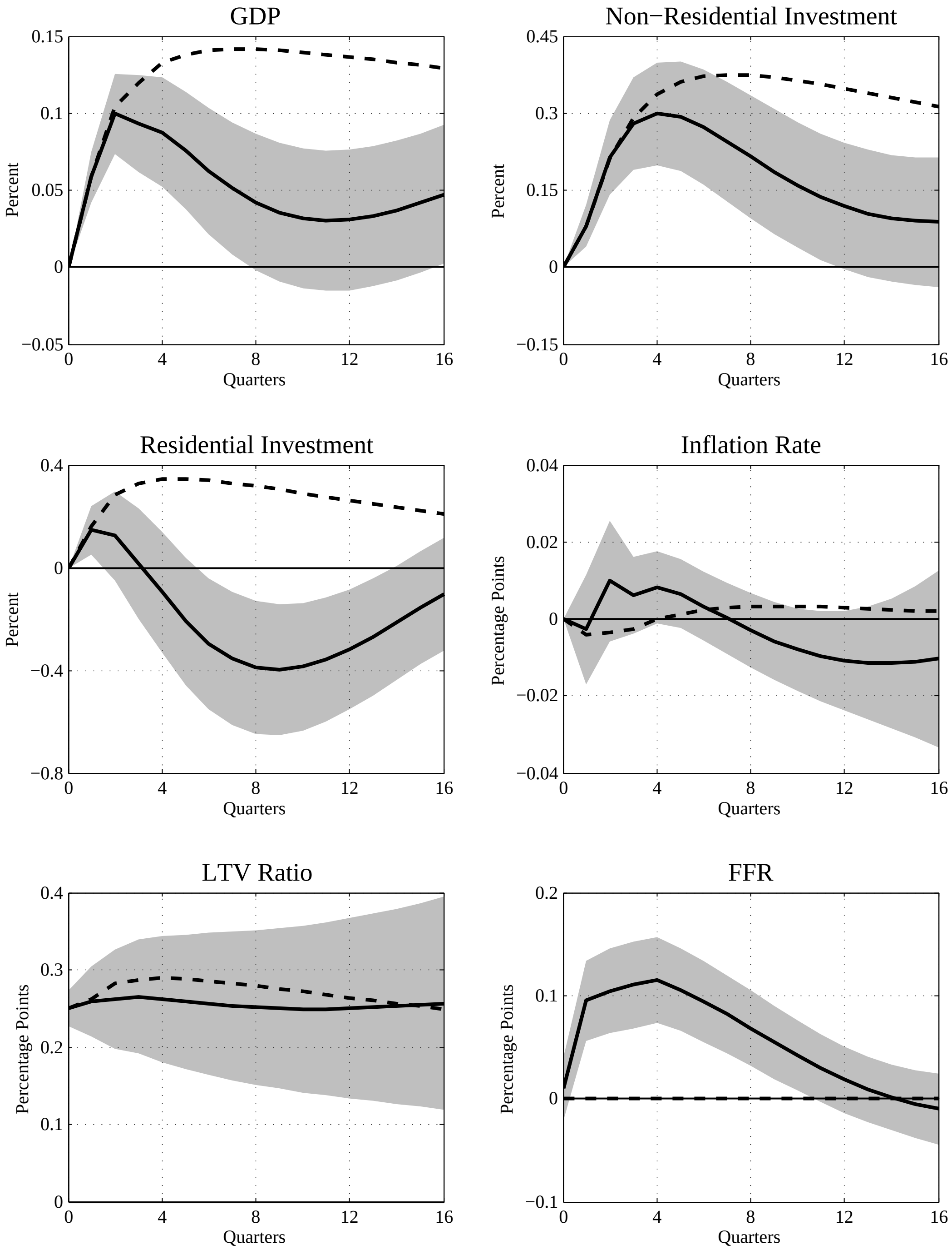
Notes: The x-axis represents time in quarters. The solid lines represent point estimates of impulse responses for the VAR, using $\boldsymbol{x}_t = [i_t^{nr}\ i_t^{r}\ \Delta ltv_t\ r_t\ r_t^{m}\ r_t^{baa}]'$ (the impulse response function for the LTV ratio is cumulated from the one for Δltv_t). Shaded areas display one standard deviations confidence intervals obtained from 5,000 replications of the recursive-design wild bootstrap procedure of Goncalves and Kilian (2004). The dashed lines represent impulses for the case of a passive monetary policy authority that does not react to the shock as in Bernanke et al. (1997) and Sims and Zha (2006).

Figure 7: Bivariate VARs: mortgage rate versus corporate bond yield shock



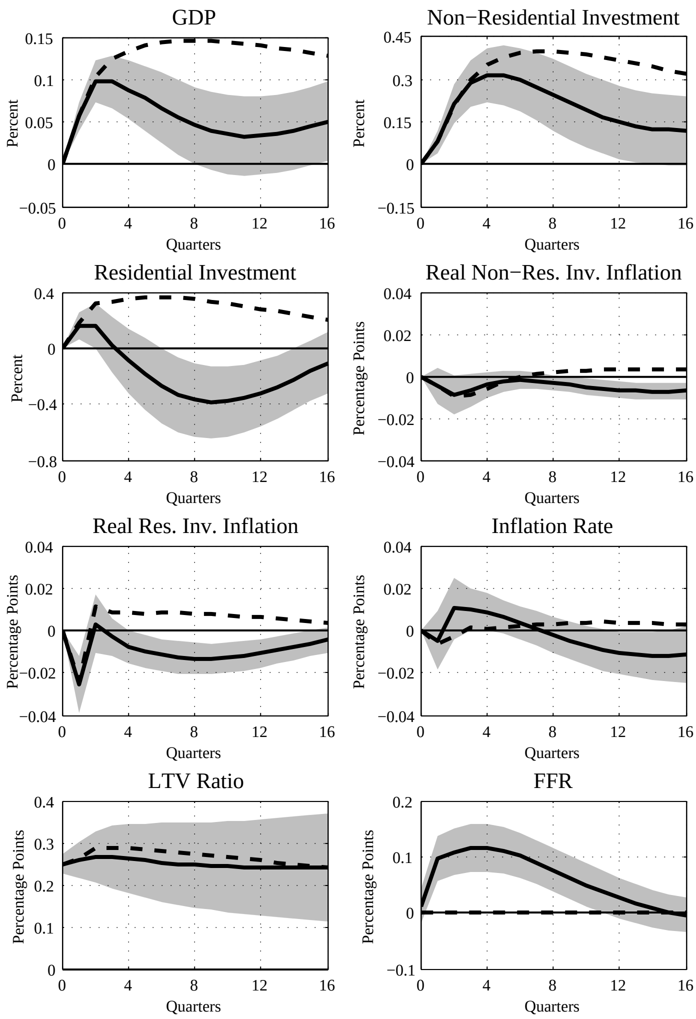
Notes: The x-axis represents time in quarters. The solid lines represent point estimates of impulse response functions for two separate, bi-variate VARs (reported in columns), using $\boldsymbol{x}_t = [i_t^{nr} \;\; r_t^{baa}]'$ or $\boldsymbol{x}_t = [i_t^{r} \; r_t^{m}]'$ and representing a corporate bond yield and a mortgage rate shock, respectively. Shaded areas display one standard deviations confidence intervals, which we obtain from 5,000 replications of the recursive-design wild bootstrap procedure of Goncalves and Kilian (2004).

Figure 8: LTV shock and passive monetary policy



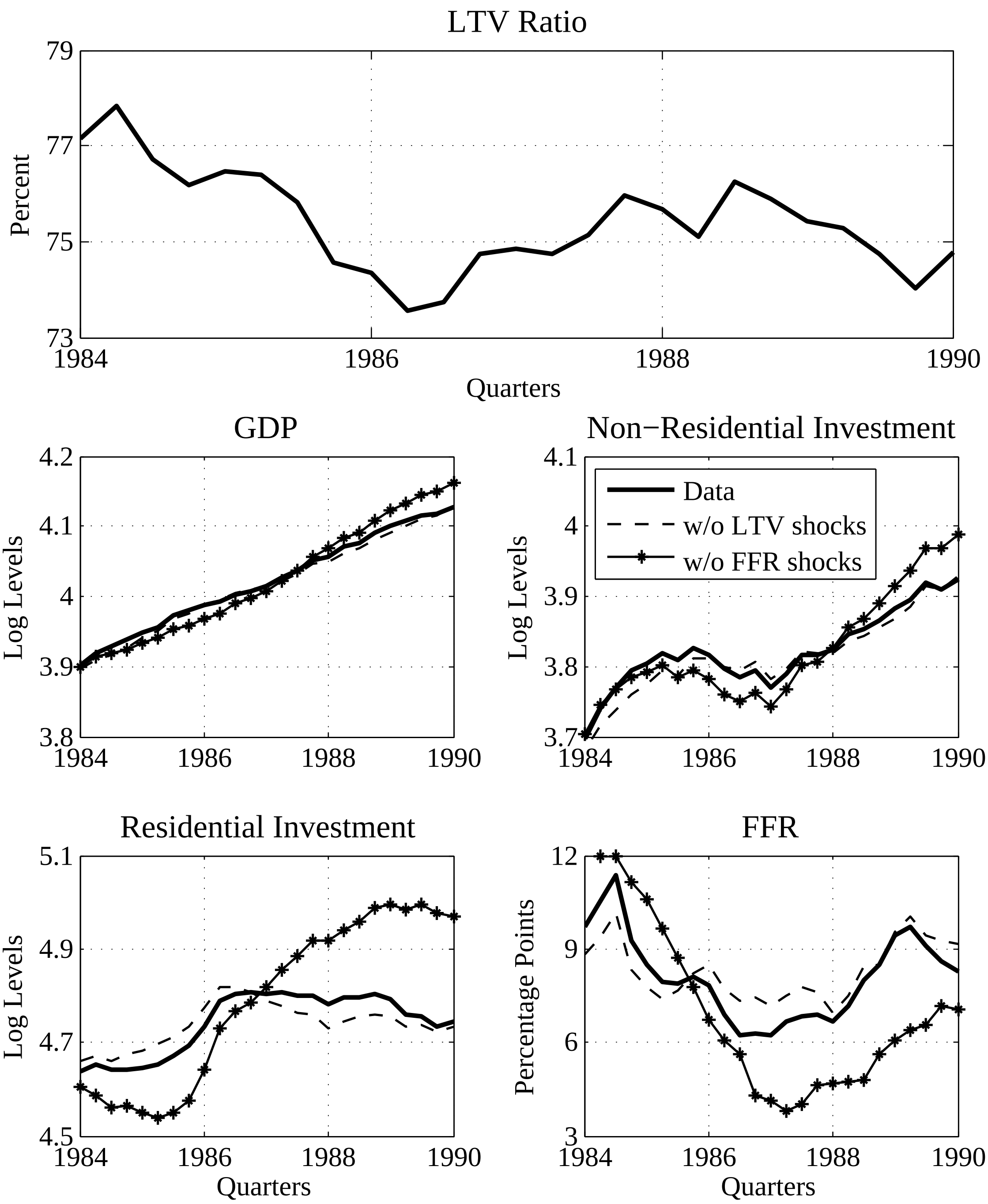
Notes: The x-axis represents time in quarters. The solid lines represent point estimates of impulse response functions for the VAR, using $\boldsymbol{x}_t = [y_t \; i_t^{nr} \; i_t^{r} \; \pi_t \; \Delta ltv_t \; r_t]'$ (the impulse response function for the LTV ratio is cumulated from the one for Δltv_t). Shaded areas display one standard deviations confidence intervals obtained from 5,000 replications of the recursive-design wild bootstrap procedure of Goncalves and Kilian (2004). The dashed lines represent impulse responses for the case of a passive monetary policy authority that does not react to the shock at all, as in Bernanke et al. (1997) and Sims and Zha (2006).

Figure 9: LTV shock and real sectoral investment price inflation rates



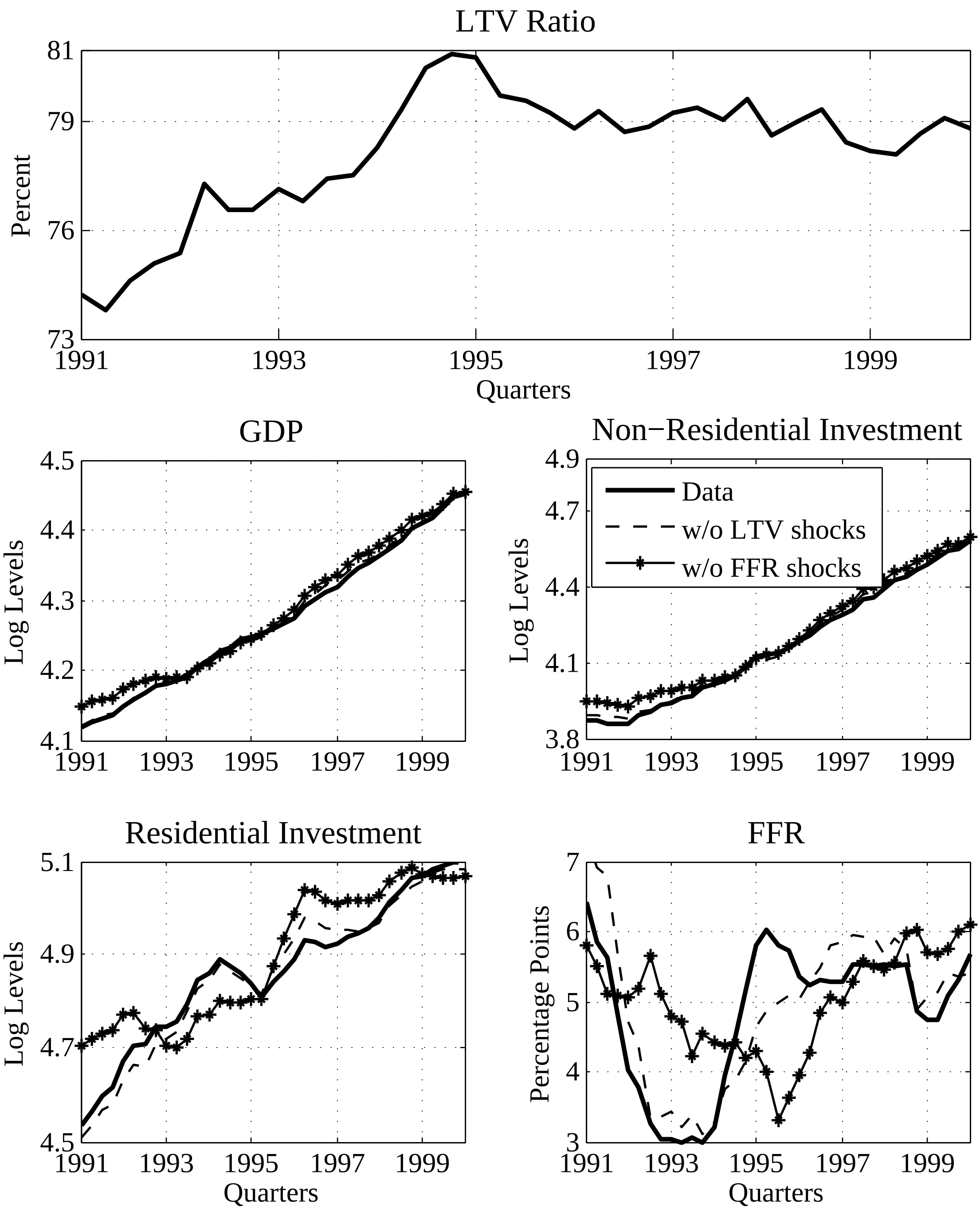
Notes: The x-axis represents time in quarters. The solid lines represent point estimates of impulse response functions for the VAR, using $\boldsymbol{x}_t = [y_t\ i_t^{nr}\ i_t^r\ \pi_t^{nr}\ \pi_t^r\ \pi_t\ \Delta ltv_t\ r_t]'$ (the impulse response function for the LTV ratio is cumulated from the one for Δltv_t). Shaded areas display one standard deviations confidence intervals obtained from 5,000 replications of the recursive-design wild bootstrap procedure of Goncalves and Kilian (2004). The dashed lines represent impulse responses for the case of a passive monetary policy authority that does not react to the shock at all, as in Bernanke et al. (1997) and Sims and Zha (2006).

Figure 10: Historical decomposition 1984-1990



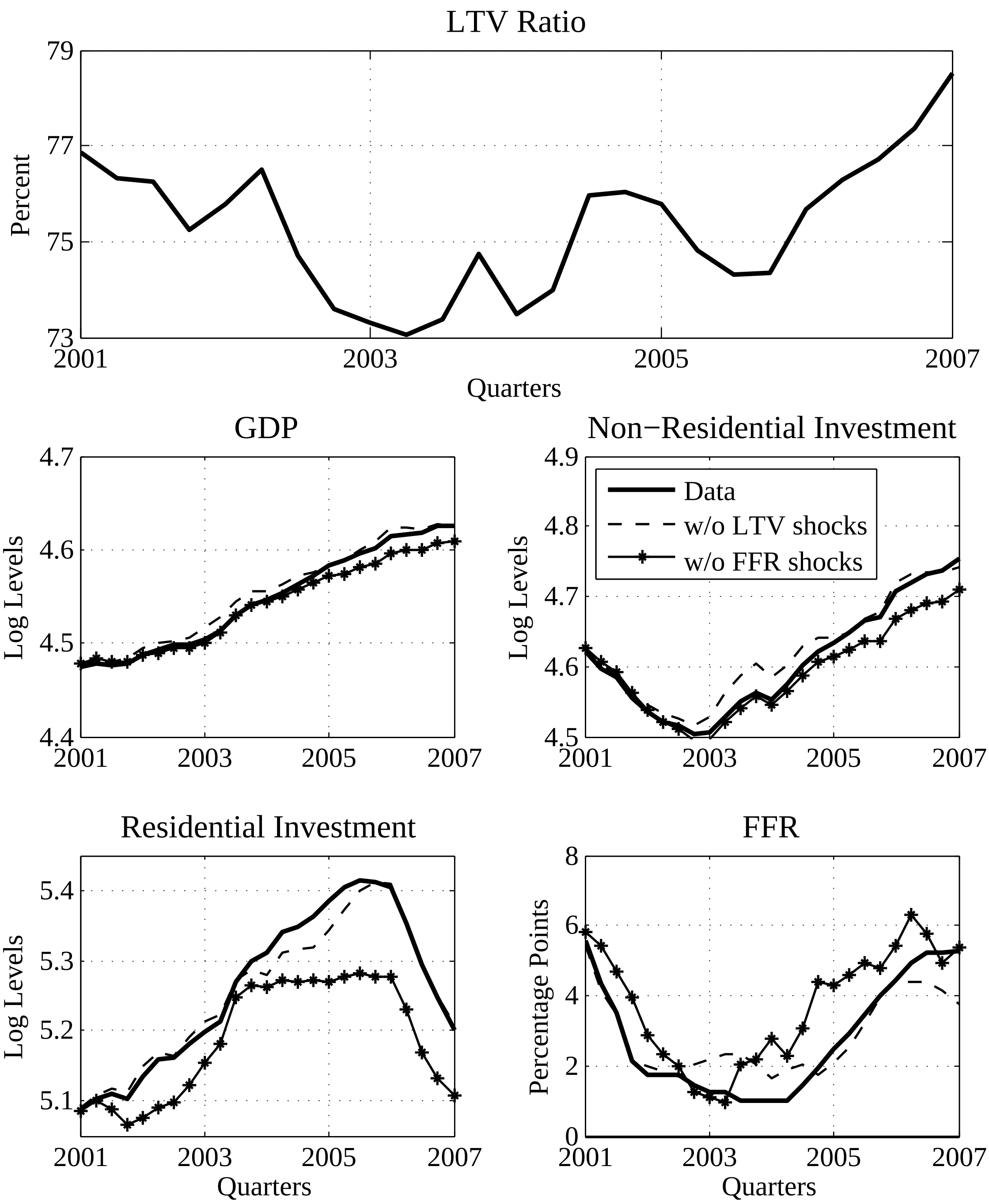
Notes: The x-axis represents time in quarters. The top panel displays the evolution of the LTV ratio in percent, while each of the lower four panels, shows the data as it enters the VAR (solid line), a counterfactual evolution without the contribution of LTV shocks (dashed line), and a counterfactual evolution without the contribution of monetary policy shocks (solid line with asterisks). We obtain these results from the recursively identified six-variable monetary policy VAR with $\boldsymbol{x}_t = [y_t \; i_t^{nr} \; i_t^{r} \; \pi_t \; \Delta ltv_t \; r_t]'$.

Figure 11: Historical decomposition 1991-2000



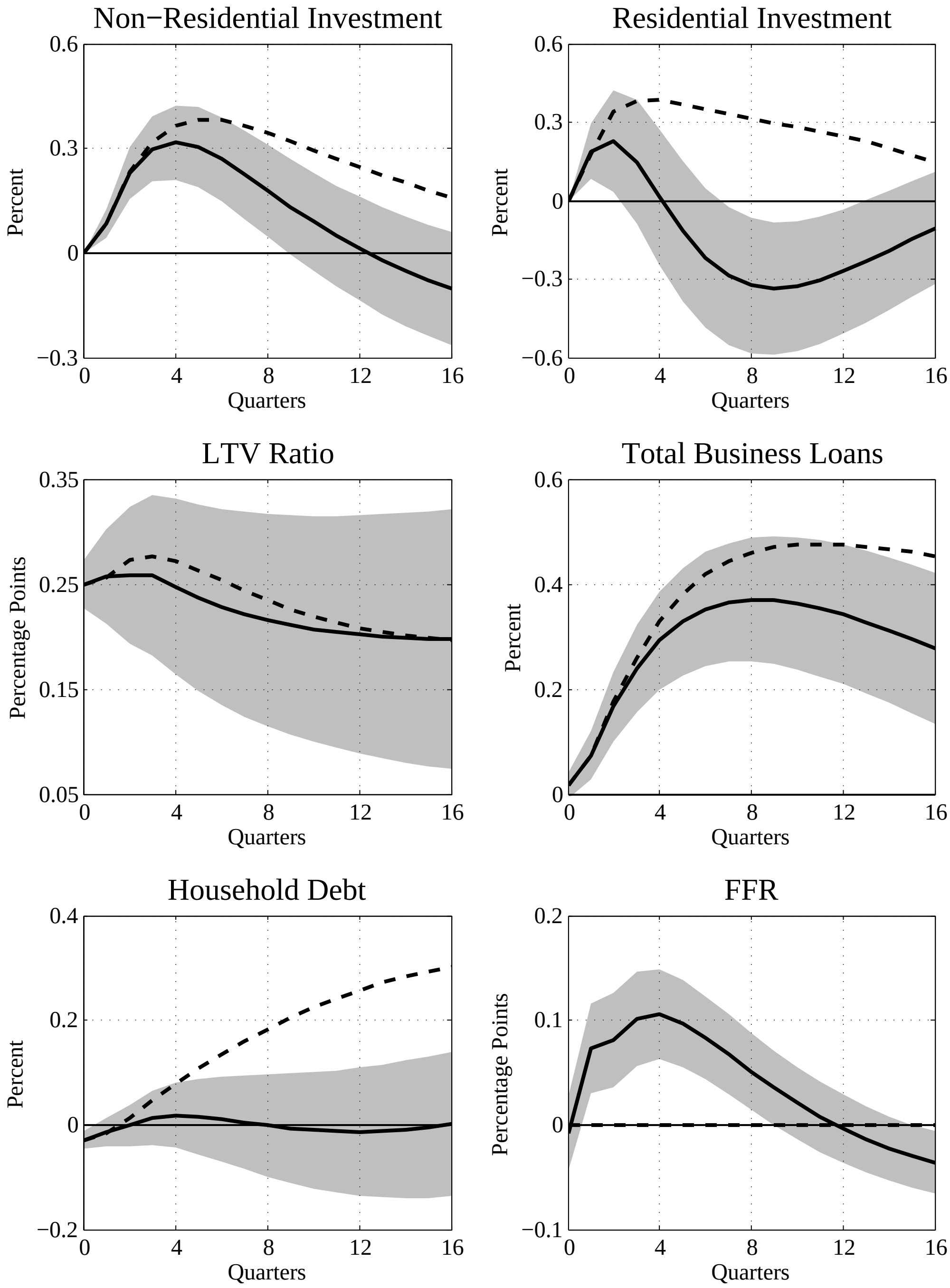
Notes: The x-axis represents time in quarters. The top panel displays the evolution of the LTV ratio in percent, while each of the lower four panels, shows the data as it enters the VAR (solid line), a counterfactual evolution without the contribution of LTV shocks (dashed line), and a counterfactual evolution without the contribution of monetary policy shocks (solid line with asterisks). We obtain these results from the recursively identified six-variable monetary policy VAR with $\boldsymbol{x}_t = [y_t \ i_t^{nr} \ i_t^{r} \ \pi_t \ \Delta ltv_t \ r_t]'$.

Figure 12: Historical decomposition 2001-2007



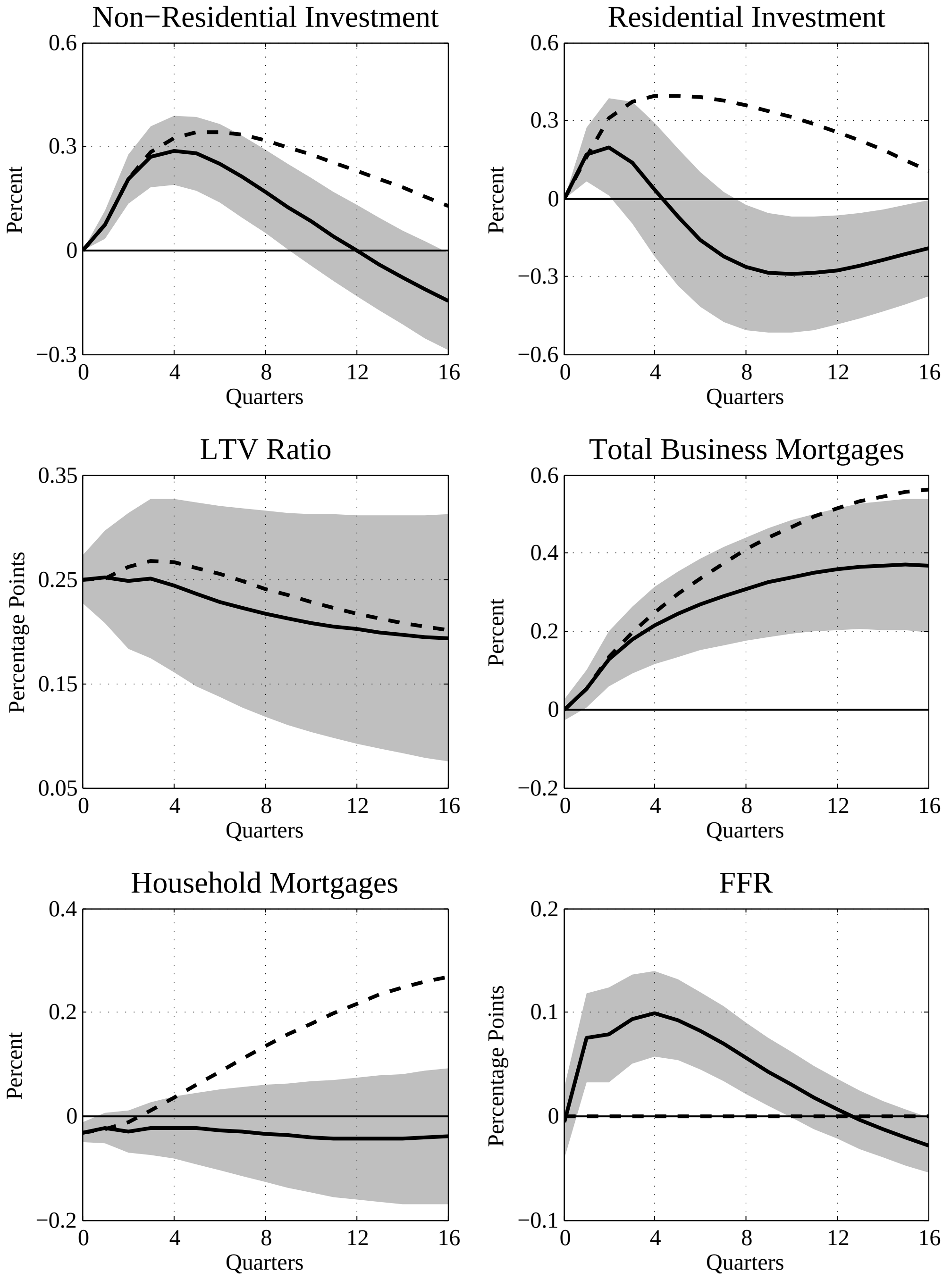
Notes: The x-axis represents time in quarters. The top panel displays the evolution of the LTV ratio in percent, while each of the lower four panels, shows the data as it enters the VAR (solid line), a counterfactual evolution without the contribution of LTV shocks (dashed line), and a counterfactual evolution without the contribution of monetary policy shocks (solid line with asterisks). We obtain these results from the recursively identified six-variable monetary policy VAR with $\boldsymbol{x}_t = [y_t \; i_t^{nr} \; i_t^{r} \; \pi_t \; \Delta ltv_t \; r_t]'$.

Figure 13: LTV shock and debt of households and firms



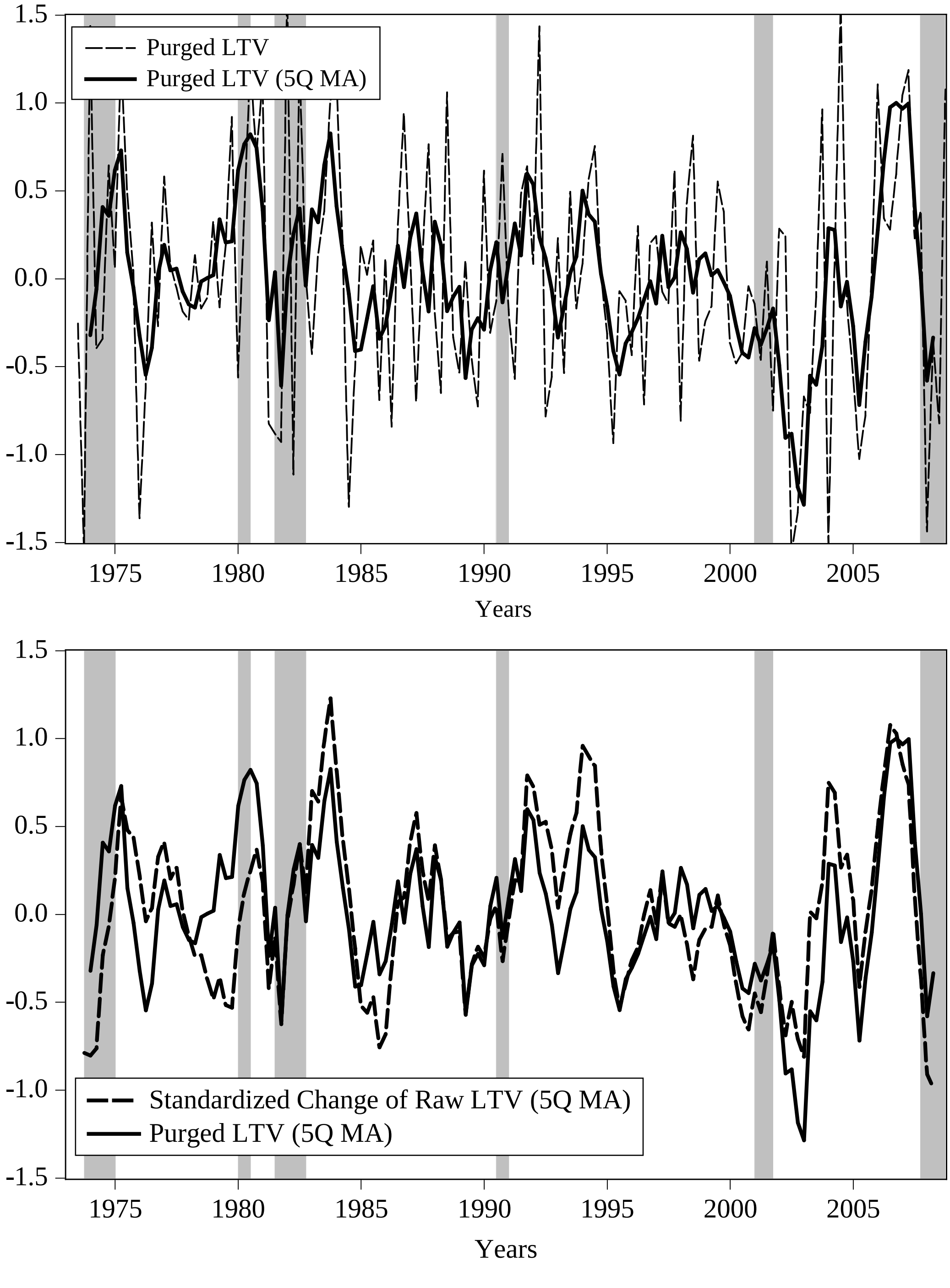
Notes: The x-axis represents time in quarters. The solid lines represent point estimates of impulse response functions for the VAR, using $\boldsymbol{x}_t = [i_t^{nr}\ i_t^{r}\ \Delta ltv_t\ b_t^{b}\ b_t^{h}\ r_t]'$ (the impulse response function for the LTV ratio is cumulated from the one for Δltv_t). Shaded areas display one standard deviations confidence intervals obtained from 5,000 replications of the recursive-design wild bootstrap procedure of Goncalves and Kilian (2004). The dashed lines represent impulse responses for the case of a passive monetary policy authority that does not react to the shock at all, as in Bernanke et al. (1997) and Sims and Zha (2006).

Figure 14: LTV shock and mortgage debt of households and firms



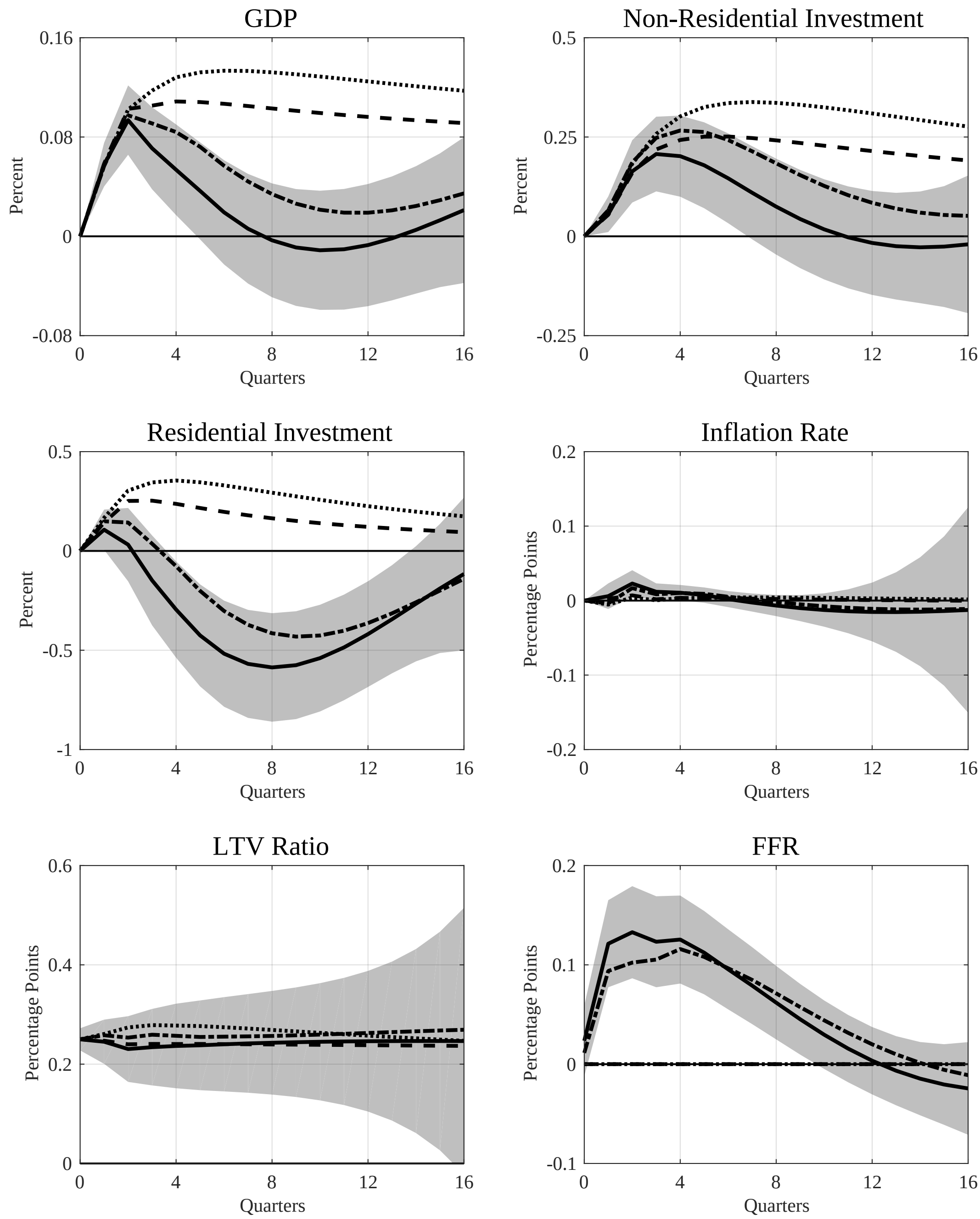
Notes: The x-axis represents time in quarters. The solid lines represent point estimates of impulse response functions for the VAR, using $\boldsymbol{x}_t = [i_t^{nr}\ i_t^{r}\ \Delta ltv_t\ b_t^{bm}\ b_t^{hm}\ r_t]'$ (the impulse response function for the LTV ratio is cumulated from the one for Δltv_t). Shaded areas display one standard deviations confidence intervals obtained from 5,000 replications of the recursive-design wild bootstrap procedure of Goncalves and Kilian (2004). The dashed lines represent impulse responses for the case of a passive monetary policy authority that does not react to the shock at all, as in Bernanke et al. (1997) and Sims and Zha (2006).

Figure 15: Loan-to-value ratio purged from putative demand factors



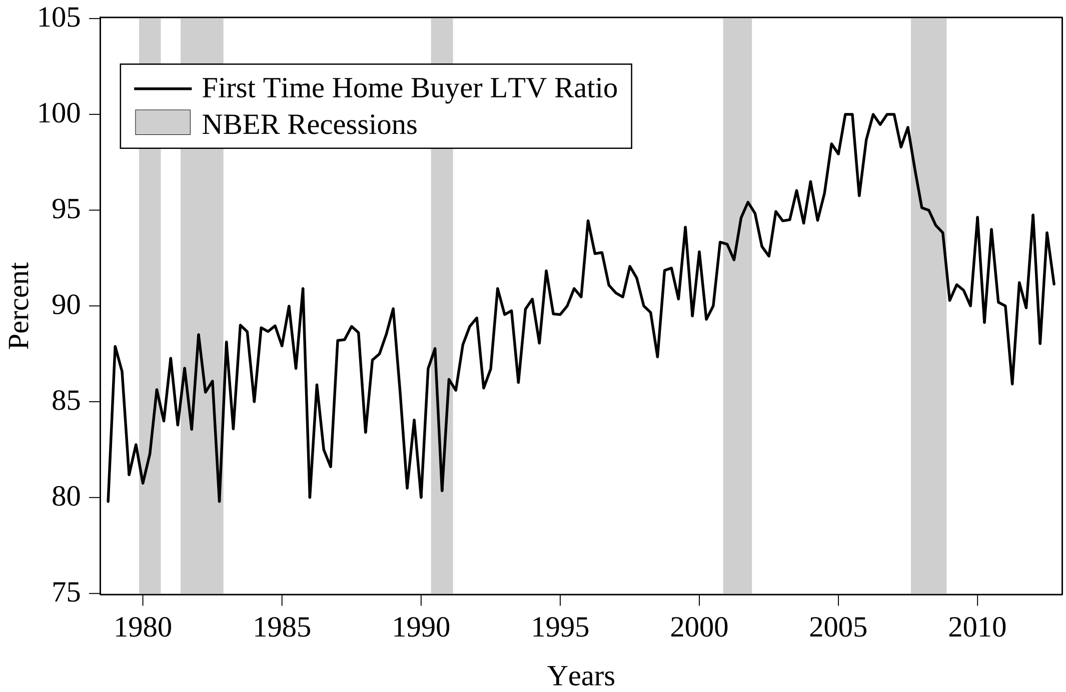
Notes: The upper panel of this figure displays the residuals of Equation (12), i.e., ε_t^{ltv}, standardized by the standard error of estimation, together with a central five-quarter moving average of these standardized residuals. The lower panel of this figure displays the five-quarter moving average series of the standardized residuals together with changes (also standardized-by-its-standard-deviation) of the raw LTV ratio from Figure 1. The correlation between both series (without the moving average) is 0.9. The shaded areas represent NBER-dated recession episodes in the US.

Figure 16: Shock to LTV ratio purged from putative demand factors



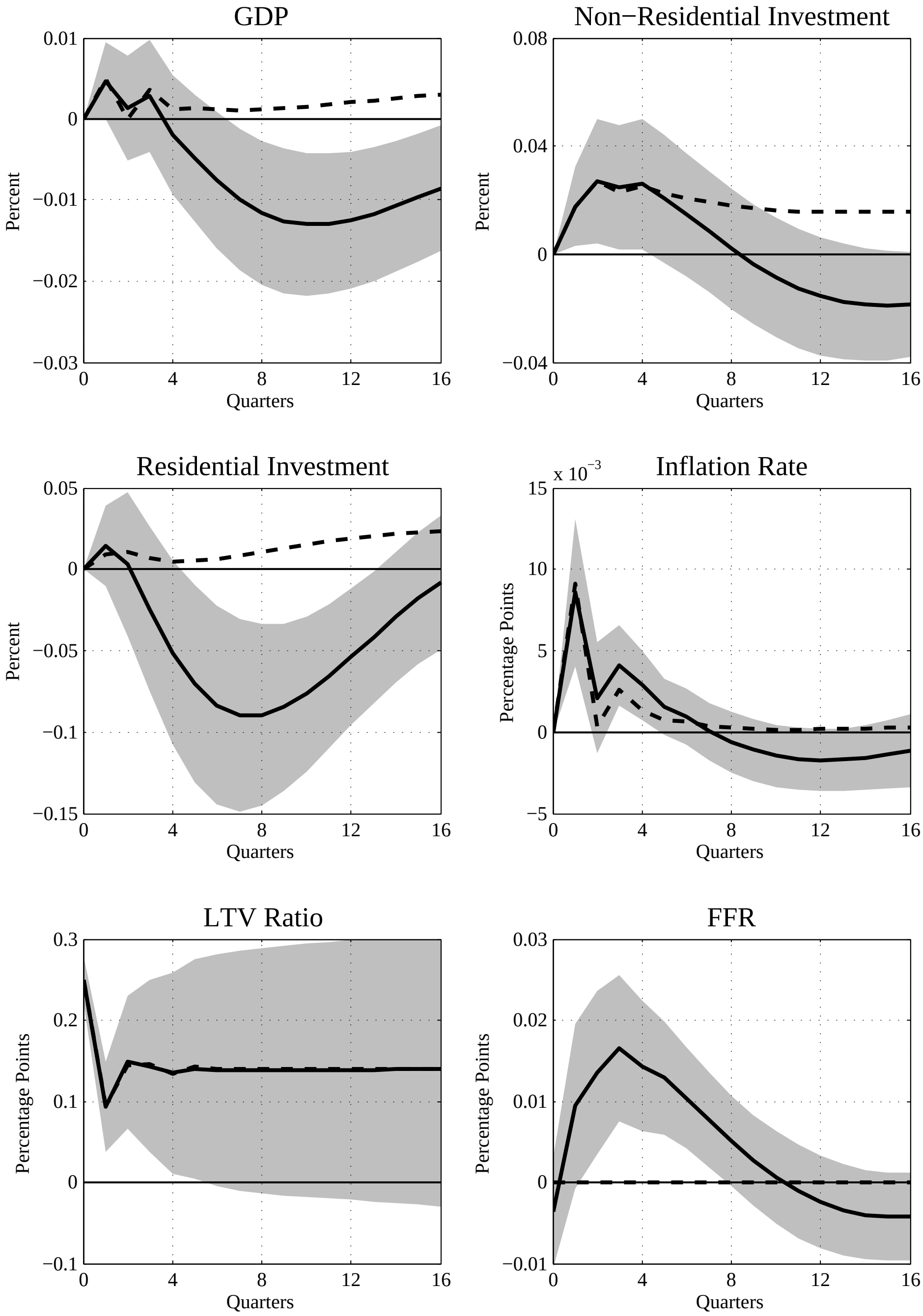
Notes: The x-axis represents time in quarters. The solid lines represent point estimates of impulse response functions for the VAR, using $\boldsymbol{x}_t = [y_t \; i_t^{nr} \; i_t^{r} \; \pi_t \; \varepsilon_t^{ltv} \; r_t]'$, where ε_t^{ltv} denotes the residuals of Equation (12); the impulse response function for the purged LTV ratio is cumulated. The dashed-dotted lines represent the analogous impulses for a shock to the residuals of Equation (11), i.e., $\tilde{\varepsilon}_t^{ltv}$. Shaded areas display one standard deviations confidence intervals obtained from 5,000 replications of the recursive-design wild bootstrap procedure of Goncalves and Kilian (2004) following a surprise in ε_t^{ltv}. The dashed lines represent impulse responses for the case of a passive monetary policy authority that does not react to the ε_t^{ltv} shock at all, as in Bernanke et al. (1997) and Sims and Zha (2006). The dotted lines represent adjustment patterns for the case of a passive monetary policy authority after a innovation in $\tilde{\varepsilon}_t^{ltv}$.

Figure 17: Loan-to-value ratio of first-time home buyer mortgage loans



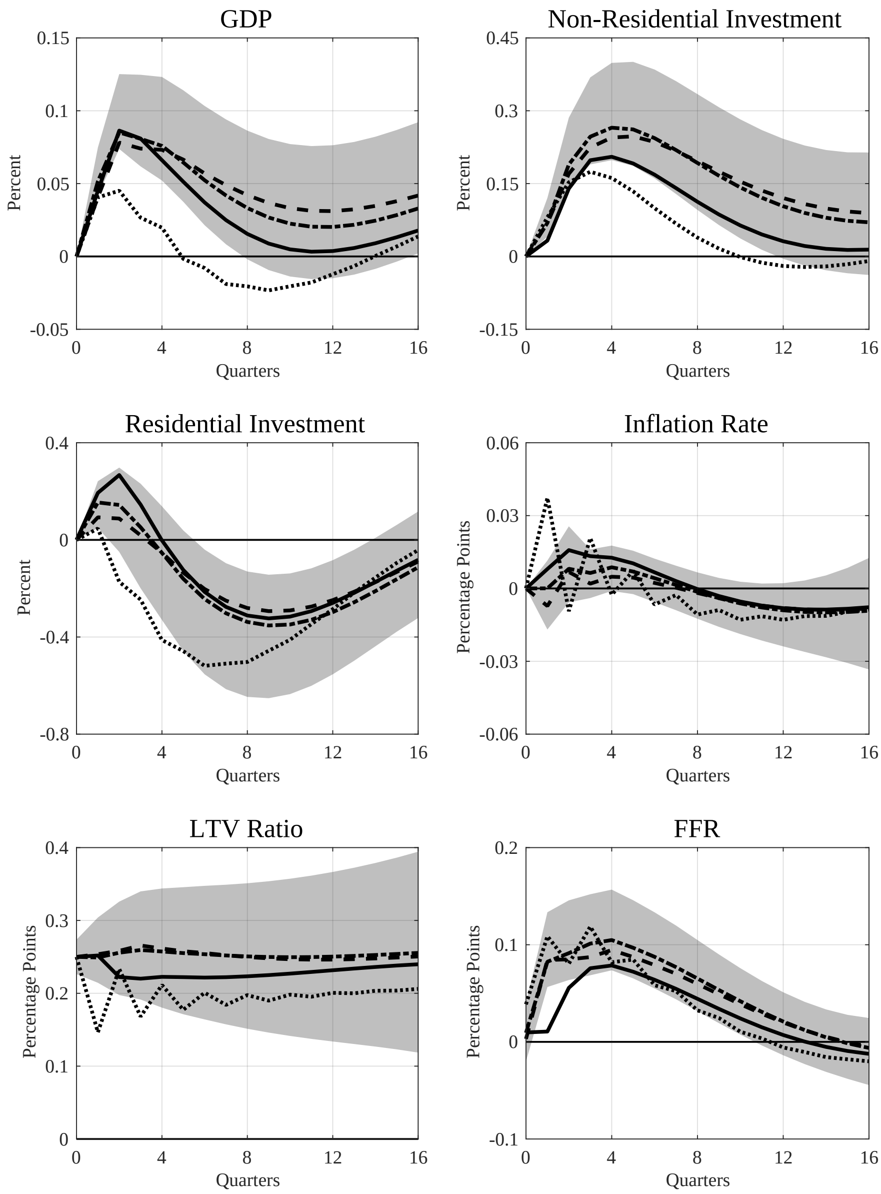
Notes: The figure displays the loan-to-value ratio for first-time home buyer mortgage loans, based on the American Housing Survey (AHS) and purged for certain cyclical factors, such as, e.g., the unemployment rate, seasonal factors, and some exceptional events (see for details Duca et al., 2011, 2013). This series has been provided to us by Duca et al. (2011, 2013). Data are at the quarterly frequency and we express them in percent, i.e., as a ratio of the granted mortgage loan and the underlying house price multiplied by 100. The shaded areas represent NBER-dated recession episodes in the US.

Figure 18: Shock to the first-time buyer LTV ratio



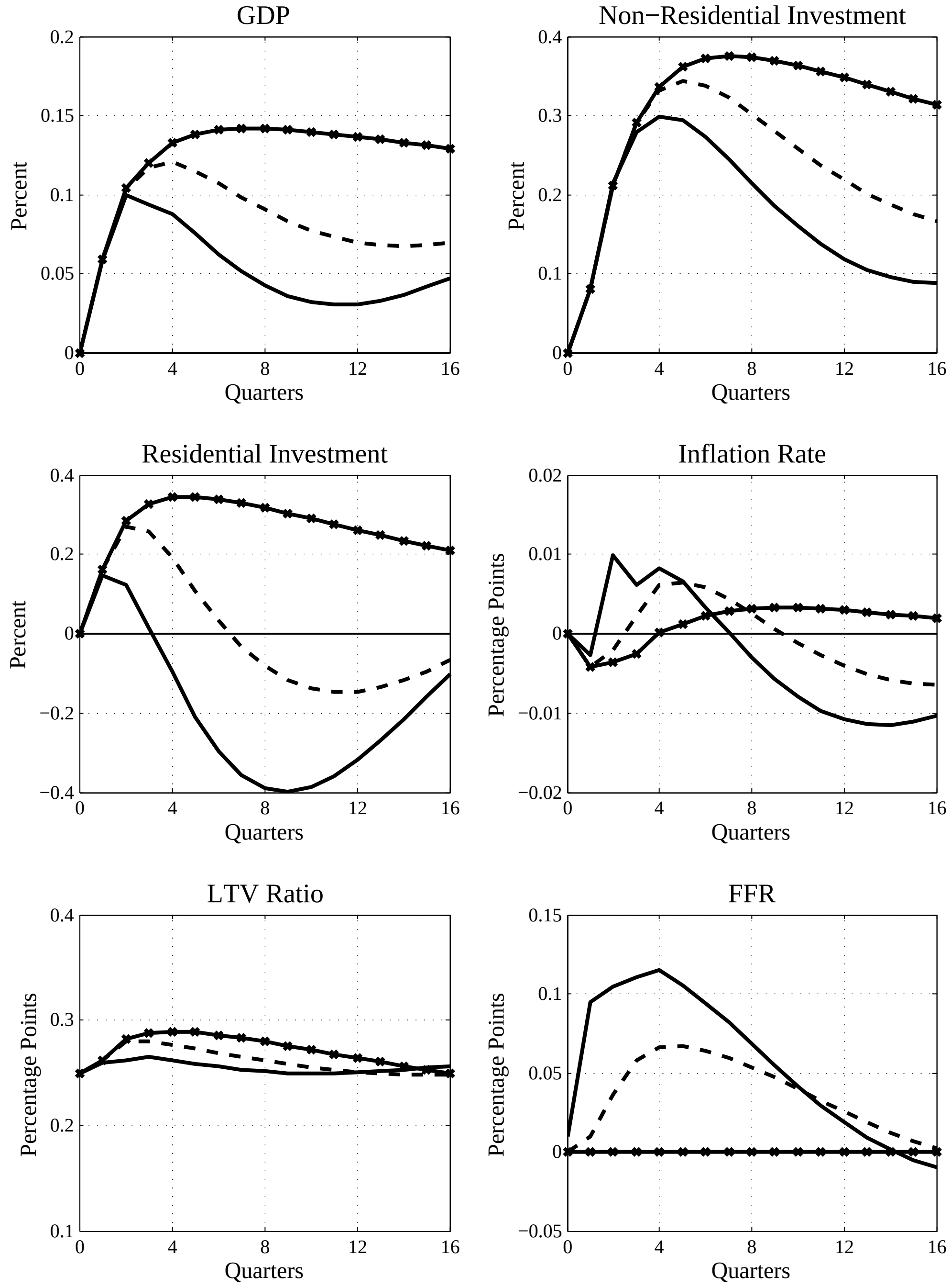
Notes: The x-axis represents time in quarters. The solid lines represent point estimates of impulse response functions for the VAR, using $\boldsymbol{x}_t = [y_t \; i_t^{nr} \; i_t^r \; \pi_t \; \Delta ltv_t{}^{first} \; r_t]'$, where $ltv_t{}^{first}$ stands for the first-time buyer LTV ratio series, which has been provided to us by Duca et al. (2011, 2013) (the impulse response function for the LTV ratio is cumulated from the one for $\Delta ltv_t{}^{first}$). Shaded areas display one standard deviations confidence intervals obtained from 5,000 replications of the recursive-design wild bootstrap procedure of Goncalves and Kilian (2004). The dashed lines represent impulse responses for the case of a passive monetary policy authority that does not react to the shock at all, as in Bernanke et al. (1997) and Sims and Zha (2006).

Figure 19: Shock to LTV ratios for different subgroups: newly built homes, previously occupied homes, fixed-rate mortgages, and adjustable-rate mortgages



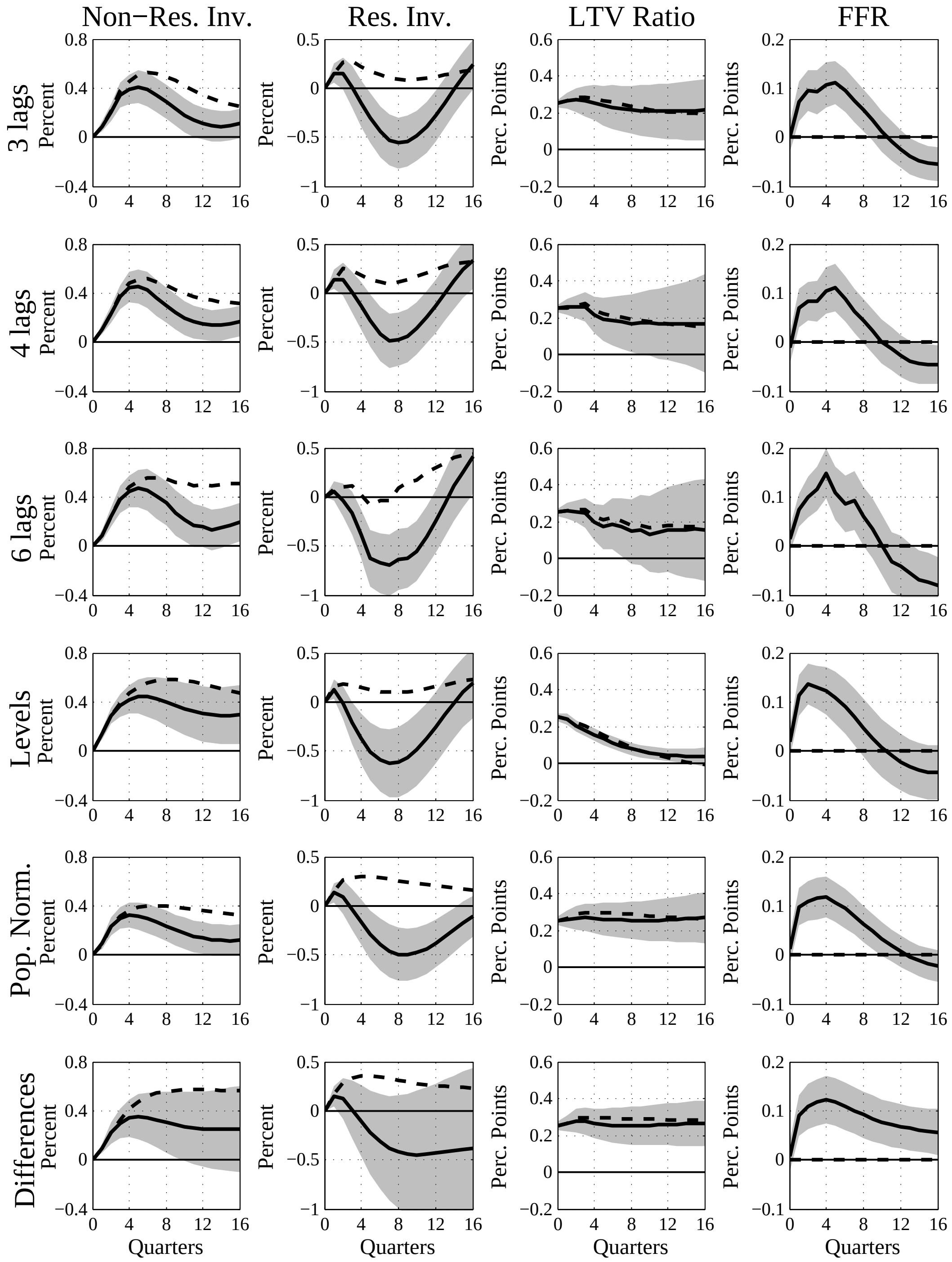
Notes: The x-axis represents time in quarters. The black lines represent point estimates of impulse response functions for the VAR, using $\boldsymbol{x}_t = [y_t \; i_t^{nr} \; i_t^{r} \; \pi_t \; \Delta ltv_t^j \; r_t]'$, where ltv_t^j denotes the four disaggregate LTV ratio series we use (the impulse response function for the LTV ratio is cumulated from the one for Δltv_t^j). We analyze the following subgroups, j, for LTV ratios on mortgage loans from the FHFA MIRS: newly built homes (solid line), previously occupied homes (dashed line), fixed-rate mortgages (dashed-dotted line), and adjustable-rate mortgages (dotted line), which we obtain from the MIRS, Tables 18, 19, 20, and 23, respectively. Because the latter two are only available from 1986Q1, we fill in the rest by backcasting them to 1973Q1, using the overall LTV ratio together with the series on newly built and previously occupied homes. Shaded areas display one standard deviations confidence intervals obtained from 5,000 replications of the recursive-design wild bootstrap procedure of Goncalves and Kilian (2004) following a surprise in Δltv_t, i.e., the average LTV ratio for *all home buyers* (our benchmark series).

Figure 20: LTV shock and passive monetary policy according to Kilian and Lewis (2011)



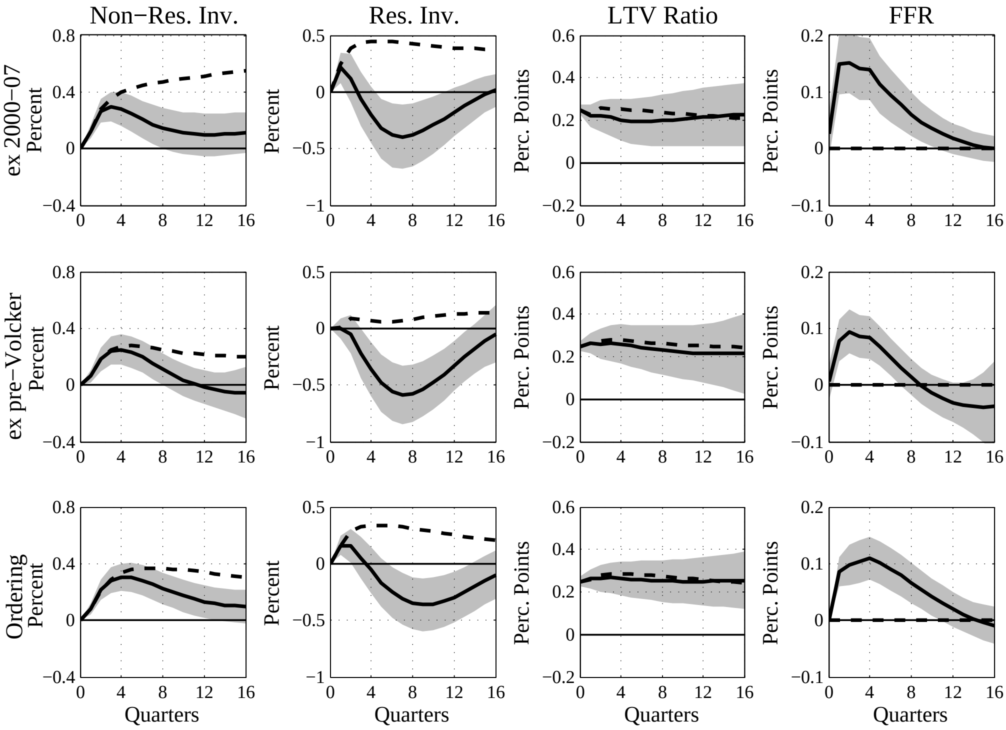
Notes: The x-axis represents time in quarters. The solid lines represent point estimates of impulse response functions for the unrestricted VAR, using $\boldsymbol{x}_t = [y_t \; i_t^{nr} \; i_t^{r} \; \pi_t \; \Delta ltv_t \; r_t]'$ (the impulse response function for the LTV ratio is cumulated from the one for Δltv_t). The dashed line displays the adjustment patterns following an LTV shock for the Kilian and Lewis (2011) decomposition. The lines with nodes represent impulse responses for the case of a passive monetary policy authority that does not react to the shock at all, as in Bernanke et al. (1997) and Sims and Zha (2006).

Figure 21: Robustness: VAR specification



Notes: The x-axis represents time in quarters. The solid lines represent point estimates of impulse response functions for the VARs, which use $\boldsymbol{x}_t = [y_t \; i_t^{nr} \; i_t^{r} \; \pi_t \; \Delta ltv_t \; r_t]'$ as their point of departure (the impulse response function for the LTV ratio is cumulated from the one for Δltv_t). Shaded areas display one standard deviations confidence intervals obtained from 5,000 replications of the recursive-design wild bootstrap procedure of Goncalves and Kilian (2004). The dashed lines represent impulse responses for the case of a passive monetary policy authority that does not react to the shock at all, as in Bernanke et al. (1997) and Sims and Zha (2006).

Figure 22: Robustness: sample and Cholesky ordering



Notes: The x-axis represents time in quarters. The solid lines represent point estimates of impulse response functions for the VARs, which use $\boldsymbol{x}_t = [y_t \; i_t^{nr} \; i_t^{r} \; \pi_t \; \Delta ltv_t \; r_t]'$ as their point of departure (the impulse response function for the LTV ratio is cumulated from the one for Δltv_t). Shaded areas display one standard deviations confidence intervals obtained from 5,000 replications of the recursive-design wild bootstrap procedure of Goncalves and Kilian (2004). The dashed lines represent impulse responses for the case of a passive monetary policy authority that does not react to the shock at all as in Bernanke et al. (1997) and Sims and Zha (2006).

A Appendix - For Online Publication

Table A.1: (Un)conditional correlations between residential LTV ratios and other credit supply indicators

	(1)	(2)	(3)	(4)
$tight_t^{ci/l}$	-0.24^{**} (0.11)	-0.20^{**} (0.12)	-2.72^{*} (2.06) : Q2	-1.83 (1.49) : Q1
$tight_t^{ci/s}$	-0.26^{**} (0.12)	-0.20^{**} (0.11)	-3.41^{**} (1.83) : Q2	-2.03^{*} (1.28) : Q1
ltv_t^{auto}	0.50^{***} (0.07)	0.48^{***} (0.07)	0.64^{***} (0.23) : Q4	0.35^{***} (0.14) : Q2

Notes: The table shows conditional and unconditional correlations between ltv_t and the following credit supply indicators: from the Senior Loan Officer Opinion Survey (SLOOS) the net percentage of domestic banks, which in a quarter tightened their standards for C&I loans to large and middle-market firms, $tight_t^{ci/l}$, as well as to small firms, $tight_t^{ci/s}$, where we seasonally adjust both series (see Bassett et al., 2014, who also use the latter two series from SLOOS), and the LTV ratio for new car loans at auto finance companies, ltv_t^{auto}. The data sample runs from 1973Q1 to 2008Q4 for the latter, and, for the SLOOS data, $tight_t^{ci/l}$ and $tight_t^{ci/s}$, we start in 1990Q2. In column (1), we present unconditional contemporaneous correlations based on raw data, and in column (2), we regress each variable first on the cyclical component of real GDP (based on HP filter with $\lambda = 1,600$), before computing the correlation coefficients. Column (3) runs bivariate VARs for ltv_t and one credit supply indicator at a time and presents the maximum response of the respective indicator to a 100 basis point (for better comparability) innovation in ltv_t, where we order the latter first in a Cholesky identification scheme. In addition, we report the quarter, in which we find the maximum dynamic effect of the LTV shock on the other credit supply indicator. Column (4) runs the bivariate VARs with data entering in first differences. Standard errors are in parentheses.

*** Significant at the 1 percent level.

** Significant at the 5 percent level.

* Significant at the 10 percent level.

Table A.2: Taylor rules: econometric model modifications

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
$\psi_\pi : \mathbb{E}_{t-}\{\pi_{1,2}\}$	0.37^{***} (0.08)	0.31 (0.19)	0.21 (0.16)	0.32^{***} (0.06)	0.34^{***} (0.07)	0.35^{***} (0.05)	0.53^{***} (0.09)
$\psi_{\tilde{y}} : \mathbb{E}_{t-}\{\tilde{y}_t\}$	0.14^{***} (0.03)	0.33^{***} (0.09	0.28^{***} (0.11)	0.12^{***} (0.02)	0.14^{***} (0.03)	0.12^{***} (0.02)	0.09^{***} (0.02)
$\psi_{\Delta y} : \mathbb{E}_{t-}\{\Delta y_t\}$	0.19^{***} (0.05)	0.09 (0.06)	0.11^{**} (0.05)	0.16^{***} (0.04)	0.17^{***} (0.04)	0.22^{***} (0.03)	0.28^{***} (0.06)
$\rho_{r,1} : r_{t-1}$	0.76^{***} (0.11)			0.91^{***} (0.03)	0.77^{***} (0.15)	0.86^{***} (0.03)	0.82^{***} (0.04)
$\rho_{r,2} : r_{t-2}$	0.14 (0.11)				0.16 (0.15)		
$\rho_{\eta,1} : \eta^{TR}_{t-1}$		0.97^{***} (0.03)	1.13^{***} (0.14)	-0.07 (0.13)	0.04 (0.10)		
$\rho_{\eta,2} : \eta^{TR}_{t-2}$			-0.16 (0.15)		-0.31^{**} (0.13)		
$\psi_{\Delta ltv} : \Delta ltv_{t-1}$	0.26^{**} (0.11)	0.18^{***} (0.06)	0.17^{***} (0.05)	0.30^{***} (0.11)	0.24^{***} (0.09)	0.06^{**} (0.03)	0.20^{**} (0.09)
$\tilde{R}^2$	0.95	0.94	0.94	0.95	0.95	0.99	0.96
s.e.e.	0.81	0.90	0.90	0.80	0.75	0.28	0.73

Notes: The table shows ordinary least squares estimates for the interest rate rule from Equation (6). ψ_π denotes the central bank reaction to inflation expectations, $\psi_{\tilde{y}}$ is the response to the expected output gap, and $\psi_{\Delta y}$ is the coefficient for expected output growth. $\rho_{r,k}$ measures the degree of AR(k) interest rate smoothing, and $\rho_{\eta,j}$ defines the order (J) of serial correlation in η^{TR}_t. $\psi_{\Delta ltv}$ represents the monetary policy reaction to lagged changes in LTV ratios. We perform the estimations of models (1) to (5) using data from 1973Q1 to 2008Q4 and present Newey-West standard errors in parentheses. In column (1), we set $K = 1, 2$ and $J = 0$, in column (2), we set $K = 0$ and $J = 1$, in column (3), we set $K = 0$ and $J = 1, 2$, and column (4)/(5) estimates an ARMA(1,1)/ARMA(2,2) Taylor rule, respectively. In column (6), we estimate the benchmark model from Equation (7) for a data sample starting in 1987Q4 as in Coibion and Gorodnichenko (2012), and in column (7), we start the sample with Paul Volcker's Fed chairmanship in 1979Q3 as in Clarida et al. (2000) or Boivin and Giannoni (2006), among others. $\tilde{R}^2$ denotes the adjusted R^2 and *s.e.e.* stands for the standard error of the corresponding equation.

*** Significant at the 1 percent level.

** Significant at the 5 percent level.

* Significant at the 10 percent level.

Table A.3: Taylor rules incorporating non-housing market indicators

	(1)	(2)	(3)	(4)	(5)	(6)
$\psi_{\pi} : \mathbb{E}_{t-}\{\pi_{t+1,t+2}\}$	0.35^{***} (0.07)	0.35^{***} (0.07)	0.33^{***} (0.07)	0.33^{***} (0.08)	0.35^{***} (0.07)	0.35^{***} (0.07)
$\psi_{\tilde{y}} : \mathbb{E}_{t-}\{\tilde{y}_t\}$	0.12^{***} (0.02)	0.12^{***} (0.02)	0.11^{***} (0.02)	0.11^{***} (0.02)	0.12^{***} (0.02)	0.11^{***} (0.02)
$\psi_{\Delta y} : \mathbb{E}_{t-}\{\Delta y_t\}$	0.18^{***} (0.04)	0.19^{***} (0.04)	0.12^{***} (0.05)	0.16^{***} (0.04)	0.15^{***} (0.04)	0.18^{***} (0.04)
$\rho_{r,1} : r_{t-1}$	0.90^{***} (0.03)	0.90^{***} (0.03)	0.90^{***} (0.03)	0.90^{***} (0.03)	0.89^{***} (0.03)	0.89^{***} (0.03)
$\psi^{c}_{\Delta spr} : \Delta spr^{c}_{t-1}$	-0.35 (0.22)					
$\psi_{\Delta ebp} : \Delta ebp_{t-1}$		0.05 (0.33)				
$\psi^{baa}_{\Delta spr} : \Delta spr^{baa}_{t-1}$			-1.01 (0.71)			
$\psi^{aaa}_{\Delta spr} : \Delta spr^{aaa}_{t-1}$				-0.82 (0.56)		
$\psi^{b-a}_{\Delta spr} : \Delta spr^{b-a}_{t-1}$					-1.10 (0.99)	
$\psi_{\Delta stocks} : \Delta stocks_{t-1}$						0.001 (0.001)
$\tilde{R}^2$	0.95	0.94	0.95	0.95	0.95	0.94
$s.e.e.$	0.83	0.83	0.81	0.82	0.82	0.83

Notes: The table shows ordinary least squares estimates for the interest rate rule from Equation (6). ψ_{π} denotes the central bank reaction to inflation expectations, $\psi_{\tilde{y}}$ is the response to the expected output gap, and $\psi_{\Delta y}$ is the coefficient for expected output growth. $\rho_{r,1}$ measures the degree of AR(1) interest rate smoothing. We perform all estimations using data from 1973Q1 to 2008Q4 and present Newey-West standard errors in parentheses. In columns (1) and (2), we, respectively, use a corporate bond credit spread, Δspr^{c}_{t-1}, and the excess bond premium, Δebp_{t-1}, both proposed in Gilchrist and Zakrajsek (2012), instead of Δltv_{t-1}. Columns (3) to (5) use Moody's BAA spread relative to 10-year treasury yields, $\Delta spr^{baa}_{t-1} = \Delta(r^{baa}_{t-1} - r^{10}_{t-1})$, the AAA-rated counterpart, $\Delta spr^{aaa}_{t-1} = \Delta(r^{aaa}_{t-1} - r^{10}_{t-1})$, and the difference between BAA and AAA-rated bond yields, $\Delta spr^{b-a}_{t-1} = \Delta(r^{baa}_{t-1} - r^{aaa}_{t-1})$. Finally, we use changes in the S&P Composite Stock Price Index, $\Delta stocks_{t-1}$. The corresponding reaction coefficients are $\psi^{c}_{\Delta spr}$, $\psi_{\Delta ebp}$, $\psi^{baa}_{\Delta spr}$, $\psi^{aaa}_{\Delta spr}$, $\psi^{b-a}_{\Delta spr}$, and $\psi_{\Delta stocks}$. $\tilde{R}^2$ denotes the adjusted R^2 and $s.e.e.$ stands for the standard error of the corresponding equation.

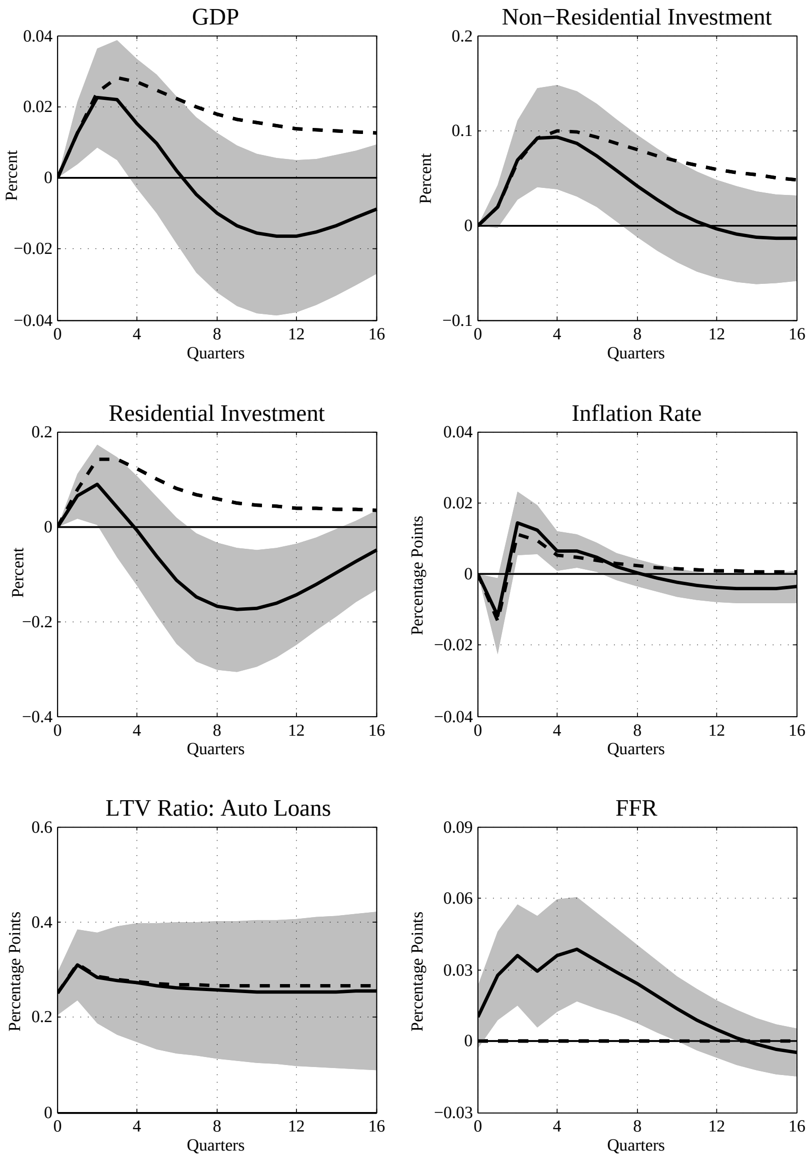
*** Significant at the 1 percent level.
** Significant at the 5 percent level.
* Significant at the 10 percent level.

Table A.4: Variance decompositions: first-time home owner LTV ratio

LTV Shocks	y_t	i_t^{nr}	i_t^r	π_t	Δltv_t^{first}	r_t
Impact	0.0	0.0	0.0	0.0	99.7	0.2
1 Year	0.2	0.7	0.1	2.5	84.9	1.9
2 Years	0.4	0.5	1.2	2.4	84.8	2.4
4 Years	1.1	0.4	1.8	2.3	84.7	2.0
FFR Shocks	y_t	i_t^{nr}	i_t^r	π_t	Δltv_t^{first}	r_t
Impact	0.0	0.0	0.0	0.0	0.0	88.4
1 Year	4.2	0.1	20.2	4.5	2.3	49.8
2 Years	15.0	2.2	29.7	5.2	2.3	34.0
4 Years	16.6	8.9	26.4	9.4	2.4	31.6

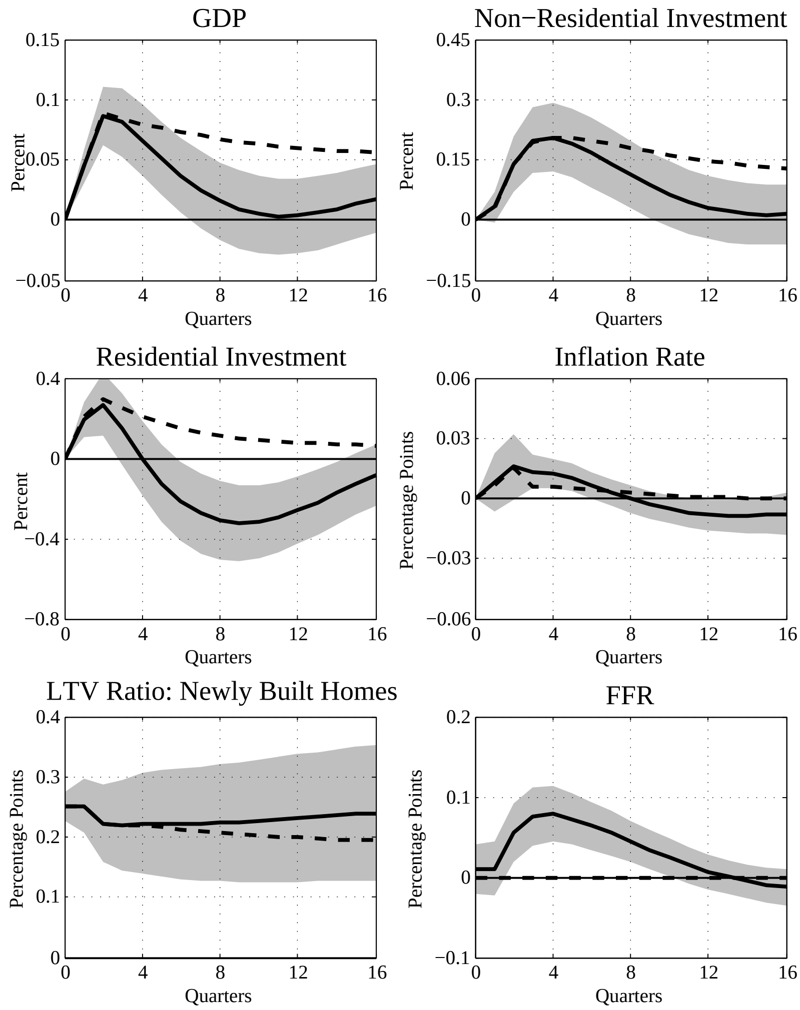
Notes: The table displays the fraction of the forecast error variance (in percent) for the variables in $\boldsymbol{x}_t = [y_t \; i_t^{nr} \; i_t^r \; \pi_t \; \Delta ltv_t^{first} \; r_t]'$, that is, the six-variable monetary policy VAR, that is explained by LTV shocks (upper panel) / Federal Funds rate shocks (lower panel) at different horizons.

Figure A.1: LTV shock for new car loans at auto finance companies



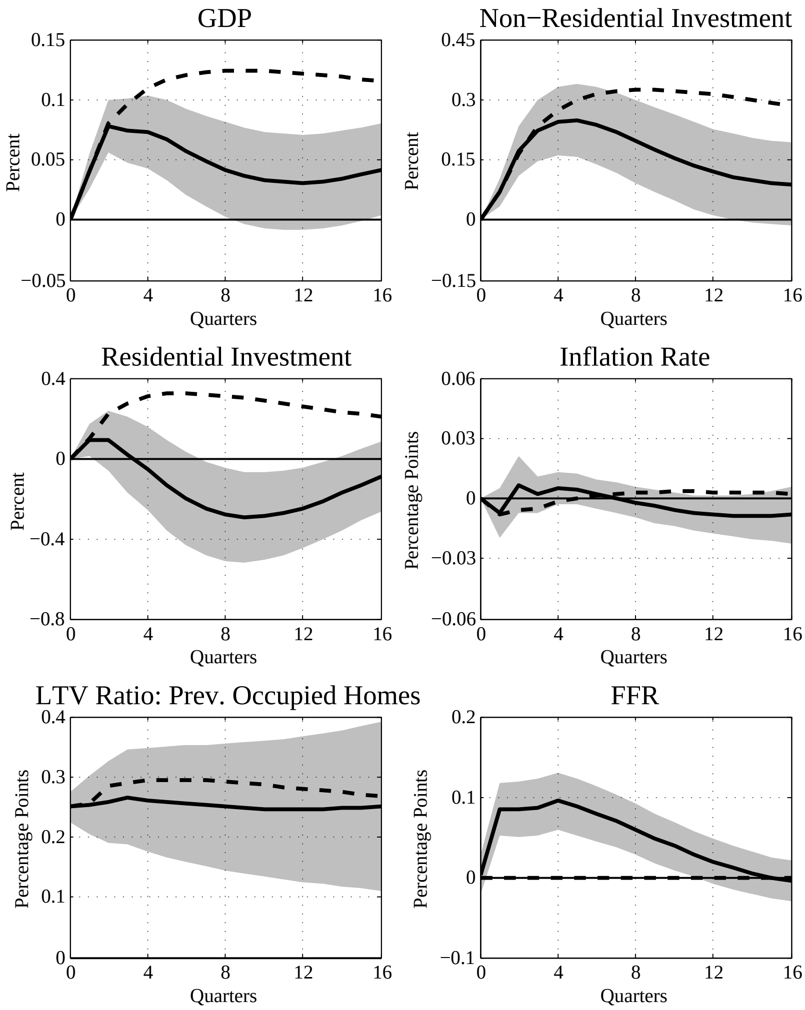
Notes: The x-axis represents time in quarters. The solid lines represent point estimates of impulse response functions for the VAR, using $\boldsymbol{x}_t = [y_t \ i_t^{nr} \ i_t^{r} \ \pi_t \ \Delta ltv_t^{auto} \ r_t]'$, where ltv_t^{auto} is the LTV ratio series for new car loans at auto finance companies from FRED, with series identifier DTCTLVNLNM (the impulse response function for the LTV ratio is cumulated from the one for Δltv_t^{auto}). We apply the Census X-12 filter to seasonally adjust this monthly LTV series and then use the quarterly average in the VAR. The sample period is 1973Q1-2008Q4, as in the baseline VAR. Shaded areas display one standard deviations confidence intervals obtained from 5,000 replications of the recursive-design wild bootstrap procedure of Goncalves and Kilian (2004). The dashed lines represent impulse responses for the case of a passive monetary policy authority that does not react to the shock at all, as in Bernanke et al. (1997) and Sims and Zha (2006).

Figure A.2: Shock to LTV ratios for newly built home mortgages



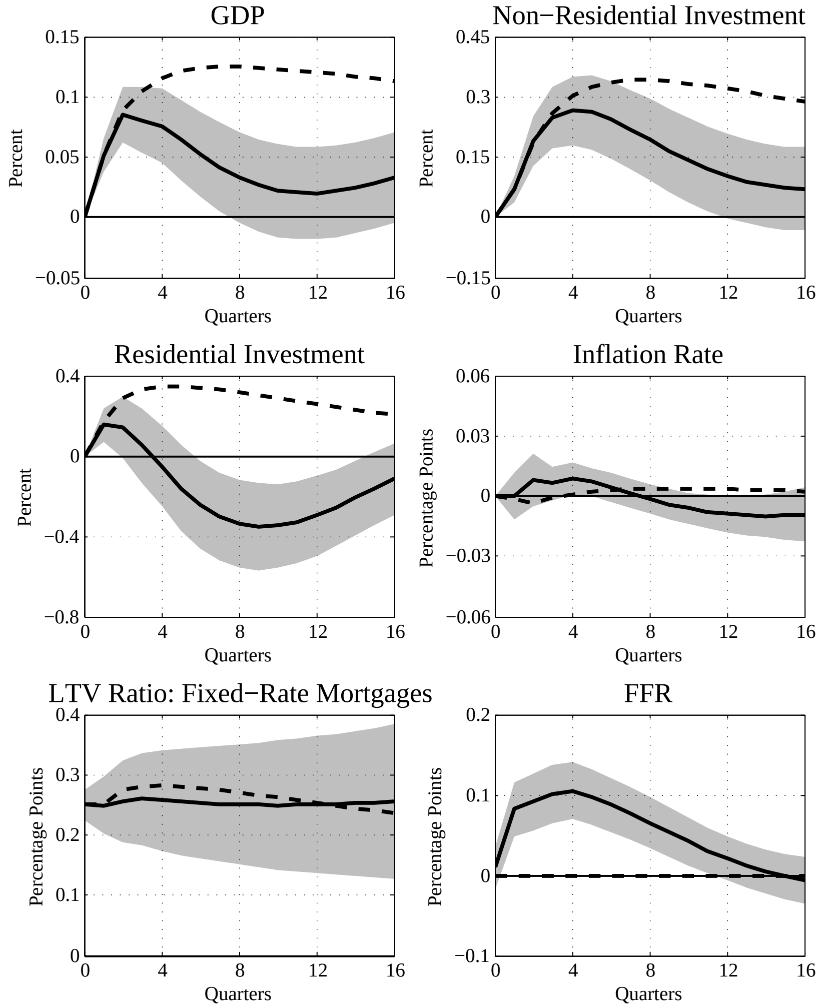
Notes: The x-axis represents time in quarters. The solid lines represent point estimates of impulse response functions for the VAR, using $\boldsymbol{x}_t = [y_t\ i_t^{nr}\ i_t^{r}\ \pi_t\ \Delta ltv_t^j\ r_t]'$, where ltv_t^j denotes the LTV ratio series of mortgages for newly built homes from the FHFA (the impulse response function for the LTV ratio is cumulated from the one for Δltv_t^j). Shaded areas display one standard deviations confidence intervals obtained from 5,000 replications of the recursive-design wild bootstrap procedure of Goncalves and Kilian (2004). The dashed lines represent impulse responses for the case of a passive monetary policy authority that does not react to the shock at all, as in Bernanke et al. (1997) and Sims and Zha (2006).

Figure A.3: Shock to LTV ratios for previously occupied home mortgages



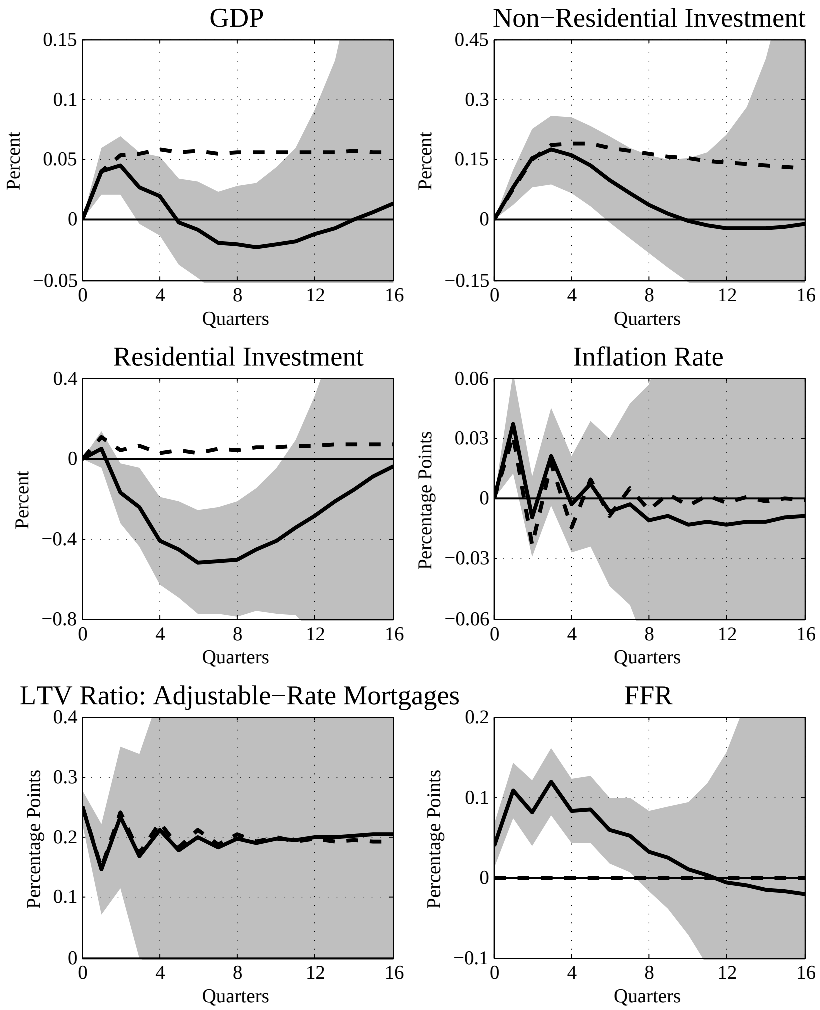
Notes: The x-axis represents time in quarters. The solid lines represent point estimates of impulse response functions for the VAR, using $\boldsymbol{x}_t = [y_t \ i_t^{nr} \ i_t^{r} \ \pi_t \ \Delta ltv_t^j \ r_t]'$, where ltv_t^j denotes the LTV ratio series of mortgages for previously occupied homes from the FHFA (the impulse response function for the LTV ratio is cumulated from the one for Δltv_t^j). Shaded areas display one standard deviations confidence intervals obtained from 5,000 replications of the recursive-design wild bootstrap procedure of Goncalves and Kilian (2004). The dashed lines represent impulse responses for the case of a passive monetary policy authority that does not react to the shock at all, as in Bernanke et al. (1997) and Sims and Zha (2006).

Figure A.4: Shock to LTV ratios for fixed-rate mortgages



Notes: The x-axis represents time in quarters. The solid lines represent point estimates of impulse response functions for the VAR, using $\boldsymbol{x}_t = [y_t \; i_t^{nr} \; i_t^{r} \; \pi_t \; \Delta ltv_t^j \; r_t]'$, where ltv_t^j denotes the LTV ratio series for fixed-rate mortgages from the FHFA (the impulse response function for the LTV ratio is cumulated from the one for Δltv_t^j). Because this series is only available from 1986Q1, we fill in the rest by backcasting it to 1973Q1, using the overall LTV ratio together with the series on newly built and previously occupied homes. Shaded areas display one standard deviations confidence intervals obtained from 5,000 replications of the recursive-design wild bootstrap procedure of Goncalves and Kilian (2004). The dashed lines represent impulse responses for the case of a passive monetary policy authority that does not react to the shock at all, as in Bernanke et al. (1997) and Sims and Zha (2006).

Figure A.5: Shock to LTV ratios for adjustable-rate mortgages



Notes: The x-axis represents time in quarters. The solid lines represent point estimates of impulse response functions for the VAR, using $\boldsymbol{x}_t = [y_t\ i_t^{nr}\ i_t^{r}\ \pi_t\ \Delta ltv_t^j\ r_t]'$, where ltv_t^j denotes the LTV ratio series for adjustable-rate mortgages from the FHFA (the impulse response function for the LTV ratio is cumulated from the one for Δltv_t^j). Because this series is only available from 1986Q1, we fill in the rest by backcasting it to 1973Q1, using the overall LTV ratio together with the series on newly built and previously occupied homes. Shaded areas display one standard deviations confidence intervals obtained from 5,000 replications of the recursive-design wild bootstrap procedure of Goncalves and Kilian (2004). The dashed lines represent impulse responses for the case of a passive monetary policy authority that does not react to the shock at all, as in Bernanke et al. (1997) and Sims and Zha (2006).