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

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

March 1, 2016

Abstract

What are the macroeconomic consequences of changes in residential mortgage market loan-to-value (LTV) ratios? In a structural VAR, real GDP and business investment increase significantly following an expansionary LTV shock. The impact on residential investment, however, is contingent on the systematic reaction of monetary policy. Historically, the FED responded directly to lower collateral requirements by significantly raising the policy instrument, thereby increasing mortgage rates and reducing residential investment. In a counterfactual policy experiment, where the Federal Funds rate remains constant after the shock, the reaction of non-residential GDP components is magnified and residential investment increases significantly. While firms increase their borrowing after a relaxation of bank lending standards, whether monetary policy reacts endogenously or is held constant, household debt only increases in an environment of a counterfactually constant Federal Funds rate.

Keywords: Loan-to-value ratio, monetary policy, residential investment.

JEL codes: E30, E44, E52.

“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.”

Stanley Fischer, Macroprudential Monetary Policy Conference
at the Federal Reserve Bank of Boston, October 2, 2015

1 Introduction

What are the macroeconomic consequences of exogenous changes in residential mortgage market loan-to-value (LTV) ratios? The most recent cycle in US housing markets saw a relaxation and subsequent contraction of borrowing constraints, leading many observers to attribute the exceptional growth in residential investment and the skyrocketing mortgage leverage to the loosening of collateral requirements. In addition, many policymakers seem to perceive movements in LTV ratios as autonomous drivers of housing markets, with supervisory limits on LTV ratios representing the most prevalent macroprudential policy tool in advanced economies.¹ However, little is known about the macroeconomic consequences of autonomous variations in LTV ratios.

The aim of this paper is to empirically identify the impact of exogenous shifts in LTV ratios on aggregate economic activity, and, in particular, investment activity and the leverage of households and firms, and, moreover, to shed light on the interaction between movements in LTV ratios and systematic monetary policy reactions.² Our empirical strategy consists of estimating structural vector autoregressions (VARs), which allow the identification of exogenous shocks to LTV ratios by employing only a few theoretical restrictions. To measure LTV ratios, we rely on survey data from the Federal Housing Finance Agency (FHFA), which polls a sample of US mortgage lenders to report terms and conditions on lending standards for conventional mortgages within the Monthly Interest Rate Survey (MIRS), representing the most extensive source of information for this segment. We isolate exogenous shifts in LTV ratios from endogenous reactions to other macroeconomic fluctuations by imposing a recursive Cholesky identification scheme. Consistent with 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.

After an expansionary 25 basis point LTV shock, the LTV ratio rises quite persistently, and we find positive spillovers to non-residential aggregate quantities, with

¹See also the quote at the beginning of IMF (2011) and Claessens (2014) for a summary of macroprudential tools and their implementation across countries.

²Our paper is thus related to a recent literature that studies the effects of shocks to bank lending standards and financial market conditions on the macroeconomy (e.g., Gilchrist and Zakrajsek, 2012; Bassett et al., 2014; Walentin, 2014; Peersman and Wagner, 2015). In contrast to the existing literature, we focus specifically on the housing market and on lending conditions in terms of quantities rather than spreads. Also, this is the first paper that includes a systematic analysis of the impact of monetary policy reacting to credit conditions.

business investment rising significantly by 0.3 percent after a year, and real GDP increasing by approximately 0.1 percent. The picture is different, however, for residential investment: after a small initial increase, residential investment significantly turns negative at 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 in the face of the LTV shock. Indeed, the Federal Funds rate responds to the more expansionary lending standards with a hump-shaped tightening of 10 basis points, counteracting the eased *quantity* restriction on mortgage loans. In addition, the endogenous policy contraction significantly passes through to mortgage rates – raising the *price* of mortgage loans – and, furthermore, is anticipated by households as measured by expectations on 12 months ahead financing conditions from the Michigan Survey of Consumers.

We analyze the systematic monetary policy response along two further dimensions. First, to answer the question, what the FED is actually responding to after a LTV easing, we perform an impulse response decomposition as in Kilian and Lewis (2011). At any horizon, the deviation of the Federal Funds rate from its conditional mean can be considered as a sum of the reaction to its own lags and of the reaction to realizations of other variables in the VAR. Thus the impulse response decomposition reveals, which variables trigger the policy tightening. As the LTV shock features 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. In contrast, based on the impulse response decomposition, the policy response is better characterized as a *direct* response to the altered financial sector conditions, rather than an *indirect* response operating through the shock propagation via other variables in the system. For short horizons, the LTV ratio itself accounts for the systematic interest rate contraction almost entirely and for longer horizons, lags of the Federal Funds rate explain the majority of the policy response. We conjecture that banks’ lending standards, as represented by LTV ratios, thus, are part of the FED’s reaction function. Second, to isolate the marginal impact of systematic monetary policy in the transmission of a LTV shock to the broader economy, we rely on policy counterfactuals as 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 creating a hypothetical economy, for which we “shut down” the FED’s interest rate reaction to a LTV shock. By generating hypothetical sequences of *exogenous* monetary policy surprises that completely offset the *endogenous* Federal Funds rate response, the policy instrument remains constant over the whole forecast horizon.³ Differences between the unrestricted and the hypothetical economy, then, indicate the quantitative importance of the systematic policy tightening. We find that the non-residential investment response is magnified by the passive monetary policy stance. More importantly, however, with a hypothetically fixed interest rate, residential investment exhibits a quite persistent increase

³The structural representation of the VAR allows the identification of counteracting monetary policy shocks with a well-established recursive identification scheme as in, e.g., Bernanke et al. (1997), Christiano et al. (2005), and Erceg and Levin (2006). Following 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.

peaking at around 0.4 percent after a year and deviates statistically significant from the unrestricted economy from quarter 3 onwards. The systematic monetary policy response, hence, determines residential investment activity not only quantitatively, but also qualitatively. This evidence of a strong interest rate sensitivity of residential investment is in line with, e.g., Erceg and Levin (2006), Monacelli (2009), and Calza et al. (2013).

We also analyze the LTV shock propagation into 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.⁴ 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 bank lending conditions, *firms* strongly increase their leverage, measured either by total bank loans or mortgage loans. This propensity to leverage is not affected by the monetary policy reaction. We infer that for firms, the quantity restriction on loans, i.e., the LTV ratio, dominates the price effects on short-term and mortgage interest rates, which are influenced by monetary policy. In contrast and resembling the evidence for residential investment, the evolution of *household* debt is contingent on the Federal Funds rate reaction. LTV shocks coincide with an insignificant and even negative impact on household debt even has the Federal Funds rate and mortgage rate rises. 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 seem to have a strong impact on leverage.⁵ Household leverage, however, increases under a hypothetically fixed interest rate policy, making the shock transmission through the monetary policy instrument, i.e., the systematic interest rate reaction, the crucial channel how LTV shocks affect household leverage.

We interpret shifts in residential LTV ratios as a *supply* indicator of banks' (mortgage) lending. This conclusion is supported by an exercise in the spirit of Bassett et al. (2014), which consists of removing influences of financial sector and macroeconomic conditions from the *raw* LTV series that might drive lending standards, but at the same time might independently affect the *demand* for residential mortgage loans. We find that, first, the impact of such factors on the LTV ratio is rather small and for the majority of control variables insignificant and, second, the macroeconomic consequences of shocks to the *purged* LTV ratio are very similar to specifications in which we employ the raw LTV series. Furthermore, shifts in residential mortgage market loan supply – as reflected by, both, the raw or the purged LTV series – feature significant spillovers to non-residential aggregates. Hence, we view residential mortgage LTV ratios as an indicator of banks' lending propensity in a broad sense rather than being indicative, exclusively, for lending standards in mortgage markets.

Finally, the residential mortgage LTV ratio evidence represents all home owners, i.e., first time as well as repeated home buyers. While Mian and Sufi (2011) show that *existing home owners* contributed substantially to the most recent leverage

⁴See, among others, Iacoviello (2005), Monacelli (2009), and Iacoviello and Neri (2010).

⁵Similarly, Midrigan and Philippon (2016) argue that monetary policy seems to counteract shocks to household debt outside of zero lower bound episodes.

cycle as about 65 percent of households already owned a property prior to the cycle and over-borrowing characterized this group, Duca et al. (2011, 2013) stress the importance of *first time home owners* as being particularly subject to collateral constraints. These authors calculate a cyclically adjusted LTV series only for the group of first time home buyers with American Housing Survey data. Although the results are – due to noise in first time home buyer data – not quite as clear-cut, the qualitative evidence for first time home buyers is very close to the results for all home owners.

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 proposes possible extensions and reviews the results along some robustness dimensions. Section 4 concludes the paper.

2 LTV shocks and monetary policy

This section presents the methodological framework and the main empirical findings. Section 2.1 describes the data. Section 2.2 provides the VAR identification strategy and presents empirical evidence for LTV shocks. Section 2.3 characterizes the systematic monetary policy response to LTV shocks in detail and isolates the policy reaction in a counterfactual analysis. Section 2.4 analyzes the role of households' and firms' leverage.

2.1 Data

We study the effects of autonomous movements in banks' lending standards as reflected by mortgage LTV ratios on aggregate economic, in particular, investment activity and the stance of monetary policy. Accordingly, a parsimonious benchmark model comprises four variables in quarterly frequency: non-residential investment (i_t^{nr}), residential investment (i_t^r), a LTV ratio (ltv_t), and a short-term nominal interest rate (r_t). We obtain the investment series from BEA in seasonally adjusted real terms. The monetary policy instrument is the quarterly average of the effective Federal Funds rate.⁶ The sample covers the period 1973Q1 to 2008Q4, where the availability of LTV data dictates the start of the sample. We confine the sample to 2008Q4 when the FED's policy instrument reached the zero lower bound. Since then, the FED engaged in several unconventional policies so that historical policy reaction functions are likely to no longer be valid during the financial crisis episode (see, e.g., Kilian and Lewis, 2011; Peersman and Wagner, 2015).

The benchmark LTV measure is the quarterly average of the seasonally adjusted monthly LTV ratios on conventional mortgage loans from the Monthly Interest Rate Survey (MIRS) conducted by the Federal Housing Finance Agency (FHFA), which provides the most extensive data on terms and conditions of mortgages for the US. For instance, at the end of our sample in 2009, the survey covers information based on more than 82,000 loan contracts. The survey polls a sample of mortgage lenders

⁶We use the BEA investment measures from NIPA Table 1.1.3., lines 9 and 13. The Federal Funds rate is from FRED database with the series ID: FEDFUNDS.

(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.⁷ As part of the survey, mortgage lenders are asked to report the agreed LTV ratios at purchase of the properties. Importantly, these LTV ratios include all types of home owners, i.e., owner occupiers as well as first time home buyers.⁸

Figure 1 plots the FHFA LTV series, i.e., the average ratio of granted mortgage loans for single family houses and the underlying property prices multiplied by 100, across time. The shaded areas represent NBER dated recession episodes in the US. The LTV ratio is procyclical and characterized by pronounced swings. Borrowing limits dramatically eased during the housing boom of the years 2002 to 2006, even though LTV ratios did not reach the levels seen at the end of 1994. This is partly driven by existing home owners, which used their increased housing wealth to roll over into new properties with lower average LTV ratios. At the onset of the Great Recession LTV ratios tightened sharply.

[INSERT FIGURE 1 HERE]

2.2 Identification of LTV shocks

This section outlines the structural VAR and presents results for LTV shocks.

2.2.1 Structural VAR

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

$$\mathbf{A}_0 \mathbf{x}_t = \sum_{l=1}^p \mathbf{A}_l \mathbf{x}_{t-l} + \boldsymbol{\varepsilon}_t, \quad (1)$$

where we drop the intercept without loss of generality for notational convenience. \mathbf{A}_l is a $n \times n$ matrix including autoregressive coefficients at lag, $l = 1, \dots, p$, and \mathbf{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 \mathbf{x}_t comprises the following n variables in this order, $\mathbf{x}_t = [i_t^{nr} \ i_t^r \ \Delta ltv_t \ r_t]'$.

We need to restrict elements in \mathbf{A}_0 , to disentangle exogenous LTV movements from endogenous reactions to other variables in \mathbf{x}_t , i.e., to uniquely recover the structural VAR. LTV shocks then have the interpretation as innovations in the banking industry. Such innovations could arise from internal reassessments of the quality of

⁷The 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.

⁸According to Mian and Sufi (2011), existing home owners contributed substantially to the buildup in household leverage during 2002 to 2006, while Duca et al. (2011, 2013) stress the importance of first time home owners. We analyze first time home buyer data in Section 3.2.

borrowers, new business models, or shifts in the supervisory and regulatory environment under which banks 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 (ltv_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, \mathbf{u}_t . Then we use the Cholesky factor for \mathbf{A}_0 , which delivers the linear mapping $\mathbf{u}_t = \mathbf{A}_0^{-1}\boldsymbol{\varepsilon}_t$ and recovers the structural representation. Within the recursive identification scheme, we allow LTV shocks, $\varepsilon_{L,t}$, to simultaneously cause shifts in the monetary policy instrument, where the subscript L is the position of ltv_t in \mathbf{x}_t . However, results are not sensitive to, e.g., ordering the Federal Funds rate, r_t , before ltv_t such as to prevent an immediate impact of LTV shocks on monetary policy (see Section 3.4).

As in Gilchrist and Zakrajsek (2012) and Bassett et al. (2014), we estimate the VAR with two lags of the endogenous variables – a lag length suggested by, both, the Schwarz and Hannan-Quinn information criterion. Results are, however, robust to higher lag orders (see Section 3.4). i_t^{nr} and i_t^r enter the VAR as natural logarithms (multiplied by 100) and we measure r_t in percent. For the LTV ratio, the Null hypothesis of a unit root cannot be rejected based on, e.g., the augmented Dickey-Fuller test. Thus we include ltv_t in first differences.⁹ To illustrate the dynamics of LTV in the VAR, we then present cumulative impulse responses for this variable, which we can interpret as LTV changes in percentage points.

2.2.2 LTV shocks: empirical evidence

Figure 2 traces out the adjustment patterns of variables in \mathbf{x}_t following an exogenous 25 basis point increase in LTV ratios. 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 stabilizing at the 25 basis point level, i.e., the exogenous shock has a fairly permanent effect on the LTV ratio. The shock significantly affects business 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. In contrast, the impulse response of residential investment rises by 0.15 percent in the first quarter, but then significantly falls by 0.4 percent until it reaches its trough after two and a half years before slowly reverting back to its pre-shock level. This result is perhaps surprising as it is inconsistent with the view that loose LTV ratios lead to construction booms, and, perhaps, housing bubbles. But why does a shock that eases borrowing constraints in the residential mortgage market coincide with a slowdown of residential investment? The impulse response in the lower right panel of Figure 2 represents a candidate answer. Monetary policy reacts to the eased lend-

⁹We find very similar results for specifications of LTV in levels. In addition, we also use specifications, in which all variables – except for interest rates – enter the VAR as first differences (see Section 3.4).

ing standards by significantly raising the Federal Funds rate by more than 10 basis points. This finding is consistent with Bassett et al. (2014), who report a significant reaction of monetary policy after a shock to their broadly defined indicator of banks' loan supply, and with Walentin (2014), who finds a monetary policy easing after contractionary mortgage spread shocks.

[INSERT FIGURE 2 HERE]

The persistent contractionary shift in monetary policy counteracts the initial easing in mortgage markets and may be dominating the expansionary effects of the LTV increase, at least, with respect to residential investment. The literature (e.g., Erceg and Levin, 2006; Monacelli, 2009; Calza et al., 2013) supports this hypothesis by documenting a strong interest rate sensitivity of consumer durables and residential investment, for which the impact of monetary policy shocks is several times larger compared to non-housing related GDP components.

We examine the monetary policy reaction hypothesis along two further dimensions. First, we analyze whether the endogenous interest rate hike is part of the information set of households, i.e., whether housing investors anticipate the adverse interest environment, 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 expectations (r_t^e), which we obtain from the Michigan Survey of Consumers. On a monthly basis, the survey asks consumers the following question: *“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, where positive values indicate a less favorable expected interest rate environment. We re-estimate the VAR with these additional variables ordered as follows $\mathbf{x}_t = [i_t^{nr} \ i_t^r \ \Delta ltv_t \ r_t \ r_t^m \ r_t^e]'$. The recursive ordering allows the Federal Funds rate to pass through to mortgage rates contemporaneously (Bernanke et al., 1997) as well as expectations to adjust to macroeconomic and financial conditions on impact. Figure 3 presents the LTV shock propagation into the newly introduced variables, where we omit the benchmark variables (that are barely affected by the new specification) to conserve space. We report the cumulative impulse response of interest expectations to recover the qualitative expectations on 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 LTV ratios on mortgage loans (quantities). The policy reaction, in addition,

is reflected by consumers' qualitative expectations on borrowing conditions, which move instantaneously and remain significantly positive for more than a year. The evidence of both variables supports the perception of systematic monetary policy being a candidate to explain 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 and, second, by performing a counterfactual analysis, which is meant to illustrate the quantitative importance of the monetary policy response.

2.3.1 What drives the monetary policy reaction?

Before we isolate the marginal effect of the systematic monetary policy reaction, it is instructive to analyze which variables in the VAR actually trigger the policy reaction, i.e., what is the central bank responding to after a LTV shock. We do so by decomposing the impulse response of the FED's policy instrument into contributions from all variables in \mathbf{x}_t , as in Kilian and Lewis (2011). 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 measures in \mathbf{x}_t from their steady state values. The relative contributions of variables in \mathbf{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

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

where the $n \times n$ matrix \mathbf{C} is strictly lower triangular. Furthermore, we can compactly summarize the structural parameters as $\mathbf{B} = [\mathbf{C} \ \mathbf{A}_1 \ \dots \ \mathbf{A}_p]$.

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

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

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

Given the FED's objective of macroeconomic stabilization and taking its "dual mandate" into account, we augment the benchmark model 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 also study the contributions

of these variables to the policy response.¹⁰ The augmented model incorporates the following six variables in the following order $\mathbf{x}_t = [y_t \ i_t^{nr} \ i_t^r \ \pi_t \ \Delta ltv_t \ r_t]'$.

The upper panels of Figure 4 plot the dynamics of y_t and π_t after the 25 basis point disturbance to the LTV ratio. Real GDP displays a hump-shaped rise of 0.1 percent, which peaks in quarter two and becomes insignificant from quarter five onwards. The impact on the inflation rate is economically small and statistically insignificant for two and a half years. Then the inflation response becomes significantly negative for a year before finally reverting back to its steady state level. 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” of inflationary pressure. Indeed, the lower panels of Figure 4 reject such a narrative as well as a “curbing the output boom” story: The endogenous monetary policy contraction is a *direct* response to the LTV shock, rather than an *indirect* response operating through other variables, in particular, output or inflation in the VAR. In the first quarter after the shock, the LTV ratio accounts for the majority of the FFR response (line with nodes) and for subsequent horizons, the lags of FFR itself explain the FFR response almost entirely (dashed line). The contributions of output, inflation, and both investment measures appear to be negligible. Apparently, lending standards in the banking industry as reflected by mortgage LTV ratios are part of the FED’s reaction function and a move against more expansionary lending practices drives the policy instrument following the LTV shock. The interest rate contraction, hence, explicitly captures the interaction of monetary policy with financial market conditions rather than just being reflective of the current state of the economy.

[INSERT FIGURE 4 HERE]

2.3.2 Shutting down the monetary policy response

To flesh out the impact of the Federal Funds rate reaction, we follow the methodology of creating policy counterfactuals as 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). The procedure consists of analyzing the dynamics of variables in the VAR model for a hypothetical economy, for which we completely remove the impact of the LTV shock from the FED’s reaction function, i.e., where the FED does not react to the LTV shock and its effects, at all. To create such an environment, we generate hypothetical sequences of monetary policy shocks that suffice to completely “shut down” the Federal Funds rate response after the LTV shock. The counterfactual economy features the same structural characteristics as the benchmark economy, however, in the face of the LTV shock, the former economy is subject to a sequence of counteracting *exogenous* monetary policy disturbances that “zero out” the *endogenous* policy response.

¹⁰We use the BEA real GDP series from NIPA Table 1.1.3., line 1. The inflation rate is the quarterly change of the Consumer Price Index with the series ID: CPIAUCSL, which we obtain from FRED database.

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

$$\boldsymbol{\varepsilon}_{F,h} = - \sum_{j=1}^n \mathbf{B}_{F,j} \mathbf{y}_{j,F} - \sum_{m=1}^{\min(p,h)} \sum_{j=1}^n \mathbf{B}_{F,mn+j} \mathbf{z}_{j,h-m}. \quad (4)$$

$\mathbf{y}_{j,0}$ is the time $t = 0$ impact of the LTV disturbance on variable j in the benchmark VAR, whereas the same impact in the counterfactual economy reads

$$\mathbf{z}_{j,0} = \mathbf{y}_{j,0} + \frac{\boldsymbol{\Phi}_{j,F,0} \boldsymbol{\varepsilon}_{F,0}}{\sigma_F}. \quad (5)$$

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

$$\mathbf{y}_{j,h} = \sum_{m=1}^{\min(p,h)} \sum_{i=1}^n \mathbf{B}_{j,mn+i} \mathbf{z}_{j,h-m} + \sum_{i<j}^n \mathbf{B}_{j,i} \mathbf{y}_{i,h} \text{ and } \mathbf{z}_{j,h} = \mathbf{y}_{j,h} + \frac{\boldsymbol{\Phi}_{j,F,0} \boldsymbol{\varepsilon}_{F,h}}{\sigma_F}. \quad (6)$$

The benchmark VAR model allows us to identify the structural monetary policy shocks, $\boldsymbol{\varepsilon}_{F,t}$, following the well established approach of the previous literature (e.g., Bernanke et al., 1997; Christiano et al., 2005; Erceg and Levin, 2006). By imposing the Cholesky factor of the variance-covariance matrix of \mathbf{u}_t on \mathbf{A}_0 and maintaining the ordering of variables as $\mathbf{x}_t = [i_t^{nr} \ i_t^r \ \Delta ltv_t \ r_t]'$, we identify monetary policy shocks with the following implicit assumptions. First, monetary policy shocks do not affect other variables in the system on impact and, second, contemporaneous as well as previous realizations of all variables in \mathbf{x}_t are reflected by the FED's time t information set.¹¹

The solid line in Figure 5 plots adjustment patterns of variables in \mathbf{x}_t after a LTV shock together with one standard error confidence intervals (shaded area) for the benchmark economy. The dashed line represents impulse response functions for a counterfactual economy, in which monetary policy does not respond to the dynamics triggered by the LTV shock at any horizon as in Bernanke et al. (1997) and Sims and Zha (2006). By definition, the impulse response of r_t is zero over the whole forecast horizon in the counterfactual experiment and, as a consequence of passive monetary policy, ltv_t features a stronger and more persistent increase compared to the benchmark economy. In a statistical sense, though, the counterfactual response of ltv_t is not different from the benchmark response. Non-residential investment, i_t^{nr} , also increases more strongly and more persistently in the absence of the policy tightening. The dynamics of residential investment, i_t^r , are most affected by the altered monetary policy regime. In the counterfactual economy, i_t^r continues the initial surge of the benchmark case by further increasing in a hump-shaped manner

¹¹An identified monetary policy shock in our structural VAR features hump-shaped responses of i_t^{nr} and i_t^r , where the amplitude of the latter is about twice as large (see, e.g., Erceg and Levin, 2006; Calza et al., 2013). ltv_t significantly and sluggishly falls after a contractionary monetary policy disturbance, giving rise to some "risk-taking channel" of monetary policy. We do not report the impulses to conserve space. Results are available upon request.

to almost 0.4 percent after one year. The response then remains strictly positive over the whole forecast horizon, whereas in the benchmark economy i_t^r turns negative after one year. 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. This finding is consistent with the strong interest sensitivity of the housing sector documented in, e.g., Erceg and Levin (2006), Monacelli (2009), and Calza et al. (2013).

Our results suggest that an exogenous loosening of LTV ratios cannot explain a boom in residential investment at least in times of conventional monetary policy. From a macroprudential perspective, the evidence represents a caveat for the use of supervisory limits on LTV ratios as a tool to curb overheating housing markets, again, at least in times of conventional monetary policy.¹² More generally, the efficacy of such policy measures seems to be contingent on the reaction function of monetary policy; macroprudential policy measures, therefore, should be designed to take into account interactions with monetary policy.

[INSERT FIGURE 5 HERE]

2.4 Leverage of households and firms

We next analyze the implications of loosened collateral requirements on mortgage loans for the leverage of households and firms. We do this against the backdrop of the most recent US housing cycle of the years 2000 to 2007, where borrowing of households and firms 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; 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 and explicitly accounts for the role of monetary policy.

To measure household leverage, 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. We obtain the data from the Flow of Funds database and use the GDP deflator to transform them into real terms (see Justiniano et al., 2015). With respect to firm leverage, we focus on bank provided loans to non-financial businesses (b_t^f), which we also obtain from the Flow of Funds database. Both debt series are stock variables, i.e., measuring the outstanding amount of loans at the end of each quarter.¹³ We re-estimate the VAR including the

¹²In the face of the Great Recession a number of countries introduced, tightened, or at least considered the introduction of supervisory limits for LTV ratios as a macroprudential policy tool. Among them are for instance, Canada, the Netherlands, Norway, Sweden, or the United Kingdom (IMF, 2011).

¹³The Flow of Funds identifiers are: Z1/Z1/FL144123005.Q for non-financial business loans, Z1/Z1/LA153165105.Q for home mortgages, and Z1/Z1/LA153166000.Q for consumer credit of

following variables in this order $\mathbf{x}_t = [i_t^{nr} \ i_t^r \ \Delta ltv_t \ \Delta b_t^f \ \Delta b_t^h \ r_t]'$. 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 6 plots the impulse responses of the debt augmented model, both for the unrestricted (solid line) and the counterfactual (dashed line) economy. The benchmark variables, i_t^{nr} , i_t^r , ltv_t , and r_t are hardly affected by the introduction of business loans and household debt. Bank loans to the non-financial business sector display a pronounced increase, which is significant over the whole forecast horizon, i.e., firms quickly and persistently take advantage of the loosened availability of loans in an economically meaningful manner. In contrast, household debt does not react significantly to the shock, where the point estimate of the impulse response function is even negative. Turning to the results for the counterfactual economy (dashed line) in which the FED remains passive in the face of the LTV shock, no significant differences emerge for the evolution of business loans. Thus the *price* of loans – indirectly influenced by the systematic monetary policy tightening – appears to be second order for firms’ propensity to borrow from banks, whereas the relaxation of the *quantity* restriction on loans, i.e., the LTV ratio, interpreted as a broader indicator of loan supply, emerges as the dominating factor. Shutting down the monetary policy tightening, however, crucially alters the leverage of the household sector. For the counterfactual economy, household debt is slowly building up after an initial dip and is statistically different from the benchmark economy for more than six quarters. In our data sample and with respect to all sectors of the US economy, households hold more than 95 percent of single family mortgage loans and account for more than 85 percent of all home mortgages (single *and* multifamily properties), on average. The strong interest rate sensitivity of households’ leverage thus rationalizes the differences in the counterfactual impulse responses for residential investment, which display the same qualitative behavior as households’ debt dynamics. Restricting the analysis only to mortgage loans for households and firms, reveals similar qualitative results, i.e., following a loosening of borrowing constraints, firms increase mortgage loans independent from the monetary policy response, whereas households reduce their mortgages in the historical experiment and increase their mortgage leverage in the counterfactual economy.¹⁴

[INSERT FIGURE 6 HERE]

3 Extensions and robustness

In this section, we reassess our main findings along the following dimensions. In Section 3.1, we test the validity of the benchmark LTV measure as an supply indicator of bank lending. Section 3.2 examines the effects of a LTV shock only for the

households and nonprofit organizations, where we apply the Census X-12 filter to seasonally adjust the series, which are not already adjusted in the Flow of Funds database. To deflate the debt series, we use the GDP deflator from FRED database with the series ID: GDPDEF.

¹⁴The Flow of Funds identifier for non-financial business mortgages is Z1/Z1/FL143165005.Q.

group of first time home buyers, and Section 3.3 provides an alternative procedure of creating policy counterfactuals in the VAR framework. Section 3.4 presents some robustness checks on the VAR specification and identification.

3.1 LTV ratio – a loan “supply” indicator?

To this point, we interpret identified exogenous shifts in LTV ratios as an indicator of changes in the effective mortgage loan *supply* of banks. However, given the endogeneity of the LTV ratio, such shifts could also, at least to some extent, be reflective of variations in loan *demand* of borrowers. Using data on changes of banks’ lending standards from the FED’s Senior Loan Officer Opinion Survey (SLOOS), Bassett et al. (2014) propose a procedure to purge loan supply measures from influences that, on the one hand, drive loan supply, but on the other hand, might independently affect loan demand. We apply their methodology to the raw LTV series and remove effects of variables capturing (a) the current state of the economy, (b) the economic outlook or economic uncertainty, and (c) general financial sector conditions. Then we test the macroeconomic predictions of exogenous shocks to the adjusted LTV measure in the benchmark VAR.

We adjust the LTV ratio for the following factors. To control for changes in lending standards that are reflective of the *current state of the economy*, we follow Bassett et al. (2014) and account for the four quarter change of real GDP, $y_t - y_{t-4}$, the four quarter change of the unemployment rate, $u_t - u_{t-4}$, and the quarterly change in the real Federal Funds rate, Δrr_t . We calculate rr_t as the difference between the quarterly average of the Federal Funds rate and the realization of price inflation in period t . The latter is represented by the period $t - 1$ log level of the core PCE price index less the respective realization a year before. According to, e.g., the SLOOS evidence in Bassett et al. (2014), another important driver of changes in banks’ lending practices is the *outlook about the future evolution of the economy*. Thus we purge the LTV series from the 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, $\Delta tspr_t$, which we measure as the slope of the yield curve for US Treasuries with constant maturity, i.e., the spread between three month and ten year Treasury yields. Inter alia, this spread captures expectations on the future evolution of policy rates. Finally, we control for the following indicators reflecting *financial sector conditions*. First, we include the change in the credit spread index, $\Delta cspr_t$, 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 and is shown to have a good predictive capability for measures of real economic activity. 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 change in private depository institutions’ net worth, Δnw_t , from the Flow of Funds database to account for the influence of banks’ capital position on lending policies.

We run a regression of Δltv_t on the described set of control variables to purge the LTV ratio from these factors. We perform the estimation by ordinary least squares and report Newey-West standard errors in parentheses. The resulting equation reads

$$\begin{aligned} \Delta ltv_t = & \underset{(0.28)}{0.10} - \underset{(0.27)}{0.46}\mathbb{E}_{t-1}\{u_{t+4} - u_t\} - \underset{(0.30)}{0.42}(u_t - u_{t-4}) - \underset{(9.49)}{1.51}\mathbb{E}_{t-1}\{y_{t+4} - y_t\} \\ & - \underset{(0.11)}{0.08}(y_t - y_{t-4}) + \underset{(0.09)}{0.04}\Delta rr_t - \underset{(0.17)}{0.14}\Delta tspr_t + \underset{(0.0003)}{0.0006}\Delta nw_t - \underset{(0.49)}{0.15}\Delta ebp_t \quad (7) \\ & - \underset{(0.36)}{0.23}\Delta cspr_t + \varepsilon_t^{ltv}, \end{aligned}$$

where the residual of the regression, ε_t^{ltv} , denotes the “cleaned up” LTV series. Except for changes in the expected unemployment rate and banks’ net worth, non of the controls is significant at the 10 percent level and with an adjusted R^2 of 0.098, the overall explanatory power of the regressors is weak. This supports the notion of the raw LTV series being a fairly clean measure of movements in banks’ *loan supply*, which is not substantially contaminated by *demand factors*. The finding of a significant negative impact of the expected change in the unemployment rate on Δltv_t is consistent with Duca et al. (2011), who report a negative correlation and a significant causal impact of changes in the unemployment rate on first time homeowner LTV ratios in a related exercise. Surprisingly, both measures of real GDP, i.e., the expected and four quarter change, also exert a negative influence on Δltv_t . However, both slope coefficients are far from being significant as in Bassett et al. (2014). The slopes for the remaining control variables are qualitatively consistent with Bassett et al. (2014), but all insignificant. A tightening of the effective real Federal Funds rate coincides with an easing of Δltv_t , which could be due to the signaling effect of better economic fundamentals as reflected by Δrr_t . Higher risk aversion of banks, i.e., an increase in Δebp_t , leads to lower LTV ratios and thus more cautious lending. Expectations on a future tightening of monetary policy ($\Delta tspr_t$) as well as increases in financial market tensions and perceived default risks ($\Delta cspr_t$), furthermore, affect lending policies of banks negatively. Ultimately, a stronger capital position of the commercial banking system, which we measure by changes in banks’ net worth (Δnw_t), allows for statistically significant laxer lending standards, however, this effect is fairly small.

Figure 7 plots the adjusted LTV ratio, ε_t^{ltv} , across time, where we standardize the residual and present a centered five quarter moving average to improve readability. According to the evolution of the purged LTV series, down payment constraints were particularly pronounced following the early 2000 recession and, interestingly, lending standards eased most during the buildup of the latest housing cycle. Now, we use the purged series to review our main empirical findings, i.e., we run the benchmark structural VAR and study the transmission of the LTV shock for the new LTV measure. Figure 8 traces out the adjustment patterns of all endogenous variables in the benchmark VAR following an exogenous shock to the purged LTV series. As in Bassett et al. (2014), the core results are little affected by the removal of factors that might drive loan supply and loan demand simultaneously, i.e., the impulse responses are similar compared to the raw LTV specification. As beforehand, the LTV shock exerts fairly persistent effects on the LTV ratio itself and

raises non-residential investment in a hump-shaped manner, albeit, the persistence is somewhat muted compared to the benchmark case. 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. Shutting down the policy response in the counterfactual economy, again, predicts a stronger reaction of non-residential investment and changes the quantitative and qualitative adjustment pattern of residential investment. The latter rises sluggishly in the counterfactual economy to a similar extent as the non-residential counterpart. In summary, the main findings of this paper are not affected by the purging exercise of Bassett et al. (2014). We therefore conclude that shifts in the raw LTV measure allow for a reasonable interpretation as changes in banks' mortgage loan supply. Furthermore, by featuring significant spillovers to non-residential sectors, the residential mortgage LTV ratio is indicative for shifts in the effective loan supply of banks in a broad sense, rather than in a narrow sense with a focus, solely, on housing markets..

[INSERT FIGURES 7 AND 8 HERE]

3.2 LTV shocks and first time home owners

In this section, we study the dynamics triggered by a LTV shock for an alternative, more limited measure of LTV ratios. 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 most recent house price increase, over-borrowing against home values of this group is crucial to understand the surge in household leverage. Beyond, Duca et al. (2011, 2013) emphasize the role of *first time home owners* for mortgage markets as a major share of this marginal group of home buyers should be subject to credit and collateral constraints. Using data from the American Housing Survey (AHS), they show that employing a measure of first time home buyer LTV ratios in a house price-to-rent ratio approach produces a superior model fit, stronger long run cointegration relations, as well as more precision in the estimation of model parameters. Inter alia, Duca et al. (2011, 2013) adjust the raw first time buyer LTV ratio from AHS for some cyclical indicators as, e.g., the unemployment rate, some seasonal factors, and some exceptional events that might bias their data. We complement their analysis, first, by studying the role of first time home owner LTV ratios for the dynamics of both, residential and non-residential investment, as well as their interaction with monetary policy and, second, by identifying structural LTV shocks, i.e., by recovering the structural VAR representation.

Figure 9 plots the estimated median LTV ratio for first time home buyers adjusted along the lines of Duca et al. (2011, 2013).¹⁵ Due to the availability of AHS data, the sample starts in 1978Q4. The first time home buyer LTV data are noisy since 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

¹⁵We kindly thank the authors for providing us their data.

high as for the benchmark FHFA LTV ratio including repeated home buyers. 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 fluctuated strongly around a constant mean of about 85 percent in the 1980s. From 1990 onwards, first time home buyer LTV ratios steadily increased before reverting at the onset of the Great Recession. On a descriptive level, thus, differences between the FHFA and the adjusted AHS LTV data are marked.

[INSERT FIGURE 9 HERE]

In Figure 10, we show the effects of autonomous changes in first time home buyer LTV ratios in the structural VAR setting. Overall, the macroeconomic effects of a 25 basis point easing in lending standards are – with an order of magnitude about 10 – significantly smaller compared to the FHFA LTV ratio evidence, reflecting the smaller number of first time home buyers. Yet the qualitative behavior of the impulse response functions appears to be consistent with the benchmark specification. Again, the loosening of LTV ratios coincides with fairly persistent movements in LTV ratios, where this effect is only significant for a year. Non-residential investment still increases, whereas we find a contractionary impact on residential investment. Both investment responses are, however, less significant as in the FHFA LTV ratio exercise. Non-residential investment is only significantly positive for a year and the drop in residential investment is only significant at the margin. The Federal Funds rate increases, albeit, insignificantly over the whole forecast horizon. Given the insignificant tightening of monetary policy, the differences for the counterfactual economy are also less pronounced and not statistically significant with counterfactual impulse responses remaining within the confidence intervals of the unrestricted economy. However, the passive monetary policy experiment still predicts more expansionary effects for non-residential investment and an initial surge of residential investment following the LTV shock.

[INSERT FIGURE 10 HERE]

3.3 Alternative policy counterfactual

So far, we rely on the framework of Bernanke et al. (1997) and Sims and Zha (2006) to include the LTV ratio in the FED’s reaction function and to sort out the impact of the systematic policy response in the face of an exogenous shift in LTV ratios. As policy counterfactual, thus, we analyze a hypothetical economy, which features the same economic structure as the unrestricted VAR, but in which counteracting monetary policy surprises completely offset the endogenous interest rate response. This counterfactual assumes that the FED does not react to the impact of the LTV loosening *at all*, i.e., the Funds rate remains constant at any horizon. In an application to exogenous oil price shocks, Kilian and Lewis (2011)

propose an alternative, less restrictive monetary policy counterfactual to isolate the policy response. Following their approach, we study a hypothetical economy in which we only shut down 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 system.

By employing the definitions of $\mathbf{z}_{j,h}$ and $\mathbf{y}_{j,h}$ from Equation 6, we can recursively calculate the sequence of monetary policy shocks required to remove the direct influence of the LTV shock from the FED's reaction function as follows

$$\boldsymbol{\varepsilon}_{F,h} = -\mathbf{B}_{F,L}\mathbf{y}_{L,h} - \sum_{m=1}^{\min(p,h)} \mathbf{B}_{F,mn+L}\mathbf{z}_{L,h-m}, \quad (8)$$

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

Figure 11 traces out the adjustment patterns in the benchmark VAR for the unrestricted economy (solid line), the Kilian and Lewis (2011) counterfactual (dashed line), and the hypothetical economy in which the Federal Funds rate remains constant (line with nodes) as in Bernanke et al. (1997) and Sims and Zha (2006). The experiment of removing only the direct effect of the LTV shock from the monetary policy reaction function (dashed line) still predicts a surge in the policy instrument. Yet, the response is more sluggish and less pronounced compared to the unrestricted economy. Concretely, the direct reaction to the LTV shock accounts for roughly one third of the policy tightening. Due to the still contractionary – but less distinct – interest rate environment in this counterfactual experiment, the deviations from the unrestricted economy are less pronounced for the remaining variables than in the Bernanke et al. (1997) and Sims and Zha (2006) economy. As a matter of fact, all responses in the Kilian and Lewis (2011) counterfactual constitute a compromise solution between the unrestricted economy, on the one hand, and the zero interest rate reaction counterfactual, on the other hand. Regarding the impact on residential investment, we find an increasing impulse response for one and a half years, which subsequently overshoots the pre-shock level somewhat before finally decaying. The initial surge peaks at almost 0.3 percent, which constitutes a larger amplitude than the subsequent overshooting into negative territory by 0.2 percent.

[INSERT FIGURE 11 HERE]

3.4 Robustness

Ultimately, we assess whether our main findings withstand some additional robustness checks concerning the VAR specification, the data sample, and the identification assumptions. First, we re-run the VAR model by allowing for higher lag orders of $p = 3, 4$, and 6 .¹⁶ Second, we check the robustness of the results with respect to the sample choice. Motivated by relative low US inflation rates and modest output fluctuations since the 1980s, Clarida et al. (2000), among others, document a significant

¹⁶We also re-estimate the VAR with LTV entering in levels and, furthermore, where all variables, except for FFR, enter the VAR in differences. Results are very similar and available upon request.

shift in the conduct of monetary policy for post 1979 data. Beginning with the appointment of 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. Following Clarida et al. (2000), we therefore re-estimate the VAR by excluding the pre-Volcker era and start the sample in 1979Q3 to test the sensitivity with respect to the previous episode. In addition, banks’ lending standards eased considerably in the buildup phase of the most recent housing cycle of the years 2000 to 2007 being suggestive to large bank lending shocks (see, e.g., Bassett et al., 2014). Figure 1 and 7 support this perception by documenting pronounced shifts in LTV ratios during this episode. To study whether our results are driven by the large lending and housing market shocks of the latest housing cycle, we exclude the latter period from the sample and re-estimate the VAR with data ending in 1999Q4. Third, we analyze the sensitivity of the ordering of variables in the recursive identification scheme. Until this point, we assume that LTV shocks affect the monetary policy stance on impact, yet, exogenous shifts in monetary policy propagate to lending standards with a time lag of one quarter. We implement this notion by ordering Δltv_t before r_t within the block of financial variables in the VAR. Now, we change the ordering of both variables such that LTV shocks propagate to all other variables with a delay of one quarter. However, in this specification, monetary policy surprises are allowed to influence lending standards simultaneously.

In Figure 12, we summarize the results of all six robustness exercises, where we display the variables of interest in columns and the different specifications in rows. While the magnitudes differ somewhat over the specifications, the qualitative patterns are unaffected by the sensitivity analyses. The main findings of this paper, thus, are robust with respect to the modifications considered in this section.

[INSERT FIGURE 12 HERE]

4 Conclusion

This paper empirically studies the macroeconomic consequences of shifts in banks’ lending standards as measured by residential mortgage LTV ratios. Employing LTV survey data from the FHFA, we find that exogenous LTV shocks feature significant spillovers to non-residential sectors giving LTV ratios an interpretation as a general loan supply indicator. With respect to residential investment and household debt, autonomous shifts in LTV ratios are not likely to be a substantial driver. The reason is the systematic monetary policy response, which depresses both measures following a LTV loosening. Orthogonal to the monetary policy stance, firms take advantage of the expansionary lending standards by increasing borrowing and non-residential investment, whereas – due to the strong interest sensitivity of the household sector – household leverage as well as residential investment only rise in a passive monetary policy regime.

The findings of this paper, at least, reach out to three paths for future research. First, the time series evidence constitutes a caveat on the use of supervisory limits on LTV ratios as a macroprudential policy tool to curb overheating housing markets. In

particular, to unfold their intended effects, such policy tools need to be calibrated to internalize potential interactions with monetary policy. Second, while we find no significant role for autonomous changes in LTV ratios as a driver of residential investment and household debt – including the housing cycle from 2001 to 2007 – our results are in line with the perception that a tightening of LTV ratios may have exacerbated the downturn in housing markets at the onset of 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 lowered interest rates in the face of the LTV tightening, however, with interest rates bounded at zero, this cushioning mechanism is absent. According to our evidence, such a situation should then be associated with a drop in residential investment, which was clearly observed during the financial crisis. Third, our analysis is purely positive in nature. Given the output versus inflation trade-off documented for the LTV shock, it is *prima facie* not clear, which normative conclusions should be drawn for monetary policy. Therefore, it would be interesting to study welfare implications by integrating lending standards, and in particular LTV ratios, into the monetary policy reaction function within, e.g., the New Keynesian framework.

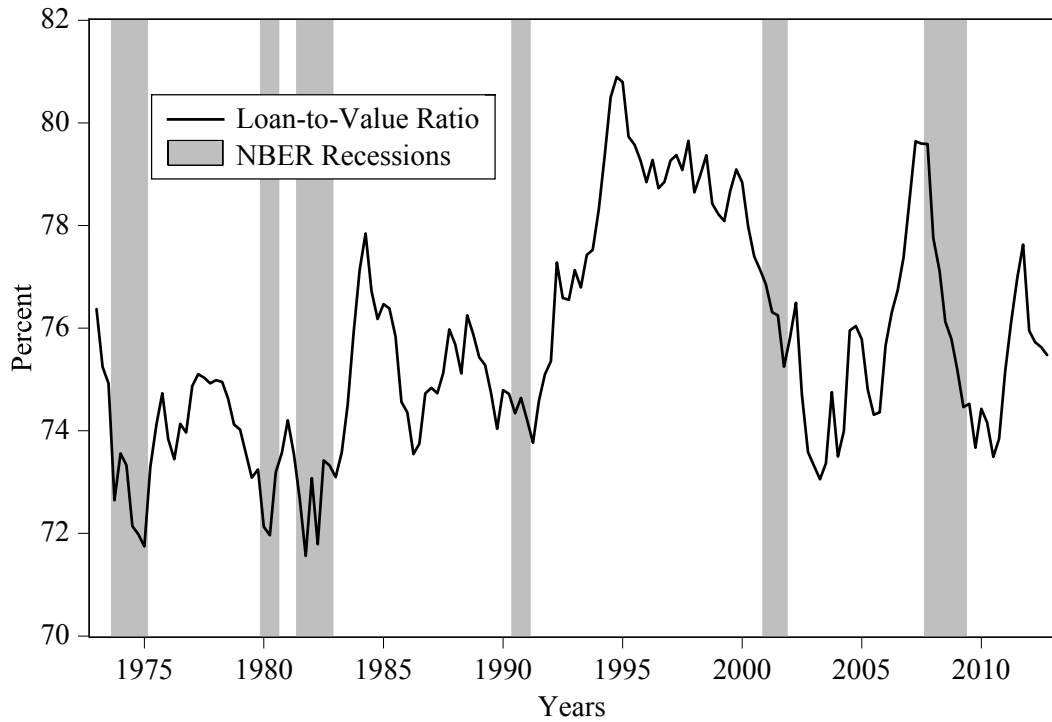
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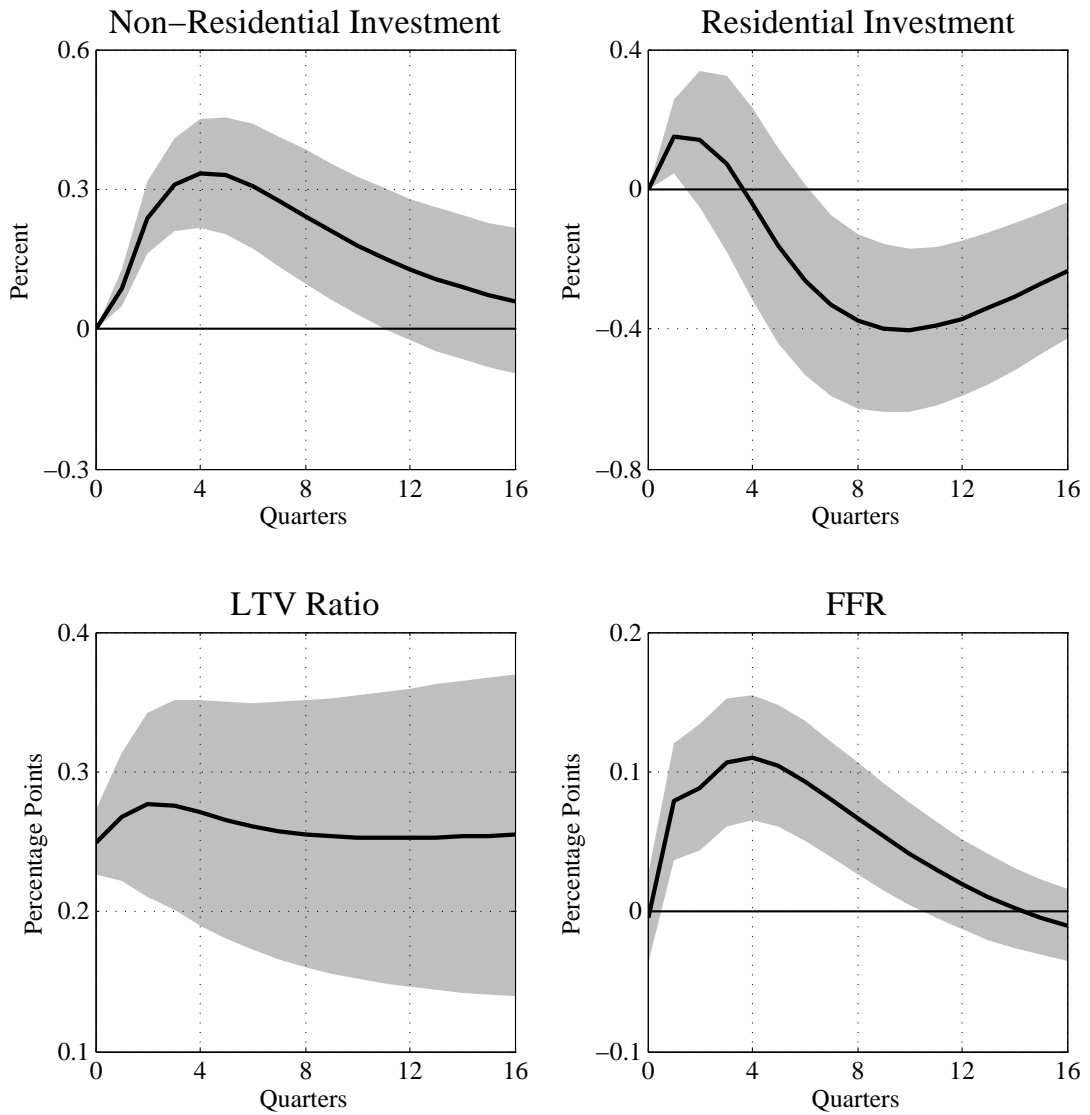
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Figure 1: Average loan-to-value ratio on conventional mortgage loans



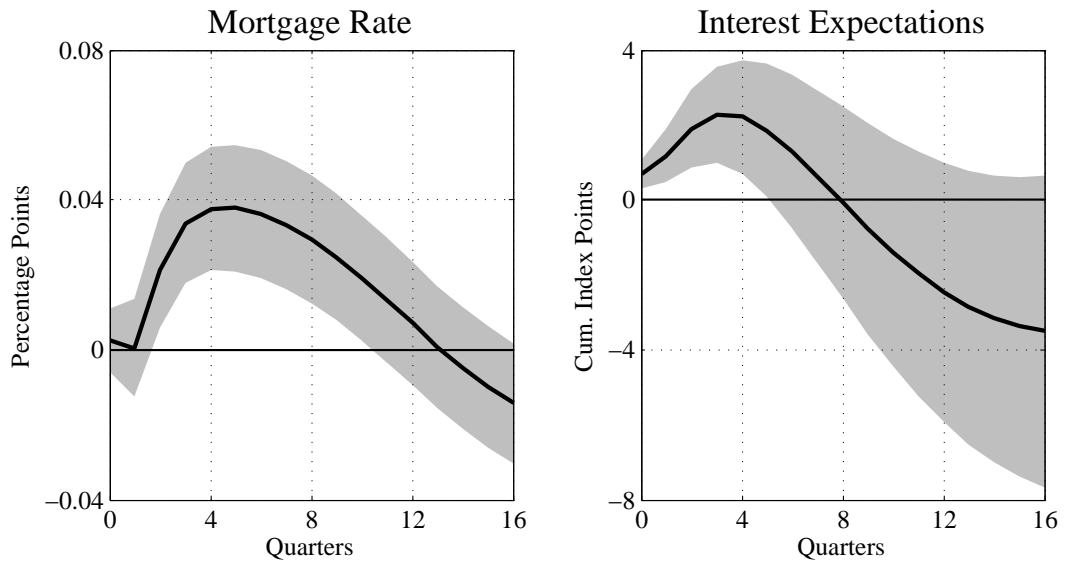
Notes: The figure displays the seasonally adjusted average loan-to-value ratio on conventional single family mortgage loans, which we obtain from FHFA. Data are in quarterly frequency and we express them in percent, i.e., as a ratio of the granted mortgage loan and the underlying house price multiplied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

Figure 2: Loan-to-value ratio shock



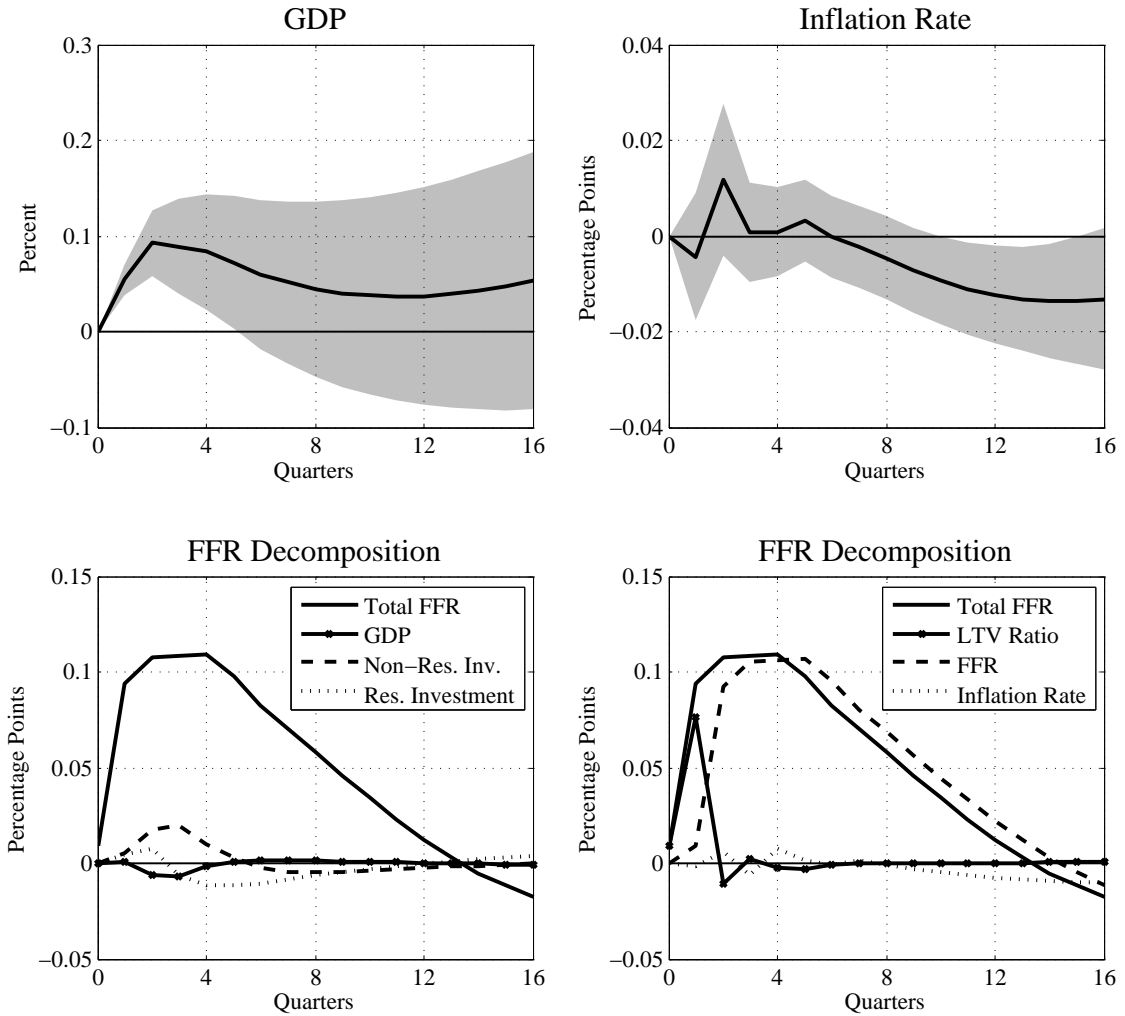
Notes: The x-axis is in quarters. The solid line represents point estimates of impulse response functions for the VAR. Shaded areas display one standard deviations confidence intervals, which we obtain from 5,000 replications of the recursive-design wild bootstrap procedure of Goncalves and Kilian (2004).

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



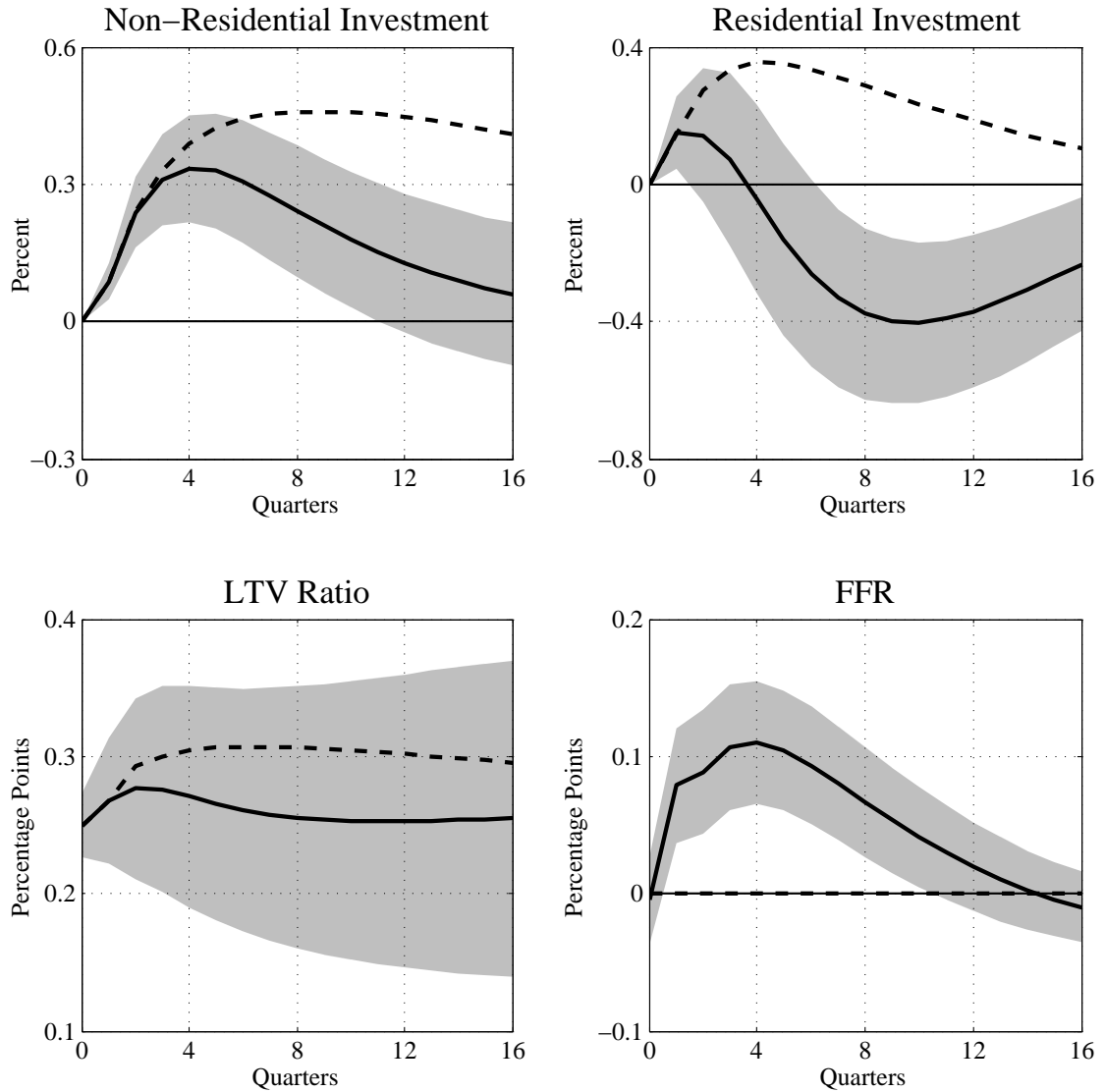
Notes: The x-axis is in quarters. The solid line represents point estimates of impulse response functions for the VAR. Shaded areas display one standard deviations confidence intervals, which we obtain from 5,000 replications of the recursive-design wild bootstrap procedure of Goncalves and Kilian (2004).

Figure 4: Decomposition of the FFR response following a LTV shock



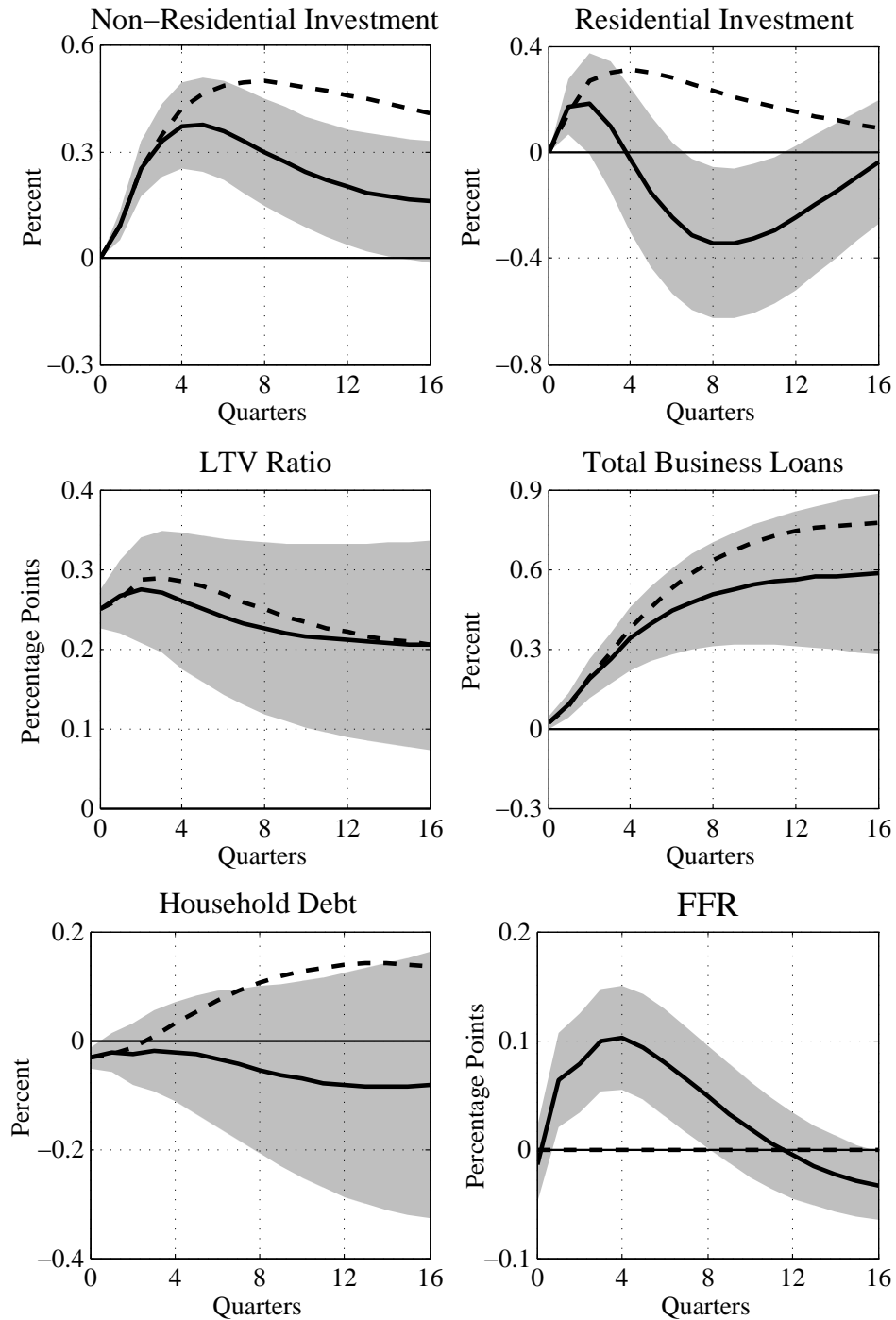
Notes: The x-axis is in quarters. In the upper panels, the solid line represents point estimates of impulse response functions for y_t and π_t , and shaded areas display one standard deviations confidence intervals, which we obtain from 5,000 replications of the recursive-design wild bootstrap procedure of Goncalves and Kilian (2004). The solid line in the lower panels is the point estimate of the FFR impulse response function after a LTV shock. The dashed, dotted, and lines with nodes denote the contribution of the respective variable to the reaction of the FED's policy instrument.

Figure 5: LTV shock in a policy counterfactual



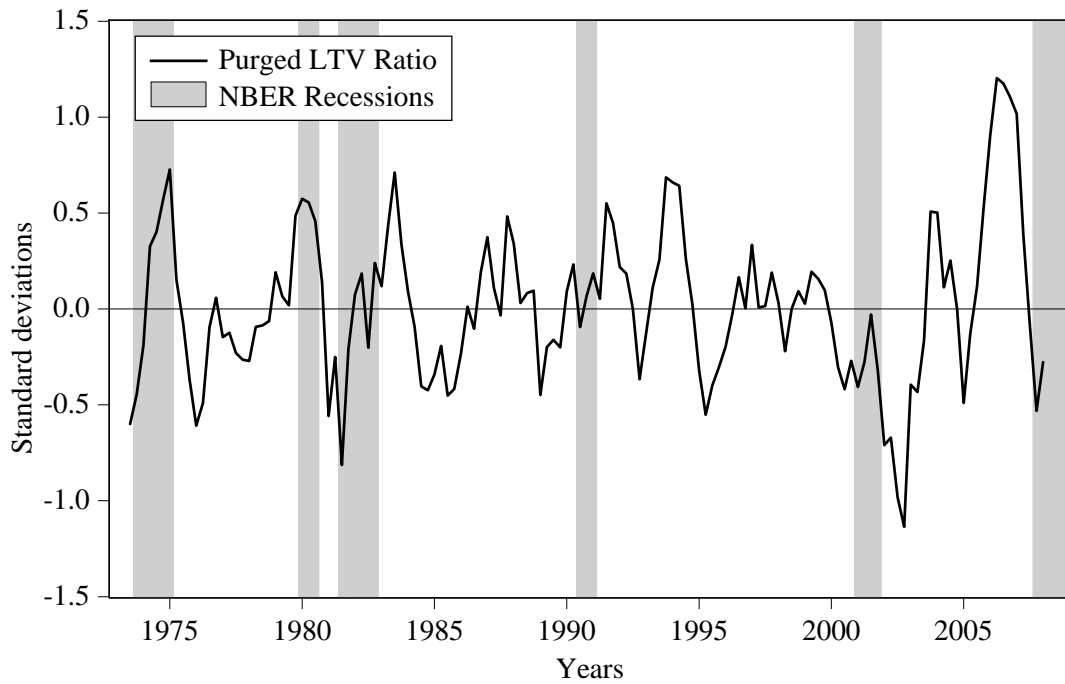
Notes: The x-axis is in quarters. The solid line represents point estimates of impulse response functions for the VAR. Shaded areas display one standard deviations confidence intervals obtained from 5,000 replications of the recursive-design wild bootstrap procedure of Goncalves and Kilian (2004). The dashed line denotes counterfactual 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 6: LTV shock and leverage of households and firms



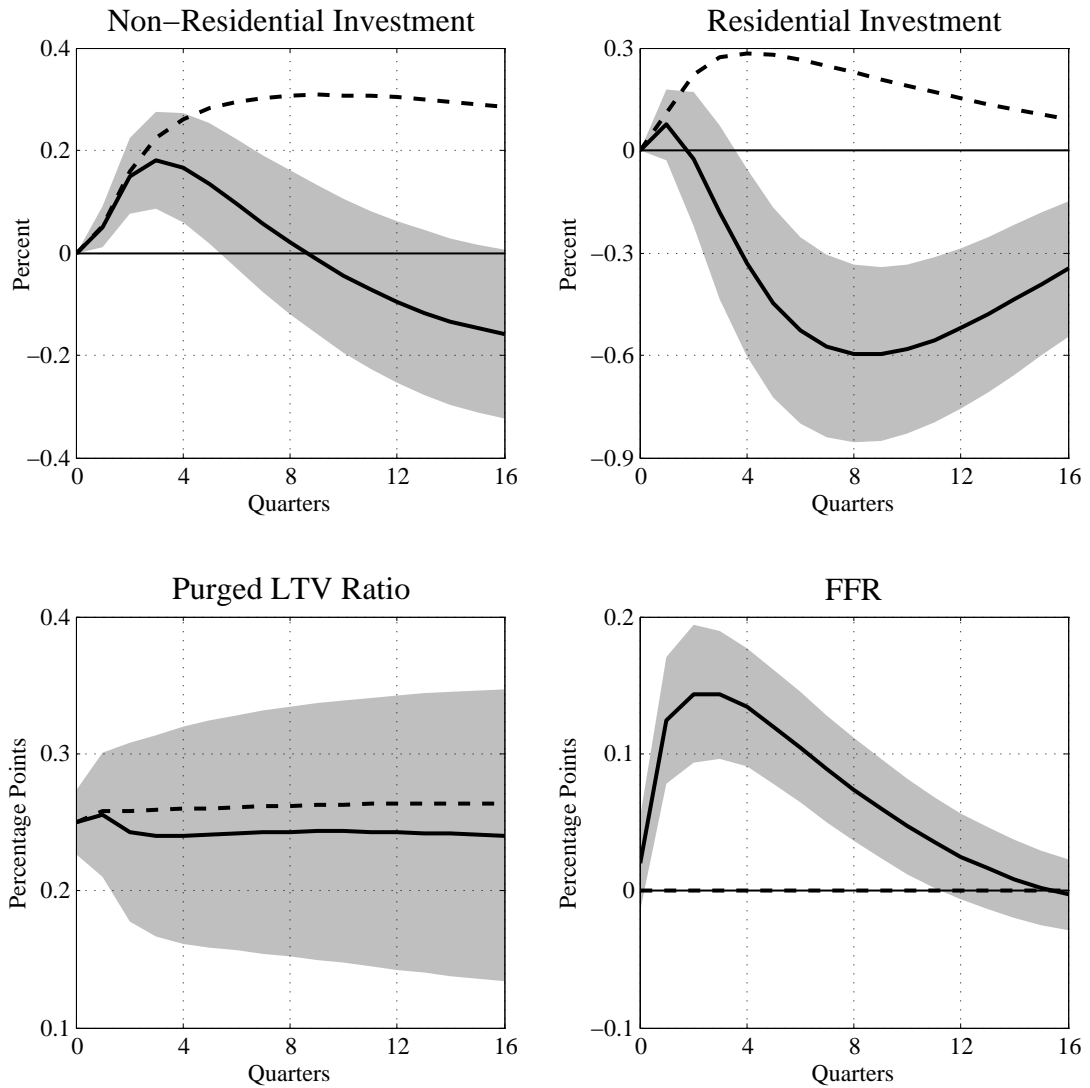
Notes: The x-axis is in quarters. The solid line represents point estimates of impulse response functions for the VAR. Shaded areas display one standard deviations confidence intervals obtained from 5,000 replications of the recursive-design wild bootstrap procedure of Gonçalves and Kilian (2004). The dashed line denotes counterfactual 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 7: Purged loan-to-value ratio



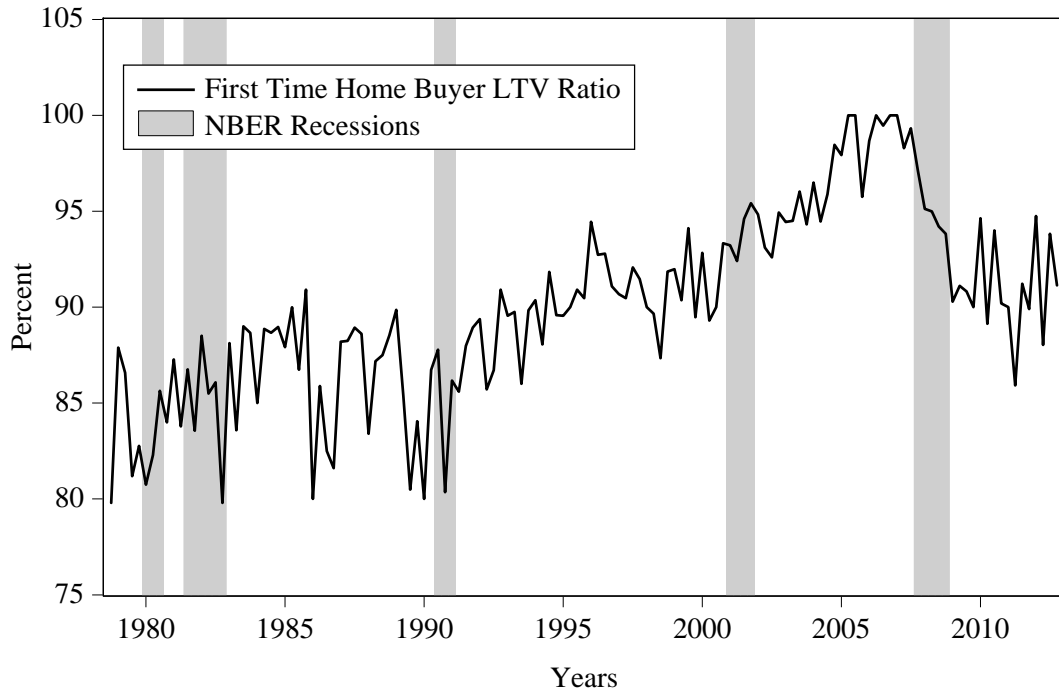
Notes: The figure displays the five quarter moving average of the purged loan-to-value ratio. Data are in quarterly frequency and we rescale them as standard deviations. The shaded areas represent NBER dated recession episodes in the US.

Figure 8: Shock to LTV ratio purged from demand factors



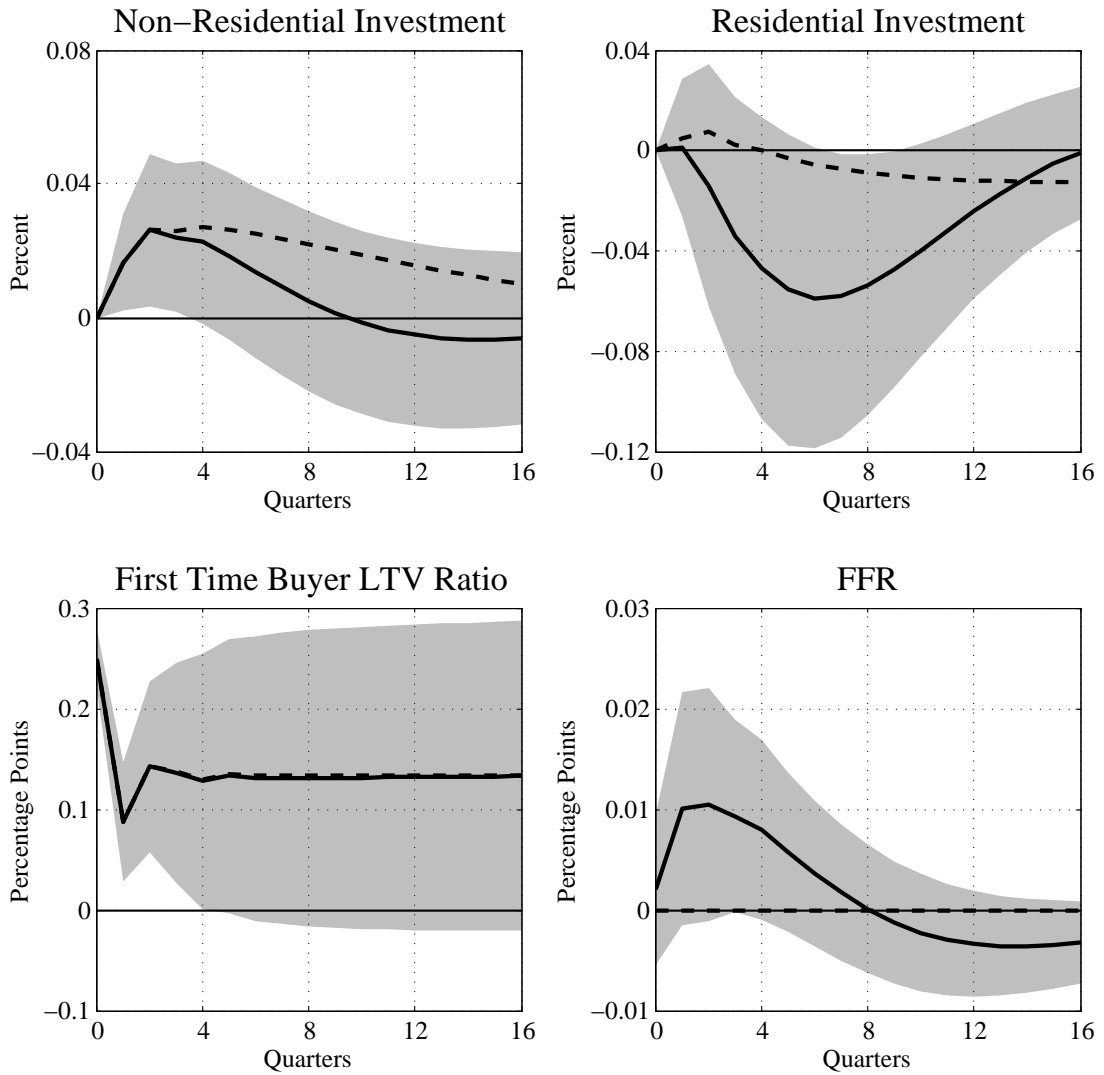
Notes: The x-axis is in quarters. The solid line represents point estimates of impulse response functions for the VAR. Shaded areas display one standard deviations confidence intervals obtained from 5,000 replications of the recursive-design wild bootstrap procedure of Gonçalves and Kilian (2004). The dashed line denotes counterfactual 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: Average loan-to-value ratio on first time home buyer mortgage loans



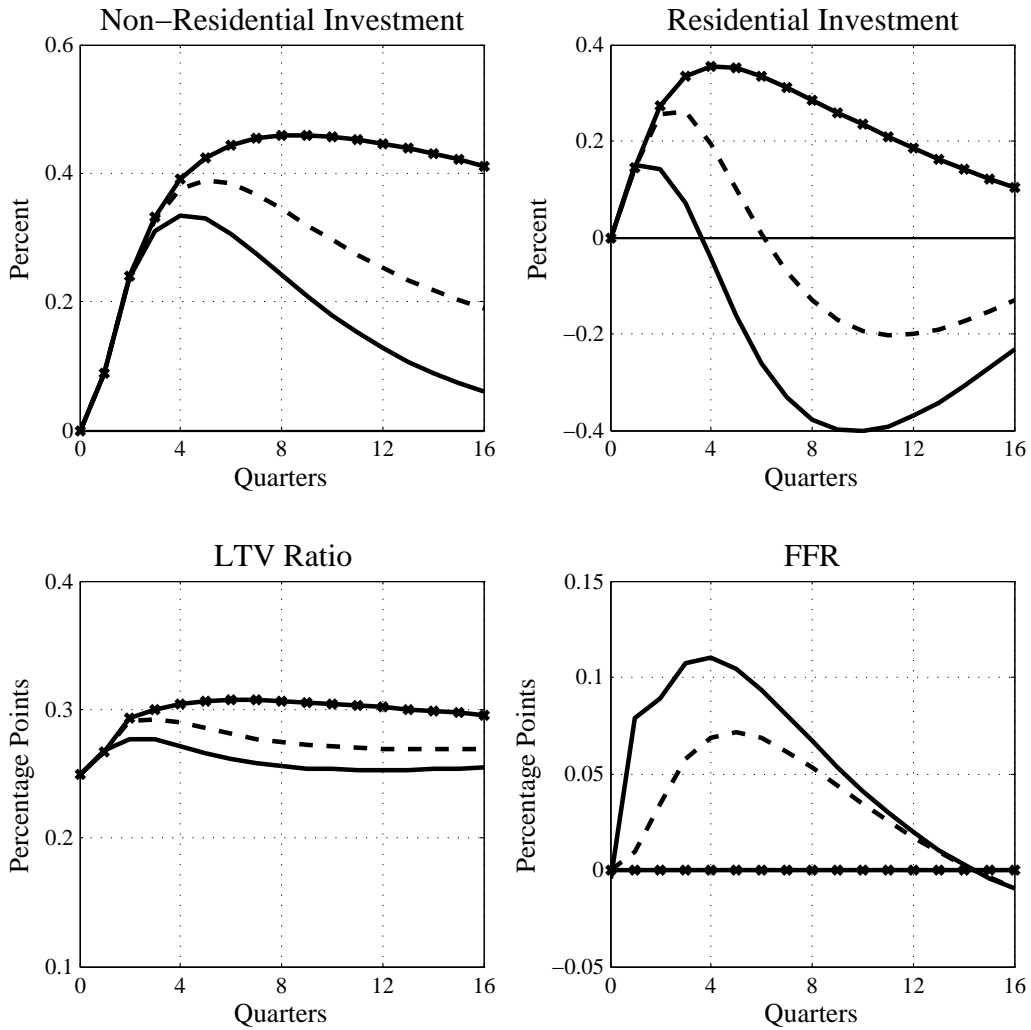
Notes: The figure displays the loan-to-value ratio for first time home buyer mortgage loans, which is provided from FHFA and adjusted as in Duca et al. (2011, 2013). Data are in quarterly frequency and we express them in percent, i.e., as a ratio of the granted mortgage loan and the underlying house price multiplied by 100. The shaded areas represent NBER dated recession episodes in the US.

Figure 10: Shock to first time buyer LTV ratio



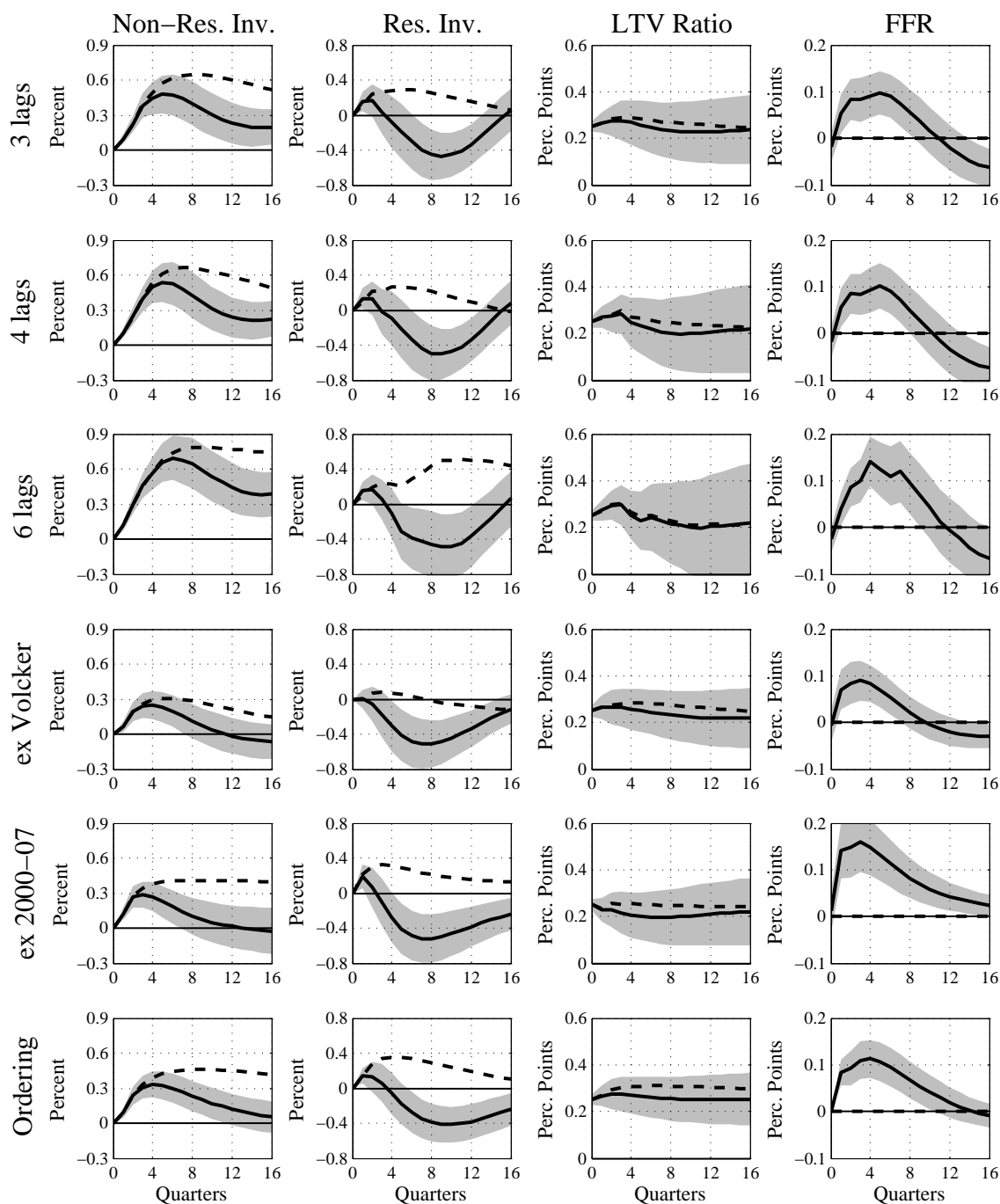
Notes: The x-axis is in quarters. The solid line represents point estimates of impulse response functions for the VAR. Shaded areas display one standard deviations confidence intervals obtained from 5,000 replications of the recursive-design wild bootstrap procedure of Goncalves and Kilian (2004). The dashed line denotes counterfactual 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 11: LTV shock for different policy counterfactuals



Notes: The x-axis is in quarters. The solid line represents point estimates of impulse response functions for the unrestricted VAR. The dashed line displays the adjustment patterns following a LTV shock for the Kilian and Lewis (2011) policy counterfactual. The line with nodes denotes counterfactual 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 12: LTV shocks: robustness



Notes: The x-axis is in quarters. The solid line represents point estimates of impulse response functions for the VAR. Shaded areas display one standard deviations confidence intervals obtained from 5,000 replications of the recursive-design wild bootstrap procedure of Gonçalves and Kilian (2004). The dashed line denotes counterfactual 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).