# Discussion Paper

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## Monetary policy, housing, and collateral constraints

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# Non-technical summary

## Research Question

In the U.S., prevailing loan-to-value (LTV) ratios in mortgage markets are not only important for house-purchasing decisions of credit-constrained homebuyers. The relative ease with which existing homeowners can extract equity from real estate additionally renders them a major determinant of mortgage equity withdrawal (MEW) decisions, a non-negligible source of U.S. household finance. As monetary policy influences house prices via its pass-through to mortgage rates it, in turn, also shifts the collateral valuation of homeowners and the required downpayments of potential homebuyers. In this paper, I raise the question as to the extent to which prevailing LTV ratios on U.S. mortgage markets affect the strength of the so-called collateral constraint channel and, thereby, the transmission of monetary policy towards the real economy.

## Contribution

Previous research largely ignored real estate and, especially, its role as collateral in the transmission of monetary policy. By estimating a non-linear model, I allow the transmission of monetary policy in the U.S. to depend on the prevailing LTV ratio in mortgage markets. The approach takes advantage of the relatively homogeneous mortgage market throughout the U.S. and exploits time-variation in average LTV ratios. Findings from the estimation provide novel insight into a mostly unexplored monetary transmission channel.

## Results

In times of high LTV ratios, effects of monetary policy on real mortgage credit, real house prices, real consumption of durables and non-durables, and, ultimately, on real GDP are more pronounced. Apparently, these findings can be at least partially accounted for by a stronger reaction of MEWs when LTV ratios are high. Additionally, LTV ratios in the U.S. are shown to be highly procyclical such that they can deliver a theoretical underpinning of previous findings on a less powerful transmission of monetary policy during recessions. Furthermore, non-linearities in the transmission are mostly due to contractionary shocks in line with predictions of the literature on occasionally binding constraints.

# Nichttechnische Zusammenfassung

## Fragestellung

In den USA spielt das Verhältnis des Kreditvolumens zum Immobilienwert (Loan-to-Value Ratio – LTV) nicht nur bei Hauskaufentscheidungen kreditbeschränkter Haushalte eine wichtige Rolle. Hauseigentümer in den USA können ihr Eigenheim auch relativ leicht zusätzlich beleihen, wobei die LTV das Ausmaß der möglichen Beleihung entscheidend beeinflusst. Diese Beleihungen (Mortgage Equity Withdrawals - MEWs) stellen für US-Haushalte eine wichtige Finanzierungsquelle dar. Da die Geldpolitik über die Hypothekenzinsen auf die Hauspreise durchwirkt, beeinflusst sie auch den Wert der Kreditsicherheiten von Hausbesitzern sowie die veranschlagten Anzahlungen potentieller Hauskäufer. In diesem Papier stelle ich die Frage, inwieweit die LTVs an den US-Hypothekenmärkten die Stärke dieses Kreditsicherheiten-Kanals und somit die Transmission der Geldpolitik auf die Realwirtschaft beeinflusst.

## Beitrag

In früheren Forschungsarbeiten blieb der Immobiliensektor bei der Transmission von Geldpolitik größtenteils unberücksichtigt, vor allem im Hinblick auf die Rolle von Wohnimmobilien als Kreditsicherheit. Die Verwendung eines nichtlinearen Modells ermöglicht die Schätzung der geldpolitischen Transmission für die USA in Abhängigkeit von der LTV an den Hypothekenmärkten. Der Ansatz nutzt die recht hohe Homogenität des US-Hypothekenmarkts und bedient sich der Zeitvariation durchschnittlicher LTVs. Die Ergebnisse liefern neuartige Einblicke in einen nahezu unerforschten Transmissionskanal.

## Ergebnisse

In Zeiten hoher LTVs sind geldpolitische Effekte auf die realen Hypothekenkredite, die realen Hauspreise, den realen Konsum von Gebrauchs- und Verbrauchsgütern und letztendlich das reale BIP stärker ausgeprägt. Offenbar sind die Ergebnisse zumindest teilweise auf eine stärkere Reaktion von MEWs zu Zeiten hoher LTVs zurückzuführen. Auch wird gezeigt, dass die LTVs in den USA hochgradig prozyklisch sind und somit eine mögliche theoretische Fundierung früherer Resultate liefern können, die auf eine schwächere geldpolitische Transmission in Rezessionsphasen hindeuten. Zudem werden die Nichtlinearitäten in der Transmission im Einklang mit der einschlägigen Literatur hauptsächlich auf kontraktive Schocks zurückgeführt.

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# Monetary Policy, Housing, and Collateral Constraints*

Thorsten Franz†

**Abstract**

House-purchasing decisions and the possibility of existing homeowners to tap into their housing equity depend decisively on prevailing loan-to-value (LTV) ratios in mortgage markets with borrowing constrained households. Utilizing a smooth transition local projection (STLP) approach, I show that monetary policy shocks in the U.S. evoke stronger reactions in the housing sector in times of high LTV ratios, which, through changes in mortgage lending and mortgage equity withdrawals (MEWs), translate into larger effects of consumption. This result is more pronounced for contractionary shocks, in line with occasionally binding constraints. The strong procyclicality of LTV ratios reconciles these findings with past evidence on a less powerful transmission of monetary policy during recessions.

Keywords: monetary policy, LTV ratio, mortgage equity withdrawals, collateral constraints, local projections, non-linear impulse responses

JEL-Classification: E21, E52, G21, R31

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# 1 Introduction

Real estate is prominently featured on U.S. household balance sheets, whether on the asset side or through outstanding mortgage debt on the liabilities side. Changes in mortgage market characteristics can, therefore, have a major impact on household balance sheets, in particular when borrowing constraints are binding: not only decisions of potential homebuyers are affected but also the possibility of homeowners to tap their housing equity through this so-called collateral constraint channel. In the transmission of monetary policy, it is often just referred to the effect the policy rate has on housing demand via mortgages rates. However, the propagation of ensuing changes in house prices on household decisions crucially depends on other mortgage market characteristics. Notably, prevailing loan-to-value (LTV) ratios have been identified as an important contributor to housing booms (see e.g. Cerutti, Dagher, and Dell'Ariccia, 2017) and thereby constitute a decisive factor of the sensitivity of mortgage lending towards changes in house prices.

Within a Dynamic Stochastic General Equilibrium (DSGE) framework that allows for collateralizable housing, Calza, Monacelli, and Stracca (2013) show that this is indeed the case and go on to present first empirical evidence on a non-linear monetary policy transmission from averaged impulse response functions over 19 industrialized countries depending, among others, on LTV ratios. Leaning on their work, I argue that mortgage lenders' downpayment requirements, or inversely LTV ratios, are particularly vital in the propagation of monetary policy shocks in the U.S. High LTV ratios allow homeowners to extract more equity from house price increases, while the chance of having a negative equity stake in real estate, possibly leading to default and foreclosure, enhances when house prices decrease. Additionally, if mortgage debtors are more leveraged in times of high LTV ratios, the cash-flow channel should be more prominent.[1] For potential homebuyers, the mitigating effect of higher downpayment requirements with increasing house prices is smaller in a high LTV environment. Taken together, monetary policy, by initially affecting mortgage rates and, therefore, housing demand and house prices, is amplified much more in times of high LTV ratios. Results from state-dependent impulse response functions (IRFs) from a local projection approach developed by Jordà (2005) and utilizing the smooth transition framework in Granger and Teräsvirta (1993) are very much in favor of this theoretical explanation.

In contrast to Calza et al. (2013), results depend on a relatively homogeneous mortgage market of a single country with a time-varying LTV ratio and widely available

[1] The cash-flow channel describes the direct effect of a change in interest rates on regular mortgage repayments of existing mortgage credit with variable rates.

mortgage equity withdrawal (MEW) instruments.[2] When LTV ratios are high, a contractionary monetary policy shock leads to a significant decrease in real mortgage credit, real house prices, real consumption of durables as well as non-durables, and ultimately to lower real GDP. When LTV ratios are low, in comparison, responses are virtually muted and monetary policy does not seem to have a significant effect on the real economy. These differences in responses are both statistically as well as economically significant: a contractionary monetary policy shock that leads to a 100 basis point increase in the Fed funds rate implies real house prices and non-durables consumption will decrease by about 4 percentage points and 6.5 percentage points points more in high LTV states compared to low LTV states after around two years. Utilizing a self-compiled proxy for MEWs, I also present suggestive evidence that these are at least partially responsible for the difference in responses between states. The results complement recent findings in Eickmeier, Metiu, and Prieto (2016), who identify the procyclicality of leverage in the U.S. financial system as an important financial accelerator mechanism that boosts the transmission of monetary policy. Research on the role of LTV ratios in the transmission process is scarce. Increasing LTV ratios and greater accessibility to mortgage equity are stated by Hofmann and Peersman (2017) as potential reasons for their findings of a stronger propagation of monetary policy via credit and housing markets since the 1980s. Within a DSGE framework, Walentin (2014) provides evidence that the component of monetary policy transmission generated by housing collateral increases with the LTV ratio in the Swedish economy, while Ungerer (2015) places special emphasis on the endogenous reaction of LTV ratios to monetary policy. However, the present study is, to my knowledge, the first that provides direct empirical evidence on a state-dependent propagation of monetary policy utilizing a continuous and time-varying LTV ratio for a single country.

In the next step the main results are brought in line with previous findings by Tenreyro and Thwaites (2016) of a less powerful monetary policy transmission during recessions. It is shown that LTV ratios are highly procyclical and that impulse responses follow a similar path in booms compared to high LTV states. Berger and Vavra (2015) argue that fixed costs of durables adjustment make up a larger fraction of household income during recessions, rendering a reaction to shocks more costly. While this might be one reason for the weaker sensitivity of durables consumption during recessions, it fails to explain the statistically and economically significant difference in responses of non-durables consumption. In comparison, a state-dependent collateral constraint channel suggests a higher sensitivity of durables and non-durables consumption to monetary policy shocks in times of booms as ob-

[2] MEWs can make up as much as 5% of disposable income in the U.S. even in "normal" times (see appendix).

served.
Recent studies have also sparked interest in occasionally binding constraints. Guerrieri and Iacoviello (2017) as well as Jensen, Ravn, and Santoro (2018) propose models where collateral constraints might become slack in times of loose lending conditions. It is argued that under these circumstances expansionary shocks are without much effect considering that constraints become non-binding for most households. The quintessence is an asymmetry in responses to shocks when LTV ratios are high. Allowing for such asymmetries in the local projection framework, results are at least partially in favor of the occasionally binding constraints story. Responses to contractionary monetary policy shocks are much stronger in line with past evidence (see, e.g., Angrist, Jordà, and Kuersteiner, 2017) and qualitatively mimic those from the symmetric responses. Expansionary shocks, on the other hand, have only weak effects and display no clear-cut direction in the difference of responses between high and low LTV states.
These findings entail major implications for the timing of monetary policy. Policymakers should take into account the limited effects traditional monetary policy measures have on the real economy when lending conditions on mortgage markets are tight. Furthermore, Del Negro and Otrok (2007) show that developments in regional real estate markets are heavily influenced by local factors. Potentially desynchronized real estate cycles throughout the U.S. imply heterogenous effects of monetary policy due to different sensitivities of the collateral constraint channel. This is in line with the findings in Beraja, Fuster, Hurst, and Vavra (2018), who stress the importance of regional heterogeneities in housing markets with respect to house price developments for monetary policy. However, they do not consider possible differences in lending conditions on mortgage markets. A second important policy implication addresses the use of macroprudential instruments in the real estate sector. Boom-bust cycles in asset markets, especially the housing sector, have been identified as one of the main predictors of upcoming financial distress. To counter these potentially unhealthy build-ups in the form of soaring house prices, mandatory caps on LTV ratios have become a popular policy measure.[3] While these are generally found to be effective in curbing real estate cycles (see, e.g., Claessens, Ghosh, and Mihet, 2013) and increasing financial stability,[4] their implementation impairs the effects of traditional monetary policy instruments through a weakened collateral constraint channel. These policy implications have far-reaching relevance for all countries where MEWs are an important source of household financing.

[3] In 2013, 44 out of 119 countries in the Global Macroprudential Policy Instruments Database by the IMF implemented some form of regulatory provision on maximum LTV ratios.

[4] Kumar (2018), e.g., finds that the likelihood to default on mortgages is lower in Texas, the only U.S. state that restricts MEWs by capping the combined LTV ratio at a maximum of 80%, compared to bordering states.

The remainder of this paper is structured as follows: the next section emphasizes the role of housing in the transmission of monetary policy with a special focus on LTV ratios. In Section 3 the econometric framework and data are described. Results of the empirical application are presented in Section 4, while Section 5 concludes.

## 2 LTV Ratios and the Transmission of Monetary Policy

The residential real estate sector has been ignored in a large part of the literature on business cycles. Only over the last decade has it gained prominence, not least due to the financial crisis (see, e.g., Leamer, 2007, 2015). Housing is prominently featured on households' balance sheets: a look at the Financial Accounts of the United States reveals that real estate makes up nearly 25% of all asset in 2018Q1, while on the liabilities side mortgages dominate with around 65% of all liabilities. Monetary policy influences households' balance sheets not only via its pass-through to rates of newly originated mortgage credit but also via its influence on variable rate mortgages of existing mortgage credit.[5] As demand in the housing sector crucially depends on mortgage rates, monetary policy triggers house price changes, which themselves trigger amplification effects through adjustments in the wealth of homeowners and their constraints on borrowing. Past findings on a sizeable housing wealth effect (Case, Quigley, and Shiller, 2005, or Bostic, Gabriel, and Painter, 2009) are generally attributed to constrained homeowners in more recent research (Mian and Sufi, 2011, Mian, Rao, and Sufi, 2013, Bhutta and Keys, 2016, or Aladangady, 2017), emphasizing the importance of the collateral constraint channel, which by some authors is assigned a pivotal role in the transmission of U.S. monetary policy (Musso, Neri, and Stracca, 2011, or Cloyne, Ferreira, and Surico, 2016).

Within DSGE models, collateral constraints are usually modeled in the fashion of Iacoviello (2005), whereby LTV ratios are exogenously fixed parameters despite observable time variation in the data.[6] As derived in Calza et al. (2013), besides real income, the present value of housing equity is a crucial determinant of current

[5]While hybrid rate mortgages are available in the U.S., fixed rate mortgages dominate; the cash-flow channel, therefore, works in the U.S. mostly through mortgage refinancing; findings in Di Maggio, Kermani, Keys, Piskorski, Ramcharan, Seru, and Yao (2017) point on a sizable cash-flow channel, but recent research also highlights the path-dependent effects of monetary policy on mortgage refinancing (see e.g. Berger, Milbradt, Tourre, and Vavra, 2018, or Eichenbaum, Rebelo, and Wong, 2018).

[6]Data from the Federal Housing Finance Agency places the average LTV ratios in the U.S. at between 70% and 80% over the last 40 years, while data compiled by Duca, Muellbauer, and Murphy (2016) from the American Housing Survey including government-insured mortgages depicts the median LTV ratio for first-time homebuyers at between 85% and nearly 100%; variation in regional data is possibly even more pronounced.

household expenditures as long as housing is collateralizable. Via an increase in the sensitivity of household expenditures to fluctuations in housing equity, higher LTV ratios can have substantial influence on the propagation of shocks to the real economy. The calibration of LTV ratios in DSGE models with collateral constraints is therefore a non-trivial matter and can have considerable effects on the transmission of monetary policy.[7]

To illustrate this non-linearity, consider two households who own identical houses with a fair market value of $500,000 each, one in a low LTV environment (70%), the other in a high LTV environment (90%). Both homeowners are borrowing constrained in the sense that their home equity is exactly equal to the required downpayments on the houses. Now, an expansionary monetary policy shock hits the economy, increasing house prices by 10% initially and, thus, the home equity of both homeowners by $50,000. In the low LTV environment, the homeowner is able to secure a new home equity loan worth $35,000, while the other homeowner can withdraw equity worth $45,000. Additionally, amplification of this initial effect on the collateral value is stronger in the high LTV environment due to a greater increase in borrowing activity and, therefore, housing demand. Taking into account also first-time homebuyers, the mitigating effect in housing demand is weaker under high LTV ratios where required downpayments increase initially by only $5,000 compared to $15,000 under low LTV ratios. In line with this argument, Mian et al. (2013) find a stronger MPC out of housing wealth for households with higher LTV ratios.

Additional effects through the cash-flow channel endorse the view of a non-linear transmission of monetary policy under different LTV environments. In times of high LTV ratios, households are able to borrow more freely against their home equity, building up leverage. Then, periodic mortgage repayments make up a larger part of expenditures, increasing the relevance of the cash-flow channel. Due to the prevalence of fixed rate mortgages in the U.S., this non-linearity would manifest in a higher sensitivity of mortgage refinancing. However, as laid out by Alpanda and Zubairy (2018), in times of household debt overhang, monetary transmission might be impaired. Nevertheless, households' interest rate sensitivity on assuming a mortgage should generally decrease with the downpayment requirement. As the equity stake of homeowners increases, interest expenses on mortgage repayments make up a smaller part of disposable income, potentially mitigating the impact of monetary policy.

Up until now, possible asymmetries in the propagation of expansionary and con-

[7]Figure 4 in Calza et al. (2013) shows that in their model aggregate consumption, aggregate residential investment and real house prices react more strongly to monetary policy shocks when downpayments are low, and, thus, LTV ratios are high.

tractionary shocks have been neglected. Guerrieri and Iacoviello (2017) and Jensen et al. (2018) argue that in high LTV environments the likelihood of collateral constraints becoming slack increases in response to expansionary shocks. In contrast, constraints are always binding when average LTV ratios are low. This implies that the propagation of an expansionary monetary policy shock under high LTV ratios is much weaker compared to a contractionary monetary policy shock, while shock propagation should be symmetric under low LTV ratios. The occasionally binding constraints story is empirically investigated in Subsection 4.3.
To summarize, theory argues that increasing LTV ratios amplify the propagation of monetary policy shocks, especially when collateral constraints are binding.

# 3 Econometric Framework and Data

This section first presents the smooth transition local projection (STLP) model and its merits over standard impulse response inference from a non-linear Vector Autoregressive (VAR) model. In a second step, the data is described with a special focus on the transition variable and the monetary policy shocks.

## 3.1 Smooth Transition Local Projection (STLP) Model

Estimation of impulse response functions follows the local projection method proposed by Jordà (2005). This approach is easily extended to capture non-linearities in the form of a smooth transition between states similar to Granger and Teräsvirta (1993). Following Auerbach and Gorodnichenko (2013) and Tenreyro and Thwaites (2016), the regression equation is given by

$$\begin{aligned} y_{t+h} = \tau_h t + F(z_t)(\alpha_h^{(1)} + \boldsymbol{\gamma}_h^{(1)'} \mathbf{X}_t^c + \beta_h^{(1)} \varepsilon_t) \\ + [1 - F(z_t)](\alpha_h^{(2)} + \boldsymbol{\gamma}_h^{(2)'} \mathbf{X}_t^c + \beta_h^{(2)} \varepsilon_t) + u_{t+h} \end{aligned} \tag{1}$$

where $\tau_h$ is a time trend, $\alpha_h^{(i)}$ is the state-dependent constant and $\boldsymbol{\gamma}_h^{(i)}$ are the state-dependent coefficients on the $K \times 1$ vector of controls $\mathbf{X}_t^c$ for $i = 1, 2$. Monetary policy shocks are represented by $\varepsilon_t$ and, thus, have to be identified outside of estimation. The transition between states is given by the function

$$F(z_t) = \left(1 + \exp\left\{-\mu\left(\frac{z_t - \mathbb{E}(z_t)}{\sigma_z^2}\right)\right\}\right)^{-1}, \quad \mu > 0 \tag{2}$$

where $\mu$ governs the smoothness of the transition between states, which are defined via the standardized transition variable $z_t$ . This formulation of the transition function allows (1) to encompass a linear estimation, when $\mu = 0$, and a threshold estimation with the mean of $z_t$ being the threshold, when $\mu \to \infty$. An advantage over standard threshold estimation is that weighted observations of both states are utilized for each period. The general idea behind the STLP method is to estimate Equation (1) for each forecast horizon $h = 0, 1, \ldots, H$ individually via Ordinary Least Squares (OLS), whereby $\beta_h^{(i)}$ gives the impulse responses for horizon $h$ in state $i = 1, 2$. While estimation is straightforward, the error terms $u_{t+h}$ are autocorrelated by design. Thus, standard errors are corrected following the method proposed in Newey and West (1987).

In comparison to impulse responses from a VAR model, the local projection approach has several advantages. First, even when the true data generating process (DGP) follows a VAR process, the local projection method delivers consistent estimates of the impulse responses with only small efficiency losses. If, however, the DGP is misspecified, these specification errors are aggravated at each horizon in the VAR. In comparison, the local projection method does not constrain the shape of the impulse responses, making it robust to these misspecifications. Related to this, the STLP framework automatically captures endogenous movements in the transition variable when estimating impulse responses, which is important when LTV ratios endogenously react to monetary policy as argued by Ungerer (2015). Second, the curse of dimensionality problem is circumvented. In a VAR, the number of coefficients increases quadratically with the number of dependent variables, whereby local projections economize on the coefficients and allow complete flexibility of control variables for each dependent variable. This is especially beneficial when estimating non-linear relationships. Third, when $\mu$ in the transition function is assumed to be fixed, (1) can simply be estimated via OLS.[8]

Despite the advantages of the linear projection method, its use is not a free lunch. First, due to the forecasting structure of Equation (1), the last observed shock is $H$ periods before the end of the sample. Second, impulse responses from the local projection method often display erratic behavior, especially at longer horizons. These oscillations can even become significant. Therefore, I smooth impulse responses by presenting their three period moving averages as in Tenreyro and Thwaites (2016).

## 3.2 Data

### Transition Variable

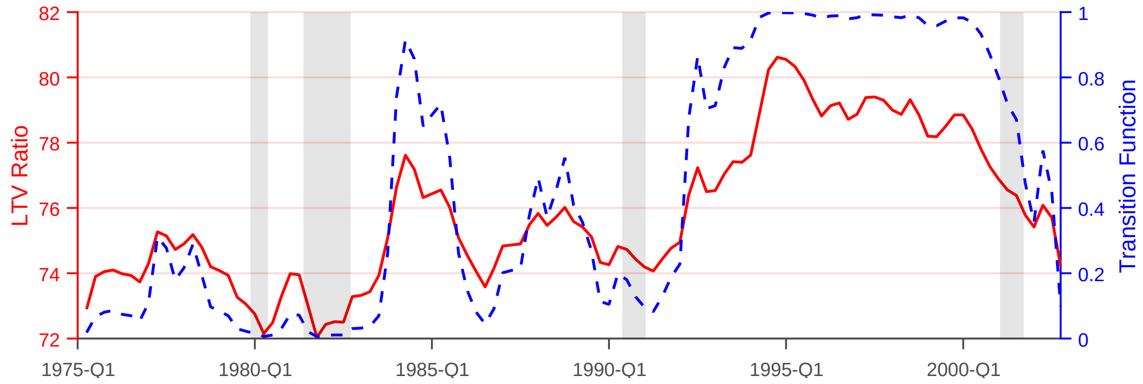
Ideally, we would observe Combined LTV ratios also capturing the ability of existing homeowners to extract equity from their real estate. Since such data is not available

[8] Although it is a rather strict assumption, a fixed $\mu$ is standard in the literature; see, e.g., Auerbach and Gorodnichenko (2013) or Tenreyro and Thwaites (2016); Auerbach and Gorodnichenko (2013) argue that due to highly non-linear moments, identification of the curvature in the transition function is potentially sensitive to unusual observations.

over a longer time span, I settle for average LTV ratios from the Monthly Interest Rate Survey (MIRS) conducted by the Federal Housing Finance Agency (FHFA). The FHFA surveys a sample of mortgage lenders who report the terms and conditions on all fully amortized single-family loans that they close during the last five business days of the month, starting in the mid-1970s. One shortcoming is the exclusion of loans created by refinancing another mortgage and home equity loans. Nevertheless, the assumption that lending conditions for MEWs develop in line with those for homebuyers is not far-fetched. When liquidity in the housing market increases, making it easier for mortgage lenders to sell homes quickly in case of borrower's default, downpayment requirements for first-time homebuyers should decrease in conjunction with the minimum equity stake demanded of existing homeowners.

Following Tenreyro and Thwaites (2016), the smoothness parameter of the transition function, $\mu$, is set to three in the baseline setup. This specification allows for a good middle ground between a threshold model and a linear model: for around 50% of the observed LTV ratios, a weight above 0.1 is given to both states in regression Equation (1). Additionally, the LTV ratio is smoothed using a two quarter moving average.[9] Figure 1 displays the LTV ratio starting in 1975Q1 up until 2002Q4.[10] There are two states of high LTV ratios in the sample: a short one in the mid-1980s and a longer one in the mid- to late 1990s. Overall, the series exhibits a slight increase along the sample period, possibly owed to financial liberalization in the form of developments in credit scoring and the surge in securitization.

**Figure 1** LTV Ratio and Transition Function with $\mu = 3$




Note: The transition function is smoothed using a two quarter moving average of the LTV ratio.

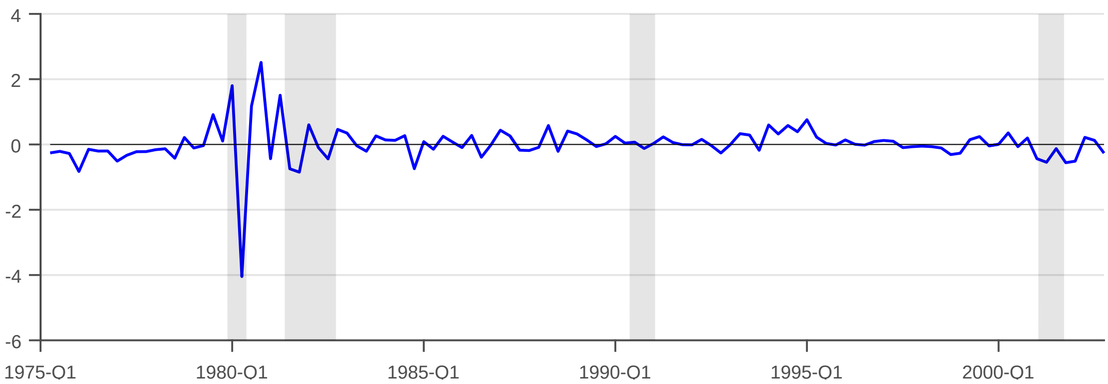
[9]In Subsection 4.4 it is shown that these design choices do not drive the main results.

[10]As mentioned above, the last $H$ periods of the sample are lost in the local projection framework; setting $H$ to 20 and cutting the sample in 2007Q4 before the zero lower bound is hit restricts the transition variable to end in 2002Q4.

### Monetary Policy Shocks

The STLP method applied here requires the identification of a structural shock series outside of estimation. Romer and Romer (2004)'s narrative approach to identify monetary policy surprises is the obvious choice.[11] The general idea is that the policy-makers' information set at each Federal Open Market Committee (FOMC) meeting is best presented by Greenbook forecasts specifically prepared for each meeting. A monetary policy innovation is then defined by changes in the intended Fed funds rate not predicted by a forward-looking Taylor Rule using this information set.
Figure 2 depicts the monetary policy shock series updated by Wieland and Yang (2016). While for most of the sample the Fed explicitly targeted the funds rate, for a short period between 1979 and 1982 it engaged in non-borrowed reserve targeting. As shown by Coibion (2012), the two possibly misspecified extreme shocks in 1980 are important drivers of the comparably strong propagation of monetary policy in Romer and Romer (2004). In Subsection 4.4, I check for the robustness of the main results to the influence of single shocks and clusters of three consecutive shocks.

**Figure 2** Updated Romer and Romer (2004) monetary policy shocks




### Control Variables

While in theory the monetary policy shocks should be orthogonal to all information available at the time of the FOMC meeting, in practice the information set of policymakers possibly contains additional variables besides the Greenbook forecasts. Thus, I follow Ramey (2016) and include one lag of the monetary policy shock, the dependent variable, the funds rate, the log of real GDP, the unemployment rate, the log of the consumer price index, the log of a commodity price index, and additionally

[11] High-frequency approaches utilizing surprises in Fed funds futures in short windows after FOMC announcements as, e.g., applied in Gertler and Karadi (2015) become increasingly popular in the literature; despite their merits, Ramey (2016) reveals some unwanted features of these shocks: they are not zero-mean, exhibit serial correlation and can be predicted to some degree by Greenbook forecasts; most importantly, they are only available from 1991 onwards, reducing the number of utilized quarterly observations in the present regression from 111 to only 47.

the log of real residential investment.[12] As dependent variables, the Fed funds rate (*FFR*) and the logs of real GDP (*GDP*), real house prices (*HP*), real consumption of durable goods (*Cons D*), real consumption of non-durable goods (*Cons ND*), housing starts (*HStarts*), real residential investment (*Res Inv*), real mortgage liabilities of households (*Mortg*) and real MEWs (*MEW*) are included in the baseline setup. All sources are given in the appendix as well as a description of the self-compiled MEW time-series.

# 4 Results

In this section impulse response functions of the STLP method are presented, starting with the baseline results in Subsection 4.1. Thereafter, in Subsection 4.2 the findings are aligned with previous evidence on a more powerful transmission of monetary policy to the real sector in times of economic booms. Possible asymmetric effects suggested by the occasionally binding constraints literature are examined in Subsection 4.3, while Subsection 4.4 provides some robustness checks towards the choice of the transition variable, the monetary policy shocks, extreme shocks and parameters of the baseline setup.

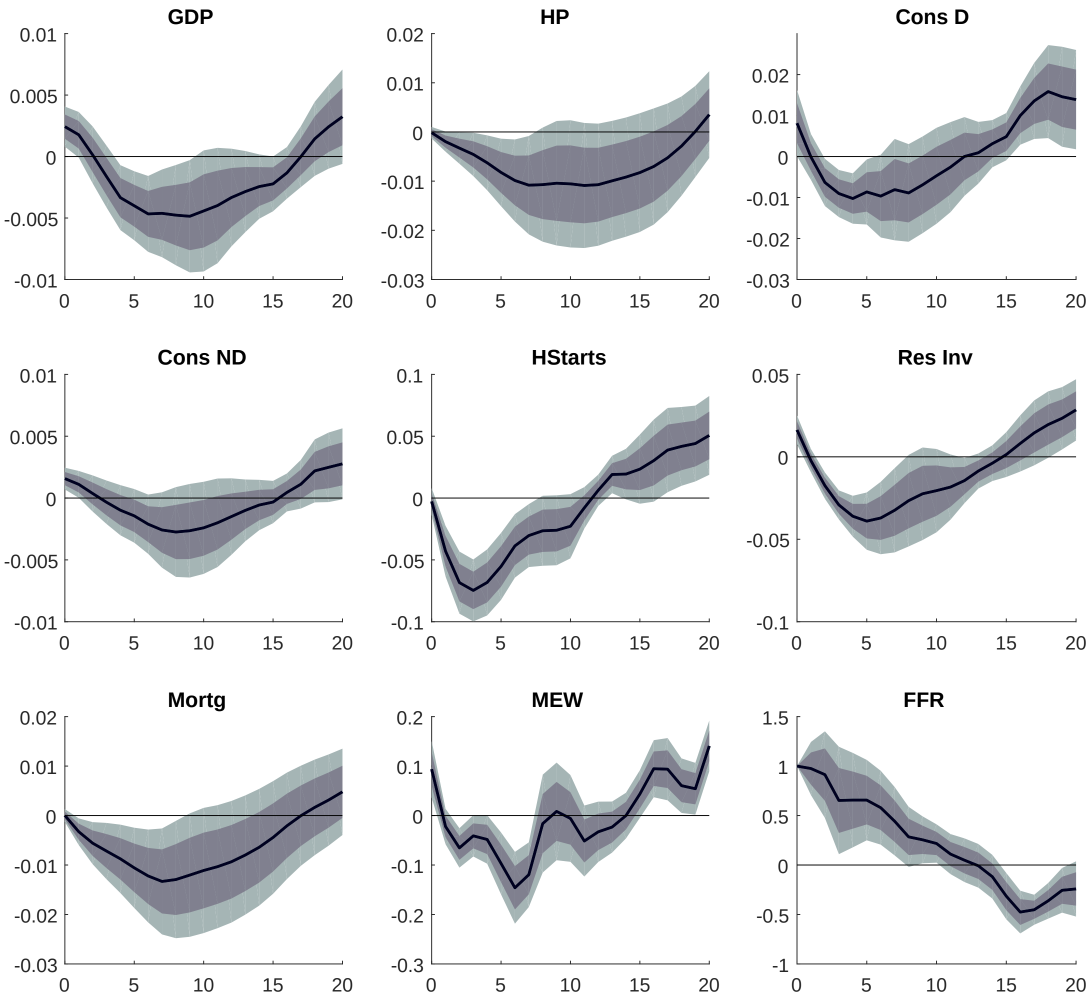
## 4.1 Baseline Results

Figure 3 displays linear impulse responses for 20 quarters to a monetary policy shock that increases the Fed funds rate by 100 basis points on impact. 68% and 90% confidence intervals are given by the gray-shaded area. Qualitatively, the results are mostly in line with standard VAR approaches. In the real estate sector, the contractionary monetary policy shock leads to lower housing demand, displayed by a significant decrease in real mortgage credit outstanding by around 1.2 percent after 2 years, mirrored by a strong decrease in housing starts and real residential investment by around 7 percent and 4 percent after 1 year and 1.5 years, respectively. Real house prices, on the other hand, only decrease by about 1 percent after 2 years, which is at the lower end of past VAR results. At least part of the reaction in the housing sector seems to come from existing homeowners who decrease MEWs by around 15% after 1.5 years. The response, however, is somewhat erratic, conceivably owed to the rather crude approximation of actual MEWs. Somewhat surprisingly, MEWs increase on impact, possibly due to slack in mortgage rates. Borrowers anticipate further adjustments in mortgage rates and antedate/delay planned activities of extracting equity from their homes. This story could partially explain the im-

[12] Ramey (2016) includes two lags of each of the variables besides residential investment, but investigates monthly data instead of quarterly data.

pact increases of real sector variables such as consumption, residential investment and GDP, which display a puzzle common to local projection estimation (see also Tenreyro and Thwaites, 2016, or Falck, Hoffmann, and Hürtgen, 2017). Overall, responses are mostly significant at the 10% level, but error bands are relatively wide, pointing to possible heterogeneities in responses.

**Figure 3** Impulse Responses of Linear Model



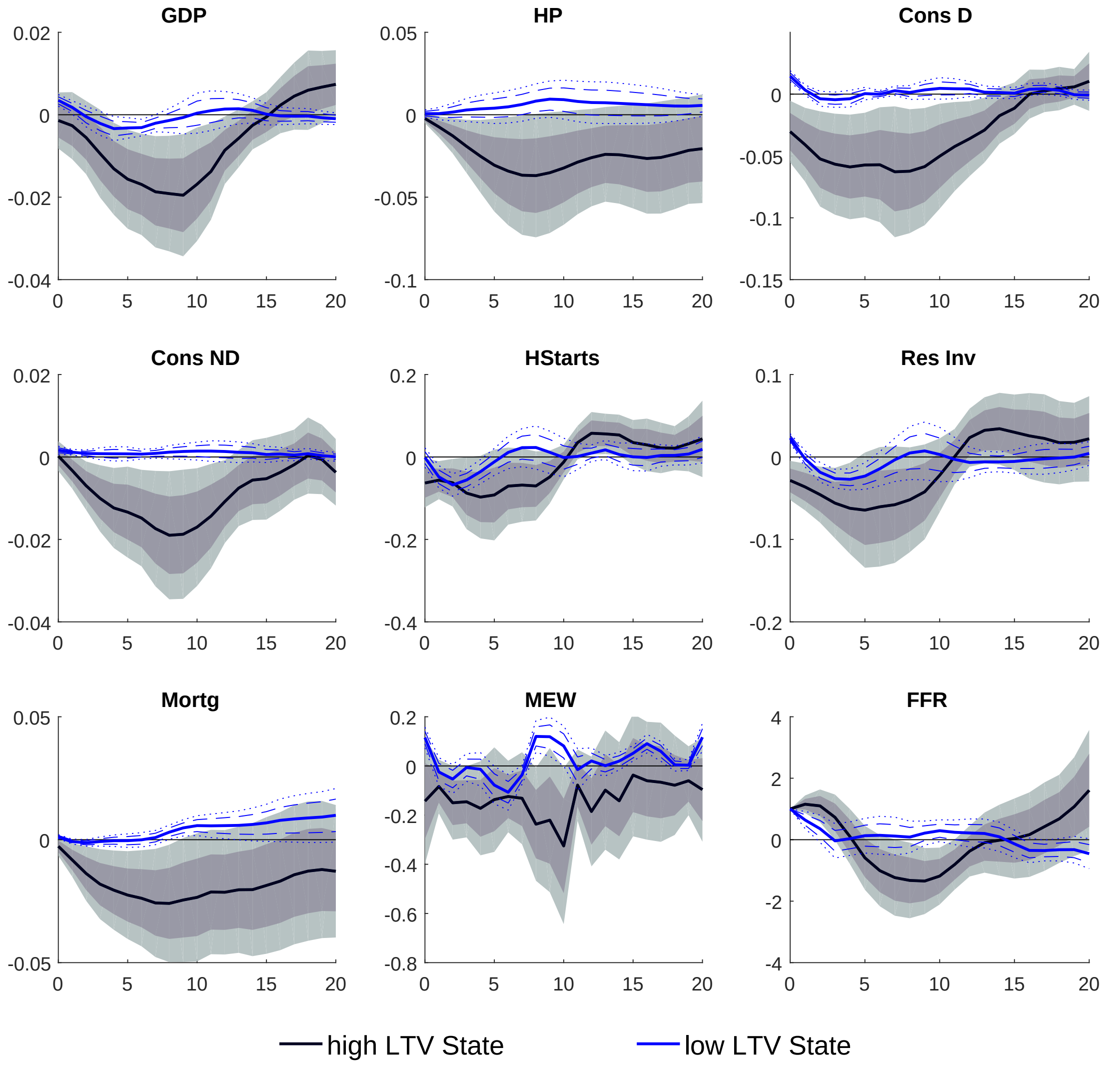

Note: The black lines depict linear impulse responses to a monetary policy shock that increases the Fed funds rate by 100 basis points on impact; gray-shaded areas give the 68% and 90% confidence intervals, respectively.

The picture looks different when the smooth transition framework in Equation (1) is applied. Monetary policy propagates much more strongly in times of high LTV ratios (black line) in Figure 4 compared to responses in times of low LTV ratios (blue line). A contractionary monetary policy shock now shrinks mortgage credit outstanding by more than 2 percent at its peak when lending conditions are loose. What is more, this leads to stronger reactions of real residential investment and housing starts and, ultimately, to a more pronounced decline in real house prices by about 4 percent after 2 years. In line with the story of a higher sensitivity of MEWs, besides the decline in durables consumption by over 5% at its peak, the decline in non-durables consumption is also much more pronounced in times of high LTV ratios compared to the linear case with around 2% after 2 years. In fact, Mian and Sufi (2011) find no evidence that home equity-based borrowing from house price hikes finances purchases of new homes or investment properties and, thus, is probably to a significant part used for non-durables consumption. Consequently, while the stronger decrease in durables consumption might be partially owed to potential first-time homebuyers, the more pronounced reaction of non-durables consumption is possibly due to monetary policy draining homeowners' equity stakes in the high LTV environment, impeding the possibility of refinancing their mortgages and, eventually, enhancing the probability of default. Supportive of this argument is the decline in MEWs by up to 30%, although in most periods only significantly so at the 10% level. Still, the difference between MEWs in high and low LTV states becomes significant at the 5% level after around two years for a few periods.

In the low LTV environment, monetary policy has only a negligible effect on housing sector variables. During the first 2 years preceding the shock there is no statistically significant reaction of either mortgage credit outstanding or house prices. Residential investment as well as housing starts drop but rebound quite fast. Without any relevant changes in house prices, there is no collateral constraint channel at work. Accordingly, MEWs do not unambiguously move into one direction and consumption stays virtually unchanged. These results point to a reduced relevance of changes in mortgages rates when strict downpayment requirements lead to large equity stakes of homeowners. Interestingly, Hofmann and Peersman (2017) find only negligible responses of mortgages and house prices in an early sample from 1955 to 1979 compared to strong responses in a later sample from 1984 to 2008, possibly attributable to a general increase in LTV ratios over time.

The observed differences in responses between states are both statistically and economically significant. For selected variables, namely real house prices, real durables and non-durables consumption, as well as real mortgage credit outstanding, column (1) in Table 1 at the end of the paper depicts significance levels of at least 5%. From an economic point of view, peak differences in responses are in the region of 4.3 percentage points for real house prices, 2.7 percentage points for real mortgage credit outstanding and 1.8 and 6.6 percentage points for real non-durables and durables consumption, respectively.

**Figure 4** State-Dependent Impulse Responses




Note: The black lines (blue lines) depict the state-dependent impulse responses to a monetary policy shock that increases the Fed funds rate by 100 basis points on impact in the high LTV state (low LTV state); gray-shaded areas (blue dashed and dotted lines) give the 68% and 90% confidence intervals for the high LTV (low LTV) state, respectively.

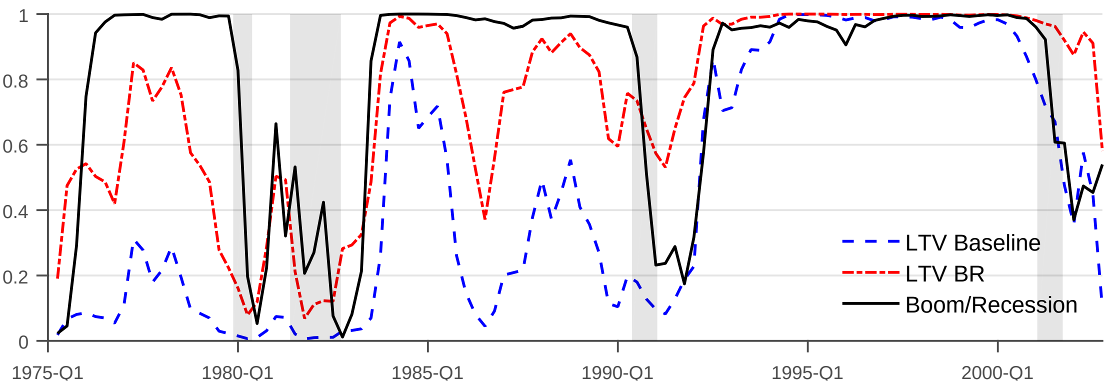
## 4.2 Relation to Boom/Recession Non-Linearities

Earlier empirical research mostly points towards monetary policy actions having larger effects on the real economy in times of recessions (see e.g. Weise, 1999, Garcia and Schaller, 2002, or Lo and Piger, 2005). These results are, however, questioned recently: Mumtaz and Surico (2015) and Tenreyro and Thwaites (2016) use Romer and Romer (2004) shocks within single-equation approaches and, both, find that monetary policy propagates stronger towards real economic activity in times of economic booms. Nevertheless, theory is mostly mute on this result. One exception is the study by Berger and Vavra (2015), where the authors argue that the sensitivity of durables expenditure to shocks is procyclical. In recessions, fixed costs of durables adjustment, such as brokers' fees or titling costs, represent a larger fraction of household income, making it relatively more costly for households to react to shocks via changes in durables consumption. This, however, cannot explain the increased sensitivity that non-durables consumption exhibits during economic booms.

Interestingly, Garcia and Schaller (2002) rationalize their findings via borrowing constraints becoming non-binding during economic booms. While this might be true for a few households, I argue that to a much greater effect higher LTV ratios during boom phases allow constrained households to increase borrowing activity. The main determinant of LTV ratios is the liquidation value for a mortgage lender in case of the borrower's default. According to Ungerer (2015), this liquidation value mainly depends on (i) the cost associated with finding a new buyer for the real estate and (ii) the transaction price when the house is eventually sold. Since liquidity in the housing market and expected house prices are procyclical, LTV ratios should also exhibit a highly procyclical behavior. Figure 5 shows that this is indeed the case. It displays the boom/recession transition variable used in Tenreyro and Thwaites (2016), which is calculated with a lagging seven quarter moving average of real quarterly GDP growth and labels 20% of the periods as recessions (*Boom/Recession*). Accordingly, an LTV transition variable is modeled that allows for only 20% to be in the low state (*LTV BR*) besides the baseline specification (*LTV Baseline*). LTV states exhibit a high correlation coefficient with the boom/recession transition function of 0.51 (*LTV Baseline*) and 0.62 (*LTV BR*), respectively. Thus, it is expected that state-dependent impulse responses in high (low) LTV states should capture much of what is found in responses during booms (recessions).

State-dependent impulse responses during boom and recession phases are depicted for real house prices, real durables and non-durables consumption, and real mortgage credit outstanding against impulse response functions in high and low LTV states in Figure 6. Especially the impulse response in boom phases seems to capture much of

**Figure 5** Transition Variable LTV State vs. Boom/Recession




Note: The *Boom/Recession* transition variable is modeled as described in Tenreyro and Thwaites (2016) such that recessions make up 20% of the observations; the *LTV Baseline* transition variable is the same as in Figure 1, while the *LTV BR* transition variable only allows for 20% of the observations to be in the low LTV state.

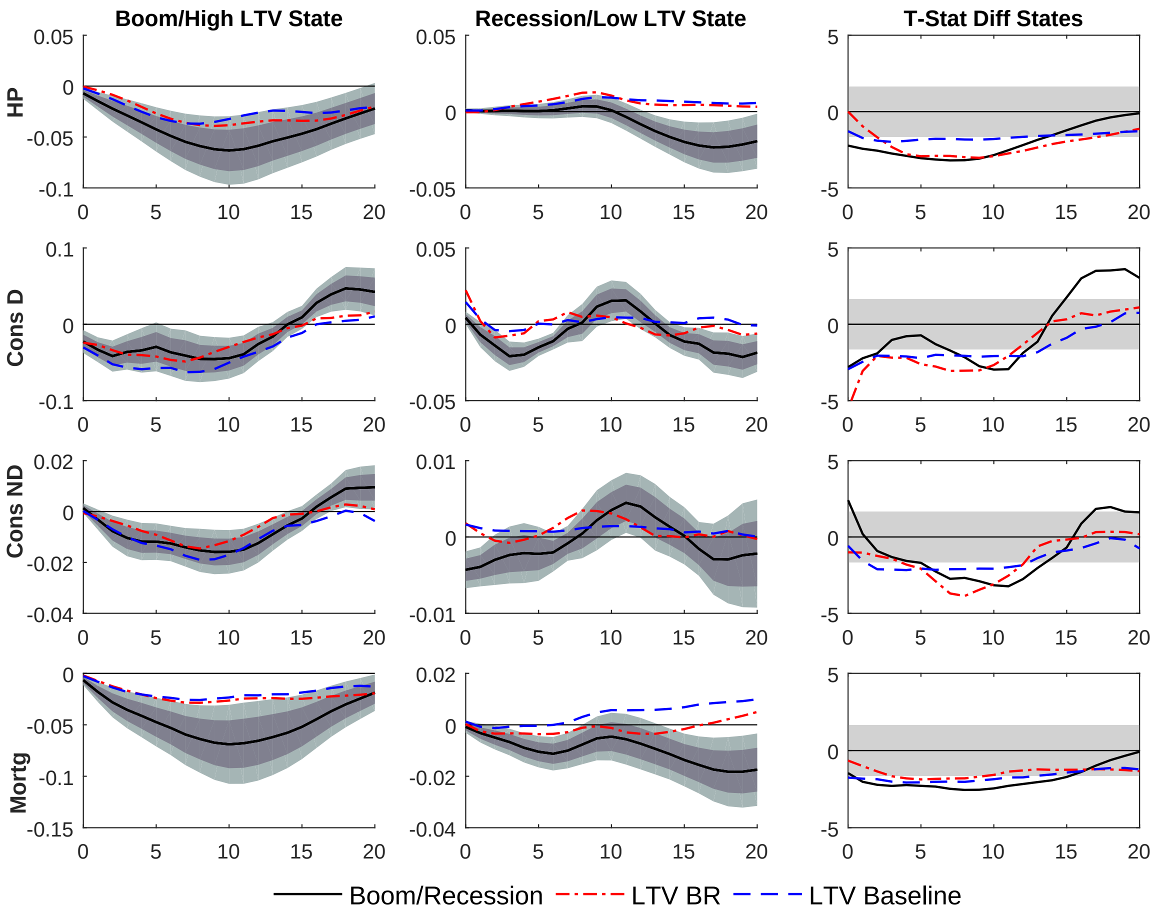
the same variation as that in high LTV states, displaying quite similar behavior. The only notable difference is the slightly stronger reaction of mortgage credit and house prices in boom phases. In recession times, differences in the responses compared to low LTV states are more pronounced. Still, qualitatively, responses are similar. Quantitatively, their relatively small magnitude ensures a comparable percentage point difference between high/low LTV states and booms/recessions. Overall, t-statistics of these differences depicted in the right column of Figure 6 are alike throughout the three specifications in the transition variable. Statistical significance of these differences is given for all four variables at least at the 10% level.
Thus, it can be argued that the amplified propagation of monetary policy to the real sector in times of economic booms is attributable to higher LTV ratios that increase the sensitivity of private consumption towards house price changes via a stronger collateral constraint channel.

## 4.3 Tightening vs. Loosening Periods

The previous results might also be driven by asymmetric responses to monetary policy shocks. Past evidence has shown that the economy reacts more strongly to contractionary compared to expansionary monetary policy (see, e.g., Angrist et al., 2017). Figure 7 displays the probability density functions of all shocks and the state-dependent shocks. In high LTV states, shocks are distributed around zero, while all outliers appear in low LTV states and the distribution is slightly shifted to the left.[13] Still, around 41% of the shocks in times of low LTV ratios are contractionary. This fact can most certainly not explain why consumption and real estate sector responses

[13]Robustness of results towards these outliers is investigated in the next subsection.

**Figure 6** Impulse Responses Boom/Recession vs. LTV States



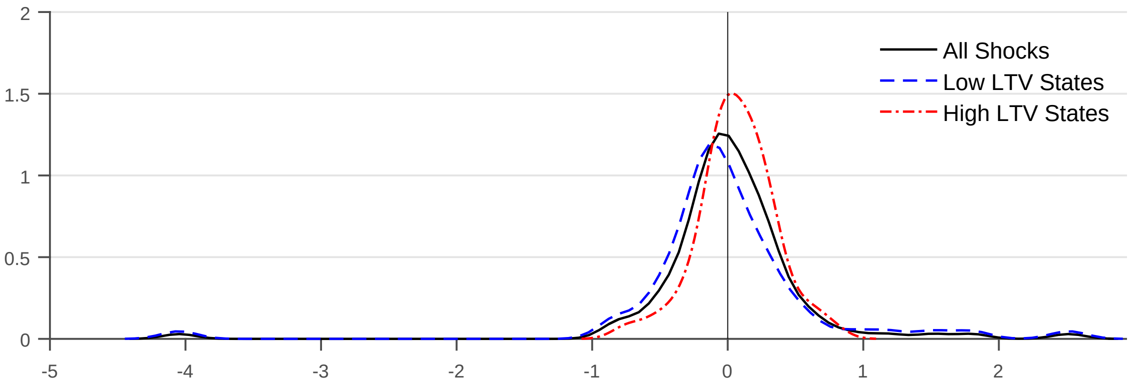

Note: The first column depicts impulse responses in boom phases (black line, 68% and 90% confidence intervals given by gray-shaded areas) and high LTV states (red and blue dashed lines for different specifications); the second column depicts the respective responses in recessions and low LTV states; the third column gives the t-statistic of the differences in responses between states; if t-statistics are outside the gray-shaded area (±1.65), differences in responses are statistically significant at the 10% level; shocks are normalized such that the Fed funds rate increases by 100 basis points on impact.

to monetary policy are virtually muted in times of low LTV environments.

As outlined above, the occasionally binding constraints literature predicts that collateral constraints might become non-binding when an expansionary shock hits the economy in times of high LTV ratios (Guerrieri and Iacoviello, 2017, or Jensen et al., 2018). If this is true, previous results should be driven mainly by contractionary monetary policy shocks. To check for possible asymmetries in responses, the STLP model is reestimated allowing for different effects of positive and negative policy shocks, using

$$\begin{aligned} y_{t+h} = \tau_h t + F(z_t)(\alpha_h^{(1)} + \boldsymbol{\gamma}_h^{(1)\prime}\mathbf{X}_t^c + \beta_h^{(1,+)}\max\{0,\varepsilon_t\} + \beta_h^{(1,-)}\min\{0,\varepsilon_t\}) \\ + [1 - F(z_t)](\alpha_h^{(2)} + \boldsymbol{\gamma}_h^{(2)\prime}\mathbf{X}_t^c + \beta_h^{(2,+)}\max\{0,\varepsilon_t\} + \beta_h^{(2,-)}\min\{0,\varepsilon_t\}) + u_{t+h} \quad (3) \end{aligned}$$

**Figure 7** Distribution of Shocks in LTV States




Note: The state-dependent as well as overall probability density functions of the monetary policy shocks are approximated via a Kernel density estimate.

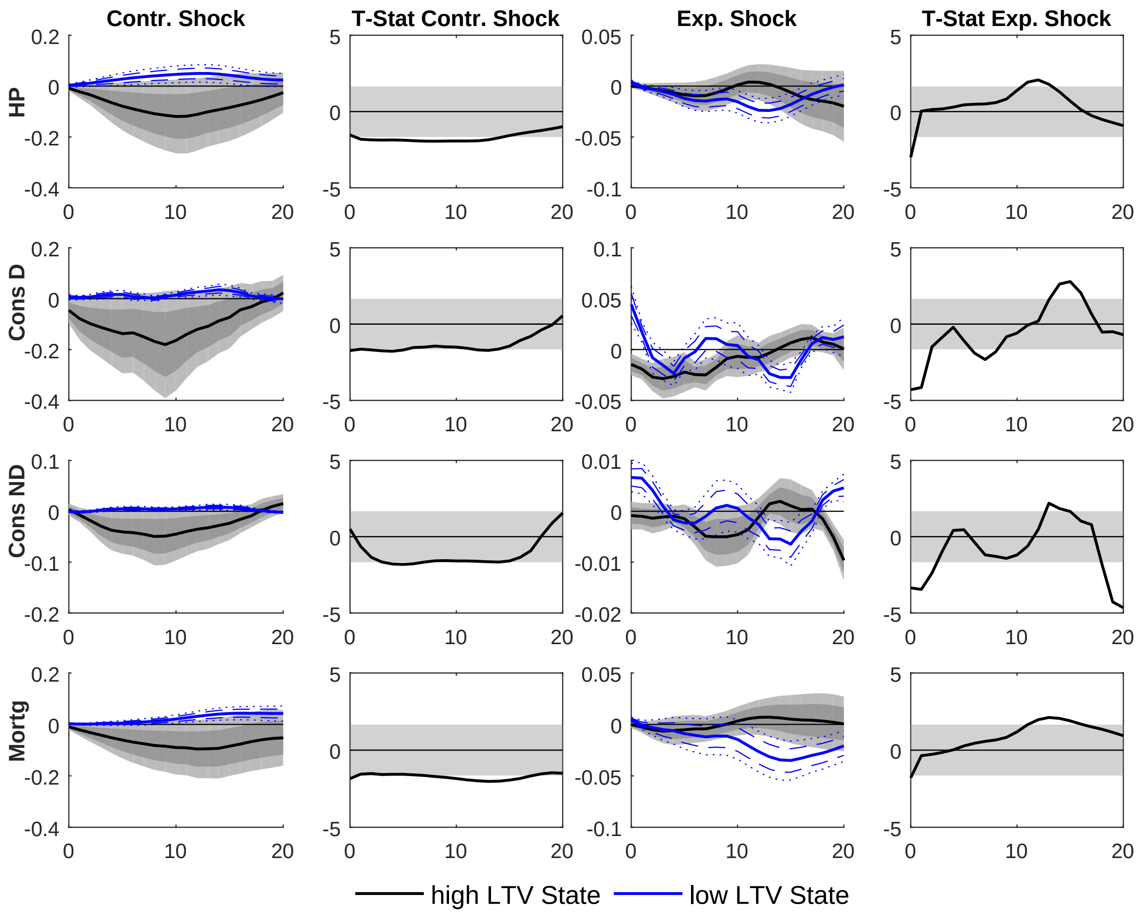
where the transition function $F(z_t)$ is given by (2) and the only difference to the baseline setup in (1) is the breakdown into responses to contractionary shocks $(\beta_h^{(1,+)}, \beta_h^{(2,+)})$ and expansionary shocks $(\beta_h^{(1,-)}, \beta_h^{(2,-)})$ in both states.
Results of this exercise are depicted in Figure 8, with expansionary shocks being mirrored to facilitate comparability. Qualitatively, impulse responses to contractionary monetary policy shocks mimic those in the symmetric case in Figure 4. In high LTV states, real mortgage credit, real consumption of both types as well as real house prices decrease strongly, while this is not the case during low LTV states. Quantitatively, however, responses in high LTV states to contractionary monetary policy shocks are much larger compared to the symmetric case although error bands are quite large. Responses to expansionary shocks are much harder to interpret. They display erratic behavior, especially in low LTV states, a problem often found in local projection approaches. Compared to contractionary shocks, responses are small, in line with past results. Overall, the direction of the difference in responses between high and low LTV states after expansionary shocks is not clear, possibly due to a weaker collateral constraint channel. These results support the occasionally binding constraints idea insofar as they attribute the stronger propagation of monetary policy in high LTV states to contractionary shocks. However, the small number of observations in each of the four states calls for a cautious interpretation of these findings.

## 4.4 Robustness Checks

### Alternative Transition Variables

The collateral constraint channel depends on borrowers being actually constrained. LTV ratios of those constrained houseowners might behave differently from average

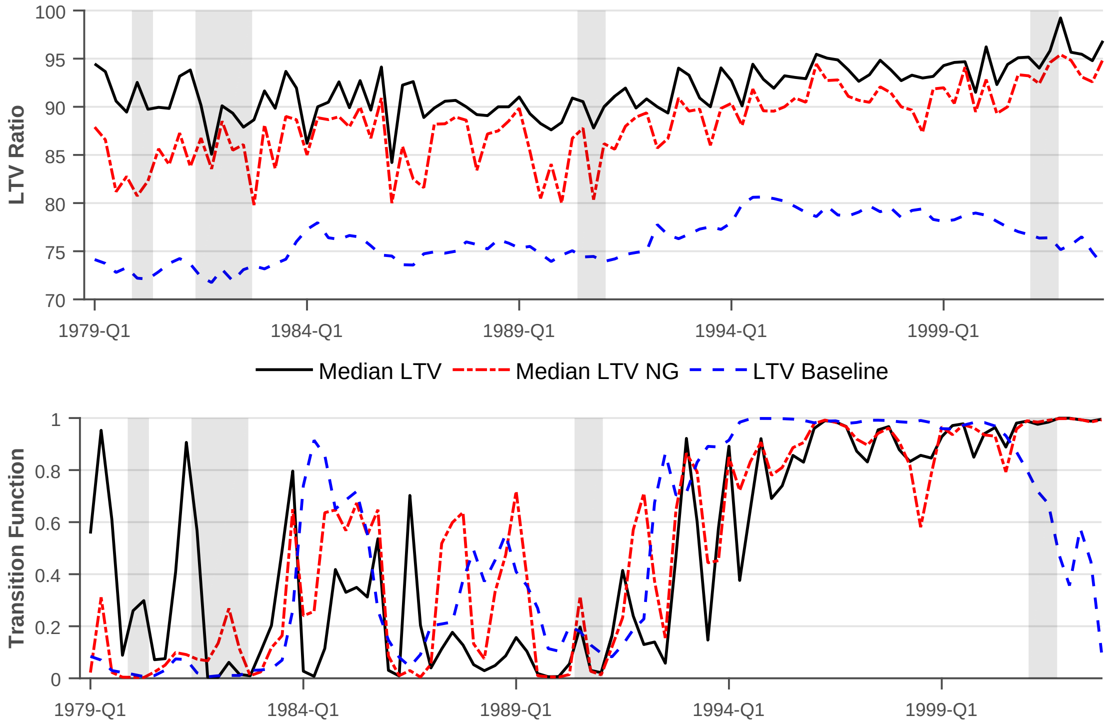
**Figure 8** Impulse Responses Expansionary vs. Contractionary Shocks




Note: The first column depicts the responses to contractionary monetary policy shocks in high LTV states (black line) and low LTV states (blue line); the third column depicts the mirrored responses to expansionary shocks, respectively; the second and fourth columns give the t-statistics of difference between the states for contractionary and expansionary shocks; if t-statistics are outside the gray-shaded area (±1.65), differences in responses are statistically significant at the 10% level; all shocks are normalized such that the Fed funds rate increases by 100 basis points on impact.

LTV ratios. To account for this potential shortcoming, I utilize alternative proxies for the sensitivity of the collateral constraint channel, namely two median LTV series deployed by Duca, Muellbauer, and Murphy (2011) and Duca et al. (2016) that are derived from the American Housing Survey (AHS). Compared to the series of the FHFA, these depict LTV ratios only of first-time homebuyers, start in 1978Q4, and one of the series additionally includes government-insured lending in the form of Federal Housing Administration (FHA) and Veteran Affairs (VA) mortgages (*Median LTV*), generally used by low-income households with a high possibility of being constrained. Figure 9 displays the LTV ratios as well as their respective transition functions in comparison to the baseline transition variable. While they follow similar patterns in the long run, the median LTV ratios are higher and more volatile than average LTV ratios, leading to erratic behavior of the transition function, especially when government insured mortgages are included.

**Figure 9** Alternative LTV Measures and their Transition Variables



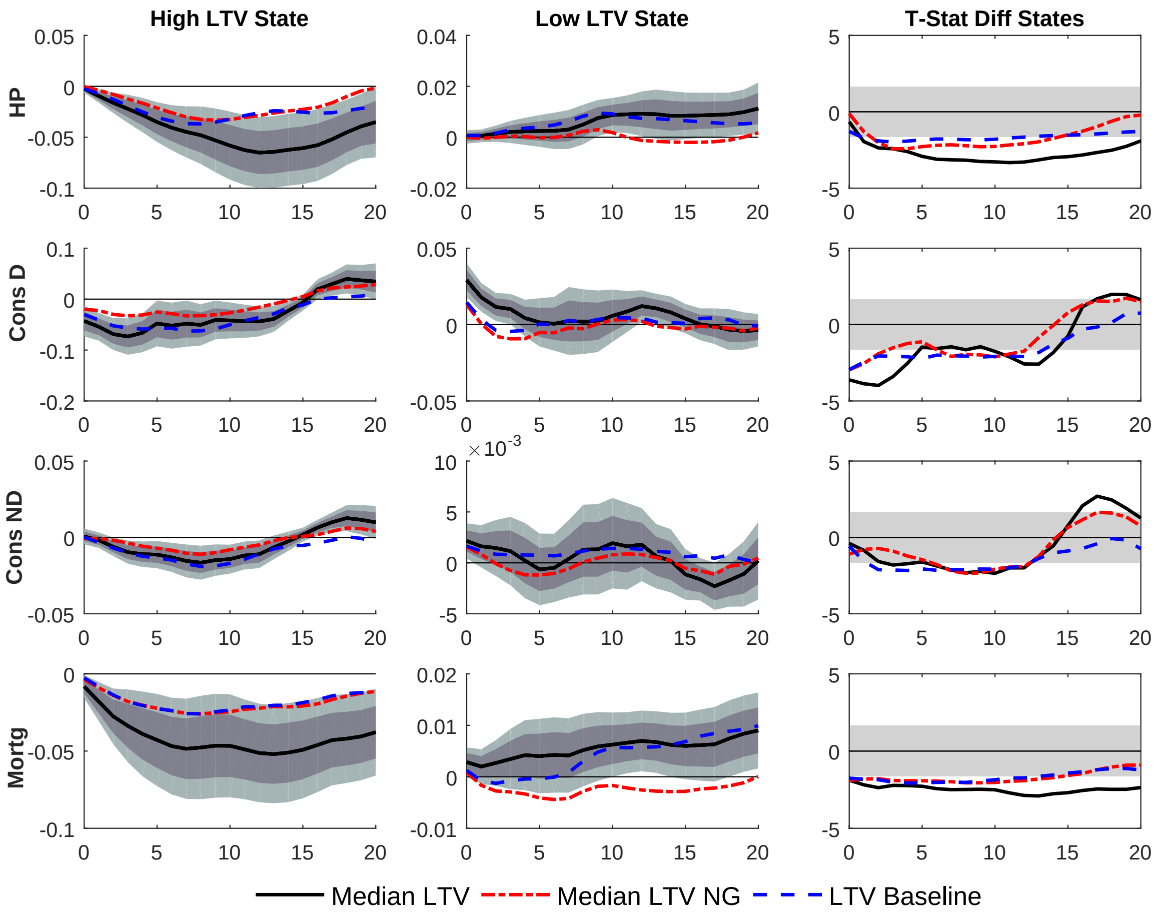

Note: The transition functions are smoothed using two quarter moving averages of their respective LTV ratios; *Median LTV* is the series used in Duca et al. (2016) that includes government-insured loans in the form of FHA and VA mortgages, and *Median LTV NG* is the series that excludes these government-insured mortgages.

Results from the STLP estimation for the new transition variables are given in Figure 10. Responses are surprisingly similar throughout the different LTV proxies. One notable difference is the stronger response of mortgage credit and house prices in the high LTV state when government-insured mortgages are additionally considered. The latter include mostly constrained borrowers and possibly better proxy for the sensitivity of the collateral constraint channel. However, consumption responses are nearly indistinguishable. Statistical and economic significance is given for all transition variables, leading to the conclusion that results are not driven by the specific choice of the LTV ratio deployed.

### Alternative Monetary Policy Shocks

If monetary policy is not adequately represented by a linear forward-looking Taylor rule, shocks from the standard Romer and Romer (2004) narrative are misspecified. This exercise by and large follows Coibion (2012) by checking for the robustness of the results against four alternative specifications of the monetary policy shock that

**Figure 10** Impulse Responses with Alternative LTV Measures




Note: The first column depicts impulse responses in high LTV states (black line for median LTV ratio, 68% and 90% confidence intervals given by gray-shaded areas; red dashed line for median LTV ratio of non-governmental mortgages, blue dashed line for baseline LTV ratio); the second column depicts the respective responses in low LTV states; the third column gives the t-statistic of the differences in responses between states; if t-statistics are outside the gray-shaded area ($\pm$1.65), differences in responses are statistically significant at the 10% level; shocks are normalized such that the Fed funds rate increases by 100 basis points on impact.

all use Taylor rule-based measures: Romer and Romer (2004) shocks (i) estimated via a time-varying parameter (TVP) model (*TVP RR*), (ii) estimated via a generalized autoregressive conditional heteroscedasticity (GARCH) model of order (1,1) (*GARCH RR*), (iii) estimated via a smooth transition framework allowing for the Taylor rule parameters to be different in high and low LTV states (*ST RR*), and (iv) monetary policy shocks from an estimated Smets and Wouters (2007) DSGE model.[14]

Some authors argue that the presence of strong heteroscedasticity in estimating

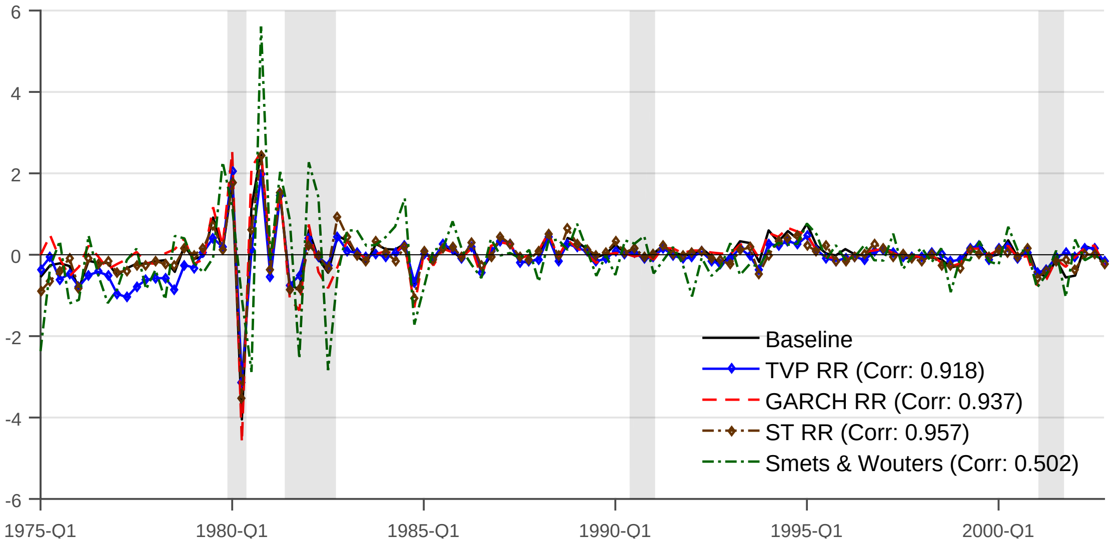
[14]For details on estimation, see Coibion (2012) and the references therein concerning (i), (ii), and (iv); (iii) is simply estimated via OLS, allowing for a smooth transition between high and low LTV states, using the transition function in (2) with $\mu = 3$ and a state-dependent constant.

Taylor rules leads to biased coefficients and, therefore, to misspecified monetary policy shocks. Hamilton (2010), for example, shows that OLS regressions overestimate the change in the reaction to inflation in the post-Volcker area compared to a GARCH(1,1) approach. Another critique on linear Taylor rule estimates is that they are completely silent on changes in the Fed's operating procedures and objectives as well as on policymakers' beliefs about fundamental mechanisms of the economy that all might influence the structural parameters. TVP models take such considerations into account by allowing for time variation in the coefficients, which are assumed to follow a random walk. Policymakers at the Fed might also be aware of possible nonlinearities in monetary policy transmission due to the LTV environment. If this is the case, a smooth transition equivalent of the Romer and Romer (2004) approach is more appropriate to represent monetary policy shocks. Lastly, I also utilize a completely different approach in the form of monetary policy shocks from the Smets and Wouters (2007) DSGE model. This workhorse New Keynesian model includes price and wage frictions and deploys a Taylor rule where the monetary authority reacts to contemporaneous inflation, output growth, and the output gap.

Figure 11 depicts the different monetary policy shocks. Correlations between the baseline shocks and the other Romer and Romer (2004) specifications are high with correlation coefficients of at least 0.918. TVP shocks are more negative in the beginning of the sample, while GARCH shocks exhibit slightly stronger peaks during the phase of non-borrowed reserve targeting. Smooth transition shocks are nearly indistinguishable from the baseline shocks, providing evidence that monetary authorities do not take into account the aggregate LTV state in decision making. Not surprisingly, the most notable difference can be found within the Smets and Wouters (2007) shocks. Its correlation coefficient with the baseline shocks is still 0.502, but it exhibits more pronounced peaks.

Figure 12 plots the responses of the baseline specification with its error bands against the responses to the alternative shocks. First of all, the different estimation of the Romer and Romer (2004) shocks has only minor influences. Significance for differences between high and low LTV states is generally still given at the 10% level, but is somewhat weaker for the TVP and the smooth transition specification and stronger for the GARCH approach. Surprisingly, responses to Smets and Wouters (2007) shocks are quite similar, despite the completely different identification. Even more so, differences all become significant at the 1% level. Thus, results are robust to shock specification, buttressing the finding of a stronger collateral constraint channel in times of high LTV ratios.

**Figure 11** Alternative Monetary Policy Shocks

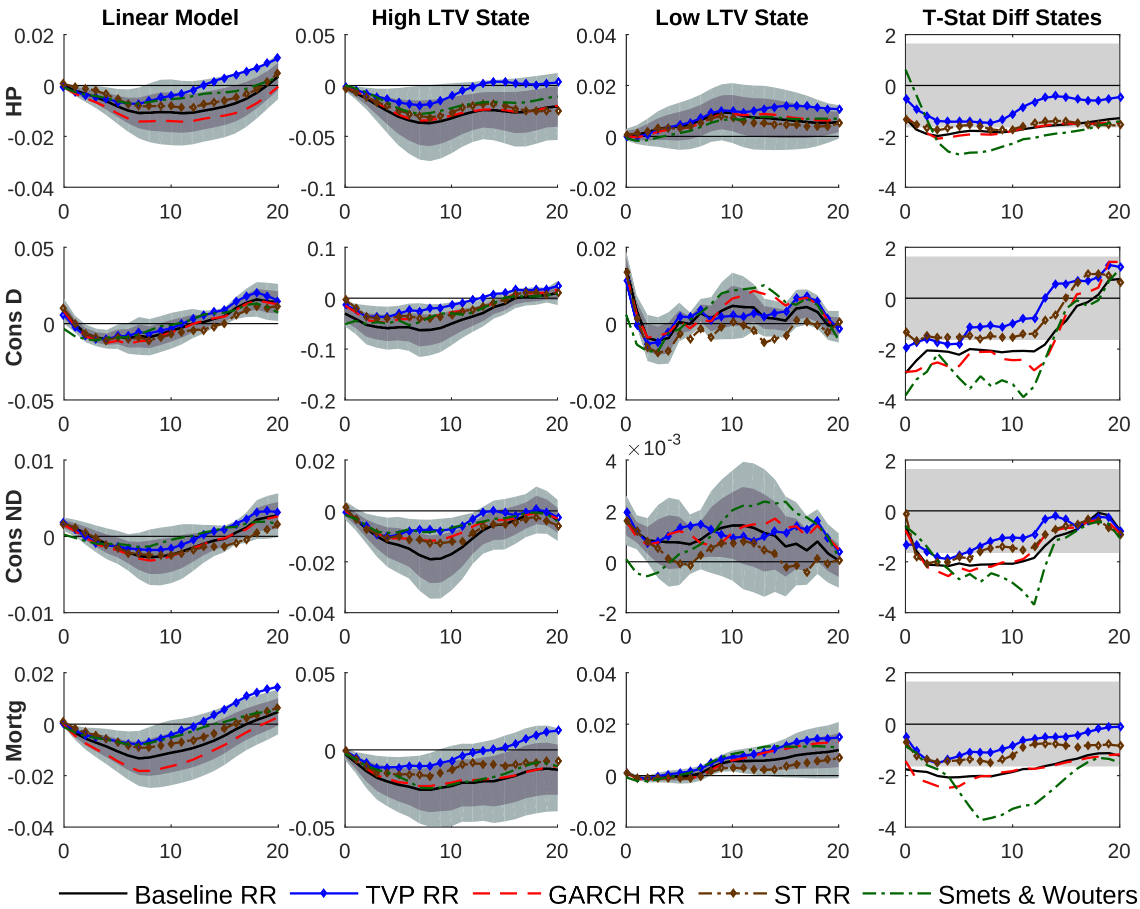



Note: The monetary policy shocks plotted are: Romer and Romer (2004) shocks estimated linearly (*Baseline*), with time-varying parameters (*TVP RR*), GARCH (*GARCH RR*), STLP with LTV as the transition variable (*ST RR*), and estimated shocks from the *Smets and Wouters (2007)* DSGE model; correlations with the baseline shock series are given in brackets.

### Sensitivity to Extreme Shocks

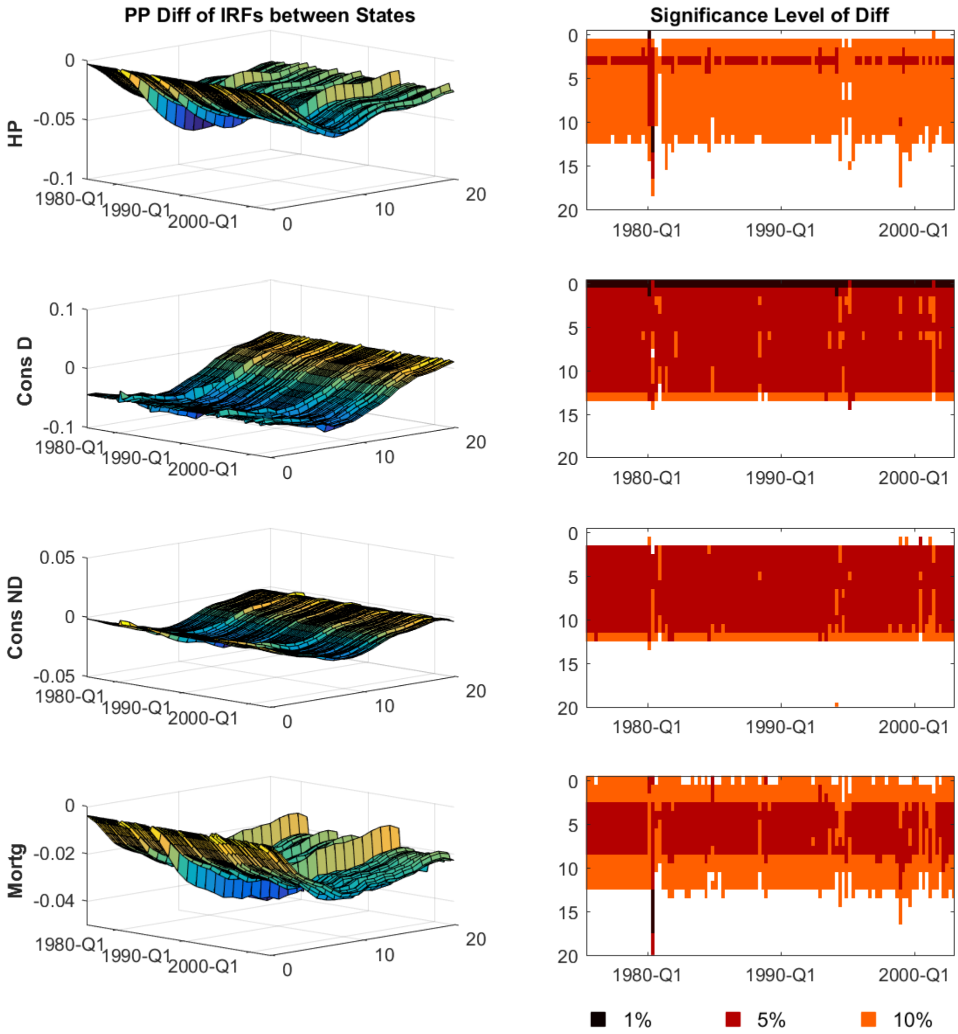
Extreme shocks, especially those in the early 1980s (see Figure 2) where identification of monetary policy via the Romer and Romer (2004) approach is problematic, could drive previous results. In the left column of Figure 13, percentage point differences between impulse responses in both states are plotted for each single shock being muted. The right column depicts the significance level of these difference at each horizon. Statistical significance, at least at the 10% level, remains at all times. The extreme shocks in the early 1980s slightly influence the magnitude of differences in house prices and mortgage credit, but not in the consumption responses.
This exercise is repeated in Figure 14 for clusters of three consecutive shocks being muted. Despite quantitative influences of some of these shock clusters, for all but house prices, differences remain statistically significant at least at the 10% level. Two clusters of shocks, the contractionary shocks at the end of 1980 and in the mid-1990s, contribute importantly to the difference in responses between LTV states in the real estate market, but if muted, differences in responses still exhibit a negative sign. While statistical significance becomes somewhat weaker for differences in consumption responses, they are in general extremely robust to this exercise. Overall, the qualitative interpretation stays the same, discarding the objection that extreme shocks might be the main driver of previous findings. This result is particularly important since theses extreme shocks occur primarily in low LTV states (see Figure 7).

**Figure 12** Impulse Responses to Alternative Shock Specifications



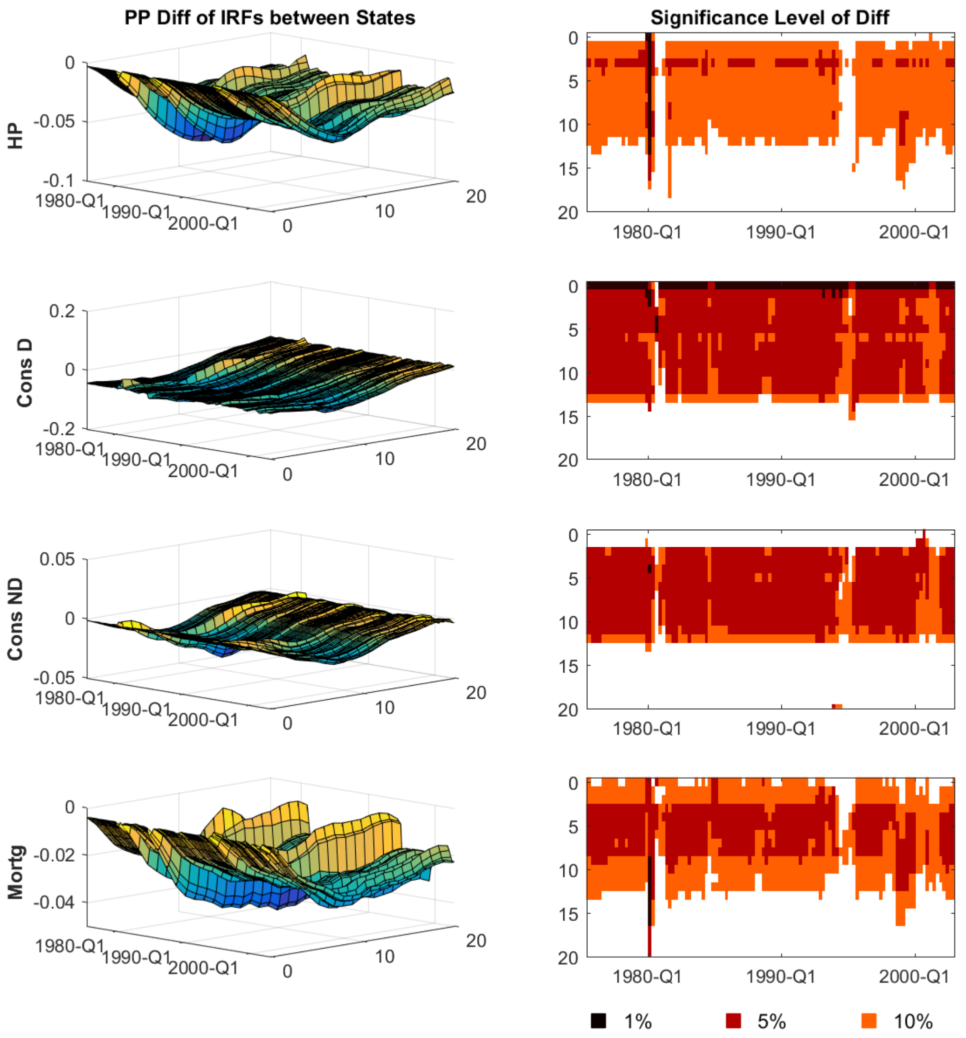

Note: The first column depicts impulse responses in the linear model (black line for baseline shock, 68% and 90% confidence intervals given by gray-shaded areas; blue line for *TVP RR*, red dashed line for *GARCH RR*, brown dashed line for *ST RR*, green dashed line for *Smets and Wouters (2007)* shocks); the second and third columns depict the respective response in high and low LTV states; the fourth column gives the t-statistic of the differences in responses between states; if t-statistics are outside the gray-shaded area (±1.65), differences in responses are statistically significant at the 10% level; shocks are normalized such that the Fed funds rate increases by 100 basis points on impact.

**Figure 13** Sensitivity to Single Shocks




Note: The left column depicts the percentage point differences of impulse responses between the high and low LTV state for each single shock being muted; the right column shows the respective significance level of these differences at each horizon $h$.

**Figure 14** Sensitivity to Clusters of Three Consecutive Shocks




Note: The left column depicts the percentage point differences of impulse responses between the high and low LTV state for each combination of three consecutive shocks being muted; the right column shows the respective significance level of these differences at each horizon $h$.

### Sensitivity to Specifications of Baseline Setup

In a last set of robustness checks, a few baseline specifications are examined more closely, namely (i) the parameter $\mu$ that governs the smoothness of the transition between states, (ii) the control set, and (iii) the moving average specification of the transition variable. Table 1 reports the percentage point differences and their significance level for horizons 1, 4, 8, 12, and 16. Accompanying the results from Figure 4, column 1 shows that in the baseline setup this difference is negative for all four variables under investigation at all reported horizons and statistically significant at the 5% level at least at one horizon. Reducing $\mu$ to 1.5 increases the smoothness of the transition function. While percentage points stay similar to the baseline setup, statistical significance becomes weaker, but is still given for all variables except real mortgage credit. In comparison, an increase in $\mu$ puts more weight on the extreme states. Statistical significance increases, although the magnitude of differences in responses between states decreases slightly. Overall, the exogenous fixation of $\mu$ does not seem to be responsible for previous results.

In theory, the battery of control variables included in the baseline regression should not influence the results since the monetary policy shocks are assumed to be exogenous. In reality, however, these control variables govern additional information to Greenbook forecasts that could be relevant for policymakers. Column (5) of the table shows results from an estimation with the reduced control set used in Tenreyro and Thwaites (2016) with only one lag of the dependent variable and the Fed funds rate included. Qualitatively, percentage point differences still tell the same story as the baseline responses, although statistical significance is weaker. However, the richer control set is preferable as it might at least partially control for possible endogeneity of the monetary policy shocks.

One last robustness check concerns the smoothing of the transition variable itself. In the baseline setup, a two quarter lagging moving average of the LTV ratio has been used to prevent erratic jumps in the transition function. Columns (6) and (7) of Table 1 show that either taking the raw series or smoothing LTV ratios even more with a four quarter lagging moving average does not change the results fundamentally, although responses of mortgage credit become statistically insignificant in column (6).

# 5 Conclusion

In this paper, I provide evidence for a strong link between downpayment requirements in mortgage markets and the impact of monetary policy on the real economy. Impulse response functions from a STLP model exhibit a much stronger respon-

**Table 1** Percentage Point Difference of Impulse Responses between LTV States

| Variable | Horizon | (1) Baseline | (2) $\mu = 1.5$ | (3) $\mu = 5$ | (4) $\mu = 10$ | (5) Contr0 | (6) MA1 | (7) MA4 |
|---|---|---|---|---|---|---|---|---|
| HP | 1 | −0.30 | −0.22 | −0.23 | −0.11 | −0.51 | −0.05 | −0.41 |
| | 4 | −2.22** | −2.19* | −1.78** | −1.14* | −2.35 | −1.31* | −2.50* |
| | 8 | −4.30* | −4.16 | −3.60* | −2.49* | −4.76* | −3.22* | −4.08* |
| | 12 | −3.68* | −2.56 | −3.30** | −2.29** | −5.14 | −2.31 | −3.65* |
| | 16 | −3.19 | −1.83 | −2.96* | −2.00* | −5.70 | −1.43 | −3.03 |
| Cons D | 1 | −4.49*** | −5.76*** | −3.77*** | −2.97*** | −4.37*** | −3.29*** | −4.30*** |
| | 4 | −5.22** | −6.65** | −4.37** | −3.11* | −4.17** | −3.69* | −5.27** |
| | 8 | −6.56** | −8.93* | −5.29** | −3.63** | −4.37 | −5.93** | −5.43** |
| | 12 | −4.67** | −5.77* | −4.23** | −3.55*** | −2.97 | −4.29** | −3.87** |
| | 16 | −1.22 | −2.27 | −1.09 | −1.20 | −1.08 | −0.57 | −0.70 |
| Cons ND | 1 | −0.14 | −0.14 | −0.13 | −0.12 | −0.10 | 0.07 | −0.23 |
| | 4 | −1.08** | −1.28* | −0.94** | −0.72* | −0.86 | −0.63 | −1.12* |
| | 8 | −1.83** | −2.45** | −1.46** | −0.99** | −1.77** | −1.65** | −1.65** |
| | 12 | −1.58** | −2.10* | −1.27** | −0.93** | −1.27 | −1.48** | −1.40** |
| | 16 | −0.59 | −0.97 | −0.43 | −0.38 | −0.32 | −0.31 | −0.45 |
| Mortg | 1 | −0.39* | −0.17 | −0.43* | −0.39* | −0.53* | −0.15 | −0.50 |
| | 4 | −1.73** | −1.20 | −1.70** | −1.32* | −0.55 | −0.97 | −2.13** |
| | 8 | −2.66** | −1.84 | −2.54** | −1.84** | −0.18 | −1.21 | −2.91* |
| | 12 | −2.69* | −0.98 | −2.74** | −1.94** | 1.09 | −0.90 | −2.67 |
| | 16 | −2.54 | −0.42 | −2.78* | −2.10** | 1.48 | −0.63 | −2.50 |

Note: *, **, *** indicate significance at the 10%, 5%, and 1% level of the percentage point difference of impulse responses between high and low LTV states after a contractionary monetary policy shock that increases the Fed funds rate by 100 basis points on impact.

siveness of real house prices, real consumption as well as real mortgage credit to monetary policy shocks in the U.S. when LTV ratios are high, or equivalently downpayment requirements are slack. These outcomes are in line with a stronger sensitivity of mortgage lending towards mortgage rates in times of loose lending conditions in mortgage markets. The higher the LTV ratio, the more equity a constrained houseowner can withdraw after an increase in house prices and the less downpayment requirements increase for potential homebuyers, promoting current demand and, thus, a stronger amplification of the initial shock. In support, responses of a newly compiled time series on equity extraction suggest that MEWs are more sensitive to monetary policy shocks in times of high LTV ratios. Since LTV ratios are highly procyclical, these findings can also deliver a theoretical underpinning of past evidence on an impaired transmission of monetary policy in times of recession. I also provide evidence that the results are mainly driven by contractionary monetary policy shocks as suggested by the occasionally binding constraints literature.

Policy implications drawn from these findings are twofold. First, the effectiveness of monetary policy, notably in the U.S., crucially hinges on timing. Expansionary monetary policy in times of tight credit conditions in mortgage markets will possibly fail to stimulate the economy via the real estate market. Furthermore, strong local components in regional housing markets potentially lead to desynchronized housing cycles such that centralized monetary policy measures can have completely different effects throughout regional markets. Second, macroprudential policies that hamper the ability of households to withdraw equity from real estate, such as mandatory caps on LTV ratios, could weaken the transmission of monetary policy. Thus, coordination of macroprudential tools and traditional monetary policy instruments is vital to obtain financial stability goals without tampering with the ability of monetary policy to affect the real economy. While these implications are specifically built on the U.S. example, they are relevant for other countries, especially those that allow MEWs. In particular, strong heterogeneities in European real estate markets could pose a difficult challenge for policymakers.[15]

Previous studies on monetary policy transmission either ignored the relevance of the collateral constraint channel or explored it in a limited time frame, mostly utilizing data around the outbreak of the Great Recession. To my knowledge, this is the first inquiry that allows for differences in responses to monetary policy shocks according to time-varying aggregate LTV ratios in the economy over a longer period including multiple business cycles. While the story is in line with the estimated responses, more granular data is needed to differentiate the exact contribution of MEWs of existing homeowners and new mortgage lending of homebuyers to these non-linearities. Regional heterogeneities of real estate markets and their influence on the propagation of shocks also provide a pivotal path of future research. Overall, in line with other recent research, this study discards the idea of a linear transmission of monetary policy and encourages empirical and theoretical consideration of non-linearities, especially with regard to real estate and mortgage markets.

[15] Within the European Monetary Union, Calza et al. (2013) classify Finland and the Netherlands as countries where MEWs are common, but Austria, Belgium, France, Germany, Ireland, Italy, and Spain as countries where MEWs are not in use.

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# Appendix

## Measuring MEWs

A guideline to proxy for gross equity extraction (GEE) is given in Greenspan and Kennedy (2005, 2008). Here, I use GEE and MEWs interchangeably, although MEWs in general net out the portion of extracted equity that is reinvested in housing. As shown in Greenspan and Kennedy (2005), MEWs can be expressed as those changes in home mortgages debt outstanding excluding construction loans (MDO), net of amortization (A), that are not due to origination of new homes (ONH):

$$MEW = \Delta MDO + A - ONH$$

Home mortgage debt outstanding can be found on a quarterly basis in the Financial Accounts of the U.S. compiled by the Fed. Due to data availability, it is abstracted from changes in construction loans, which in general only make up a small part of mortgage loans. The value of new homes is proxied via residential investment in single family structures, obtained from the U.S. Bureau of Economic Analysis, which is then multiplied by the average LTV ratio on new homes. This value is calculated as a weighted average of average LTV ratios on new homes from the FHFA for non-government-insured mortgages and a premium on these ratios for government-insured mortgages. The premium is set to the difference between non-insured and insured median LTV ratios from Duca et al. (2016) and fixed to its average of 4 percentage points where no median LTV data is available. The share of insured mortgages is taken from the New Residential Sales database of the U.S. Census Bureau and set to its average of 20% for the time preceding this database. Lastly, not all new homes are financed via mortgages. The mortgaged share is also taken from the New Residential Sales database and fixed at its average of 94% for the time preceding this database.

For total scheduled payments on outstanding mortgages, interest rate data from the FHFA are utilized. The average term to maturity is directly taken from Greenspan and Kennedy (2008), where possible. For earlier time periods, first of all, a moving average of the maturity on newly originated mortgages from the FHFA with a linear decaying weight is calculated. To control for possible defaults and early repayments, 3.4 years are subtracted, the average difference between Greenspan and Kennedy (2008) data and FHFA data in the periods in which both are available. Under the assumption of constant periodic payments, the quarterly amortization can be calculated. Taken together, this gives a raw measure of quarterly MEWs dating back to 1975 displayed in Figure A1.

**Figure A1** MEWs in Percentage of Disposable Income

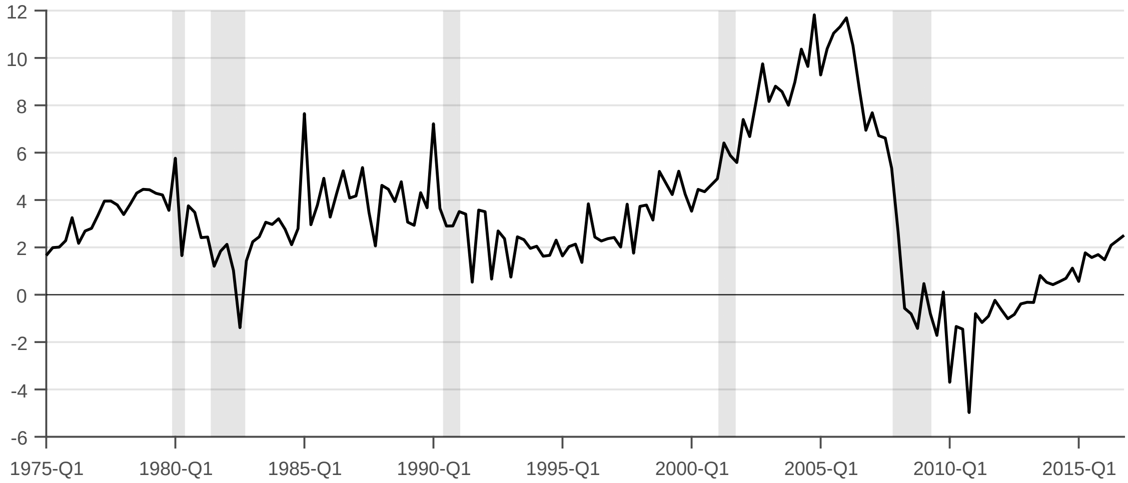


**Table A1** Data and Sources for Baseline Setup

| Variable | Abbr. | Source |
|---|---|---|
| Loan-to-Value Ratio | LTV | Federal Housing Finance Agency |
| Effective Fed Funds Rate | FFR | Board of Governors of the Fed |
| Real GDP | GDP | Fed Philadelphia |
| Consumer Price Index | CPI | U.S. Bureau of Labor Statistics |
| Real House Prices | HP | Shiller (2015) (Updated) |
| Real Durables Consumption | Cons D | Fed Philadelphia |
| Real Non-Durables Consumption | Cons ND | Fed Philadelphia |
| Housing Starts | HStarts | U.S. Bureau of the Census |
| Real Residential Investment | Res Inv | Fed Philadelphia |
| Real Mortgage Debt | Mortg | Board of Governors of the Fed |
| Commodities (Producer Prices) | CommP | U.S. Bureau of Labor Statistics |
| Unemployment | Unemp | U.S. Bureau of Labor Statistics |
| Real Mortg Equity Withdrawals | MEWs | see Appendix |

Note: Where no real series was available, the nominal series are deflated by the CPI; series are seasonally adjusted, where appropriate.