Time-varying interactions between monetary and housing credit policy

Giacomo Rella
Université du Québec à Montréal (UQAM)

September 2025
Accepted at *Journal of Macroeconomics*

The US federal government has long played a pivotal role in the mortgage market through various agencies, most notably the government-sponsored enterprises (GSEs). The importance of these agencies in the housing credit policy landscape increased during the 1990s and in the years leading up to the Great Recession. This article examines the time-varying effects of monetary policy on mortgage credit, focusing on the role of housing credit policy from the early 1990s to 2014. Using a time-varying parameter vector autoregression model and high-frequency monetary policy surprises, I show that GSEs' activity in the secondary mortgage market has shaped the response of mortgage originations to monetary policy shocks. As GSEs became more involved in housing policy, the response of mortgage refinancing originations and GSEs' mortgage purchases to monetary policy strengthened. This suggests that contractionary monetary policy, by undermining housing policy objectives and increasing profit opportunities from mortgage purchases, may prompt a stronger response from GSEs, which in turn dampens the adverse effects of monetary policy tightening on housing activity.

JEL codes: E52, E44, G28.
Keywords: TVP-VAR, Monetary policy, Mortgage market.

Acknowledgements. I am grateful to my late PhD supervisor, Marco P. Tucci, for sparking my curiosity about time-varying parameter models and for guiding me during the conception of this article. I thank the editor and two anonymous referees for comments which helped to improve the paper. I received helpful comments and suggestions from Gert Peersman, Sarah Zubairy, Alberto Dalmazzo, Maëlle Vaille, Pauline Gandré, Aymeric Ortmans, Diego Känzig, Wouter Van der Veken, and Alberto Pozzolo. All remaining errors are my own. This article is based on a chapter of my PhD thesis, which appeared as Working Paper No. 850 in the *Quaderni del Dipartimento di Economia Politica e Statistica, University of Siena,* under the title "The Fed, Housing, and Household Debt Over Time."

Funding sources. This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

1. Introduction

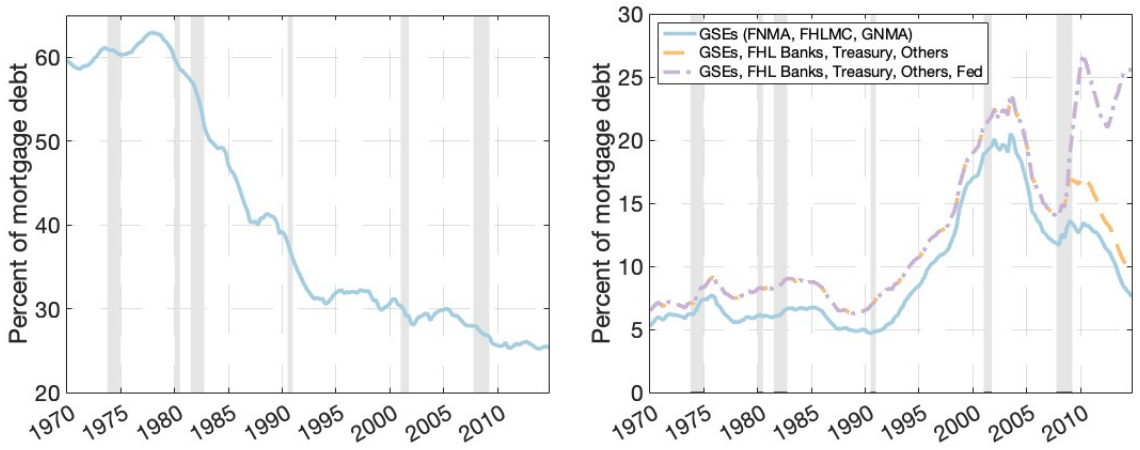
The federal government of the United States has long had a significant influence on mortgage markets, particularly through Government-Sponsored Enterprises (GSEs) such as Fannie Mae, Freddie Mac, and Ginnie Mae.[1] A key development has been the emergence of the originate-to-distribute model, which has significantly changed the structure of mortgage markets (**?**). Figure 1 illustrates the extent of this change. The share of residential mortgages held by banks fell from around 60% in the late 1970s to around 30% in the early 1990s, and continued to decline slowly (panel A). At the same time, the share of mortgages held by federal agencies, especially GSEs, increased sharply, especially from 1990 onwards (panel B). More recently, quantitative easing (QE) has made the Federal Reserve the primary holder of mortgage debt.

Housing credit policies played a critical role in contributing to the growth of GSEs by affecting the size and type of mortgages eligible for purchase (**?**). These policies often respond to cyclical mortgage market conditions, but are also driven by longer-term social policy goals such as increasing homeownership. Given the centrality of mortgage markets to the transmission of monetary policy, the implications of the rising importance of GSEs for monetary policy are surprisingly understudied. While some authors, like **?** and **?**, suggest that GSEs' mortgage purchases weaken the bank lending channel, whether the effects of monetary policy on mortgage credit have varied with the changing role of GSEs in the implementation of housing credit policy remains an open question.

This article investigates the time-varying interaction between monetary policy and housing credit policy in the US. Specifically, it asks whether the effects of monetary policy on mortgage credit have changed over time and how housing credit policy contributes to these shifts. The analysis focuses on the years from the early 1990s to 2014. This period was characterized by extraordinary growth in the activity of GSEs, followed by Conservatorship during the Great Recession. To address these questions, I use the time-varying parameter vector autoregression (TVP-VAR) model of **?**, in which monetary policy surprises act as exogenous variables. To avoid the bias from potentially non-exogenous shocks, I use the monetary policy surprises constructed by **?**, which account for macroeconomic and financial variables available to financial markets before policy announcements.

I find that mortgage originations became increasingly responsive to monetary policy shocks between 1991 and 2014. While a monetary tightening shock reduces the stock of

[1] Throughout this article, GSEs refer to Federal National Mortgage Association (Fannie Mae), the Federal Home Loan Mortgage Corporation (Freddie Mac), and the Government National Mortgage Association (Ginnie Mae). I refer to the housing finance system as a system comprising three intertwined markets. In the primary market, homeowners borrow from lenders and pledge their homes as collateral. In the secondary market, lenders sell the mortgages originated in the primary market to government agencies and private specialized investors. In the market of mortgage-backed securities (MBSs), government agencies and private specialized investors issue MBSs using mortgage pools as collateral.



A. Banking sector B. Federal agencies

FIGURE 1. Holders of residential mortgage debt

Notes: In panel A, the share of residential mortgage debt held by the banking sector includes single family (1-to-4) home mortgages and multifamily mortgages held by US-chartered depository institutions (FL763065105Q+FL763065463Q), foreign banking offices in the US (FL753065103Q), banks in US-affiliated areas (FL743065103Q), and credit unions (FL473065100Q), as share of total residential mortgages (FL893065105Q+FL893065405Q), from the Z.1 Financial Accounts. In panel B, mortgage debt data are from **?**. FNMA is Fannie Mae, FHLMC is Freddie Mac, and GNMA is Ginnie Mae.

mortgage debt, with minimal time-variation, it simultaneously leads to a rise in mortgage originations, an effect that grows stronger over time. This increase is entirely driven by refinancing activity. In contrast, mortgage originations for home purchases contract, aligning with evidence that a monetary tightening slows down housing market activity. While seemingly counterintuitive, the rise in refinancing activity following a monetary policy tightening shock is consistent with the presence of liquidity-constrained households, who use refinancing to access accumulated home equity despite rising interest rates (**??**). Demand for refinancing loans is met by originators, who can sell eligible loans to GSEs, provided they meet underwriting requirements. Accordingly, the response of GSEs' mortgage purchases to monetary policy also increased over time, especially since the mid-1990s, mirroring the heightened response of refinancing originations.

The close association between the time-varying effects of monetary policy on refinancing originations and GSEs' mortgage purchases can be attributed to the unique business model of GSEs. As hybrid institutions balancing private ownership with a public mission to stabilize the mortgage market, GSEs occupy a special position in the housing finance system. Benefiting from privileges like the ability to borrow from the Treasury, leading to an implicit government guarantee of their bonds, they enjoy bond yields close to Treasury rates, with their debt is eligible for Federal Reserve open market operations. While subject to prudential supervision, GSEs have historically faced lighter regulatory oversight compared to private banks, with fewer capital and reporting requirements. In response to

monetary tightening, GSEs increase mortgage purchases, partly driven by their statutory mandate to stabilize mortgage markets and ensure liquidity. Additionally, when interest rates rise, GSEs' financing costs relative to Treasuries increase less than the mortgage spread, creating a wedge between agency debt and mortgage rates. This allows them to profit from purchasing mortgages, even in tight monetary environments (**?**).

The mechanism by which lenders originate mortgages in the primary market and deliver them to GSEs in the secondary market is critical to understanding the interaction between monetary and housing credit policy. GSEs pre-commit to purchasing mortgages from originators (that is, they commit to buying a certain amount of mortgages at predetermined prices) thereby incentivizing lenders to originate loans that meet GSEs' standards. This suggests that secondary market purchases influence primary market lending behavior during a monetary policy tightening, a process I refer to as the originate-to-sell channel. Furthermore, GSEs' purchases may affect adverse selection dynamics in primary markets, as documented by **?**. Lenders may strategically originate large volumes of mortgages, retaining higher-quality loans while selling riskier loans in the secondary market. The strong correlation between refinancing origination responses and GSEs' activity suggests that this secondary-to-primary spillover effect also occurs following a monetary policy tightening.

To further investigate the originate-to-sell channel, I use a state-dependent local projections approach, where the effects of monetary policy depend on the stance of housing credit policy. Consistent with the results from the TVP-VAR model, I find that mortgage originations for refinancing increase following a monetary policy tightening shock when housing credit policy is expansionary, but decline in the non-expansionary state. In contrast, mortgage originations for home purchases exhibit a contractionary response across both policy stances. Additional evidence for the originate-to-sell channel emerges from the behavior of GSE-held mortgages: their share increases under an expansionary policy stance but decreases in the non-expansionary state. I also examine how the originate-to-sell channel shapes the broader impact of monetary policy on housing market activity. The negative effects of monetary policy tightening on housing activity are more severe when housing credit policy is non-expansionary. For example, mortgage rates and house prices respond more strongly in the non-expansionary state, while declines in housing starts and construction employment are deeper and more persistent. These findings suggest that GSEs' intervention mitigates the pass-through of higher funding costs from originators to borrowers. By selling illiquid assets, such as old and newly originated conventional mortgages, to GSEs, mortgage originators offset some of the increased funding costs induced by a monetary tightening. Consequently, the adverse effects of monetary policy tightening on housing activity are dampened under an expansionary housing credit policy stance.

Finally, I show that when housing credit policy is expansionary, a monetary tightening leads to an increase in cash-out refinancing, that is, loans that replace first-lien mortgages and include additional funds drawn from home equity. This suggests that home-equity extraction is the main reason households refinance following a monetary tightening shock, in line with evidence that households refinance even in high interest rates environments to smooth consumption (**?**). By purchasing cash-out refinance mortgages, GSEs provide originators with liquidity, allowing lending activity to continue even during a tightening. A necessary condition for households to extract home equity when interest rates increase is that house prices have risen since the mortgage origination. I further show that house-price booms amplify the increase in cash-out refinancing when housing credit policy is expansionary. This amplification is consistent with the view that GSEs facilitate equity extraction when institutional support is strong and borrower demand, fueled by accumulated home equity, is high.

Understanding this time-varying interaction is critical for assessing both the impact of monetary policy on mortgage markets and the broader implications of future policy on housing finance. To date, the main legislation governing the GSEs has remained largely unchanged since the 2008 Conservatorship. I conclude by discussing the implications of the interaction between monetary and housing credit policy for monetary policymaking and future reforms of GSEs.

1.1. Related literature

My work connects closely to the literature on housing credit policy in the US, particularly concerning GSEs' mortgage purchases. Earlier research found mixed results regarding the aggregate effects of mortgage purchases (**??**). More recently, **?** revisited the evidence, showing that mortgage purchases expand mortgage credit, housing market activity, and aggregate consumption. **?** shows that the expansionary effects of mortgage purchases on household consumption are largely driven by indebted homeowners with access to refinancing. Despite its importance, the literature on the interaction between monetary and housing credit policy is surprisingly small. **?** provides evidence that housing credit policy counteracts contractionary monetary shocks, while **?** demonstrates that mortgage purchases mitigate the bank lending channel of monetary policy. Motivated by the significant rise in GSEs' market activity since the 1990s, my study extends the analysis of monetary and housing credit policy interaction to a time-varying framework.

Banks and mortgage markets are central to many theories of monetary policy transmission. In the traditional bank lending channel, financial intermediation amplifies the effects of monetary policy (**?**). When interest rates rise, financial intermediaries face higher funding costs, either through increased deposit rates to avoid disintermediation or reliance on more expensive external markets. This raises the external finance premium,

reducing the supply of loans. On the demand side, non-financial borrowers also experience higher external finance premiums as their balance sheets weaken (**?**). However, changes in the banking system have weakened the reserve mechanism underlying the bank lending channel. Despite this, empirical studies show that monetary policy continues to influence bank lending. **?** argue this is due to the deposit channel. When policy tightens, banks keep deposit rates low as they maintain market power over the supply of deposit, prompting households to withdraw funds and move toward less liquid assets (e.g., money market funds). Due to the specificity of bank deposits (e.g., deposit insurance) and the costs of replacing them with wholesale funding, banks reduce lending growth. My analysis shows that, complementary to these channels, housing credit policy is an additional factor contributing to the effects of monetary policy on lending behavior.

A substantial body of research explores the impact of monetary policy on mortgage refinancing (see **?**, for a survey). In the US, long-term fixed-rate mortgages with penalty-free prepayment options enable homeowners to refinance at lower rates when monetary policy is expansionary. However, various factors can impede refinancing, weakening its effectiveness during monetary expansions. For example, cutting rates amid a secular decline in interest rates has minimal impact if most households have already locked in low rates (**?**). Rising rates may still motivate homeowners to refinance due to increased income uncertainty or liquidity needs. In a permanent income model with liquidity constraints, **?** show that households refinance not only to lower mortgage payments but also to draw on home equity during negative income shocks, even in high interest rates environments. **?** find that cash-out refinancing rises toward the end of economic expansions but declines during recessions. Refinancing during downturns often serves as a critical liquidity source for constrained households, particularly when alternative financing options are more costly. My analysis shows that housing credit policy may facilitate the use of refinancing during periods of monetary tightening.

Methodologically, this article relates to the literature on time-varying parameter models used to explore the evolving transmission of monetary policy shocks (**??**). Research on the time-varying effects of monetary policy on mortgage markets has yielded mixed results. Early studies using constant-parameter VAR models, sample splits, and timing restrictions found evidence of time variation (**?**). Similar results were found by **?**, who noted an increased response of mortgage debt since the mid-1980s. However, **?**, using a VAR model with sign restrictions, did not observe significant changes in the response of mortgage debt but noticed that, since the mid-1980s, monetary contractions lead non-banks to increase the holding of mortgages. Using a small-scale TVP-VAR model, **?** find that the response of mortgage debt to monetary policy has diminished over time, partially due to the reduced share of adjustable-rate mortgages. My analysis improves upon previous studies by employing the high-frequency identification approach, thus providing less

biased estimates of the effects of monetary policy on mortgage markets.

Road map. Section 2 outlines the econometric strategy. Section 3 presents results from a constant-parameter VAR model. Section 4 uses the TVP-VAR model to study the time-varying effect of monetary policy. Section 5 explores the role of the stance of housing credit policy. In Section 6, I discuss the policy implications. Section 7 concludes.

2. Econometric approach

The main model used in the article is a time-varying parameter vector autoregression model as developed by **?**. In this section, I introduce the model and discuss the identification based on the exogenous variable approach.

2.1. Time-varying parameter VAR framework

The reduced form time-varying parameter vector autoregression model with an exogenous variable (TVP-VARX) can be described by the following system:

$$\mathbf{y}_t = \mathbf{c}_t + \sum_{j=1}^{p} \mathbf{B}_{jt}\mathbf{y}_{t-j} + \mathbf{A}_t z_t + \mathbf{u}_t \quad \text{with} \quad \mathbf{u}_t \sim \mathcal{N}(\mathbf{0}, \mathbf{\Omega}) \tag{1}$$

where $\mathbf{y}_t$ is a $(n \times 1)$ vector of endogenous variables, $\mathbf{c}_t$ is a $(n \times 1)$ vector of time-varying intercepts, and $\mathbf{B}_{jt}$ are $(n \times n)$ matrices of time-varying parameters for $j = 1, \ldots, p$. The vector $\mathbf{u}_t$ represents the innovations, with zero mean and variance-covariance matrix $\mathbf{\Omega}$ of dimension $(n \times n)$. Time is indexed by $t = 1, \ldots, T$, with each period corresponding to a month. The exogenous variable z_t is a monetary policy surprises series with the $(n \times 1)$ vector $\mathbf{A}_t$ capturing the effects of z_t on the endogenous variables. **?** shows that the exogenous variable approach yields consistent estimates of the true contemporaneous impulse responses. Additionally, if z_t is uncorrelated with the remaining regressors in Equation 1, the approach provides consistent estimates of the true subsequent impulse responses.[2]

The exogenous variable approach differs from, but also shares similarities with the proxy-VAR approach (**?**). As with the latter, the proxy z_t must satisfy the following relevance and exogeneity conditions:

$$\mathbb{E}\left[z_t \varepsilon_{1t}\right] = \phi \neq 0 \tag{2}$$

$$\mathbb{E}\left[z_t \bar{\varepsilon}_t\right] = 0 \tag{3}$$

[2] See Propositions 1 and 2 and the associated proofs in **?**. The orthogonality between z_t and the remaining regressors in Equation 1 can always be achieved by replacing z_t with the residuals from a projection of z_t on all regressors in the model.

where ε_{1t} is the latent monetary policy shock and $\bar{\varepsilon}_t$ is a vector of all structural shocks in the model other than ε_{1t}. The advantage of the exogenous variable approach is that the model can be estimated in a single step by treating the proxy as an exogenous variable, which simplifies the analysis in a time-varying context.

Assuming that z_t is a proxy for a monetary policy shock that causes a one-unit increase in a variable y_{jt} (e.g., the policy rate R_t), the contemporaneous relative impulse response of another variable y_{it} at time t can be calculated as $r_{it} = \hat{A}_{it}/\hat{A}_{Rt}$, where $\hat{A}_{it}$ and $\hat{A}_{Rt}$ are the posterior means of the parameters in $\mathbf{A}_t$ for variables i and R, respectively, at time t. The subsequent relative impulse responses can then be derived using the estimated parameters in the matrices $\mathbf{B}$.

An additional assumption, relative to the proxy-VAR approach, concerns the relevance condition in Equation 2. The relationship between the proxy z_t and the latent structural shock ε_{1t} is:

$$z_t = \phi\varepsilon_{1t} + \eta_t \quad \text{with} \quad \eta_t \sim \mathcal{N}\left(0, \sigma_\eta^2\right). \tag{4}$$

This implies that the relationship between z_t and ε_{1t} is constant over time, and therefore the identified time variation in $\mathbf{A}_t$ does not arise from a time-varying relationship between z_t and ε_{1t}.

2.2. Identification

The high-frequency approach has become the most prominent method for identifying the effects of monetary policy. By focusing on narrow windows of time around FOMC announcements, this approach plausibly rules out reverse causality and other endogeneity problems. If monetary policy surprises cannot be predicted using any publicly available information predating the FOMC announcements, they can be used as valid instruments for identifying the effects of monetary policy in VAR models (**?**). However, recent studies challenge this view by showing that monetary policy surprises are indeed predictable using macroeconomic and financial data, thus violating the exogeneity condition.[3]

? construct monetary policy surprises using changes in a range of federal funds and Eurodollar futures contracts around FOMC announcements. These surprises should be interpreted as changes in the expected path of short-term interest rates over the next four quarters. Intuitively, this measure captures changes in the current federal funds

[3] Several explanations have been proposed for the predictability of monetary policy surprises. According to **?** and **?**, this predictability reflects the information effect of monetary policy, where policy surprises convey information about the Fed's economic forecast in conjunction with the monetary policy decision. In contrast, **?** argue that the predictability arises because financial markets lack complete information about the monetary policy rule and underestimate the Fed's responsiveness to economic data. In both scenarios, using predictable monetary policy surprises in VAR models leads to price puzzles and attenuation biases.

rate as well as some degree of forward guidance.[4] To address the potential predictability of monetary policy surprises, they are projected onto a set of variables available to financial markets prior to FOMC announcements that have an intuitive relationship with the Fed's monetary policy rule.[5] The residuals from this regression are then used as the orthogonalized monetary policy surprises. Essentially, the exogeneity violation is addressed by removing the component of the monetary policy surprises correlated with macroeconomic and financial data predating the FOMC announcements. The resulting orthogonalized monetary policy surprises are converted to a monthly series by summing all the high-frequency surprises within each month. I use this orthogonalized monetary policy series as the proxy z_t.

The relationship between the orthogonalized monetary policy surprises and the identification conditions warrants further discussion. Regarding the relevance condition in Equation 2, it is reasonable to assume that FOMC announcements constitute a significant portion of the exogenous news about monetary policy within a given month and represent information about the future path of monetary policy. Indeed, as shown by **?**, most of the variation in non-orthogonalized surprises is not explained by macroeconomic and financial data. Concerning the exogeneity condition in Equation 3, projecting out the correlation between non-orthogonalized surprises and macroeconomic and financial data prior to the FOMC announcement effectively eliminates the endogeneity problem.[6]

2.3. State-space form and estimation methods

The model presented in Equation 1 involves unobserved components and can be expressed as a state-space model (**?**). The state-space form is obtained by stacking the right-hand-side parameters in Equation 1 into a $(k \times 1)$ vector β_t, where $k = n(np + 1)$ is the number of parameters in the model. The right-hand-side variables in Equation 1 are organized into a

[4]The surprise series is the first principal component of interest rate changes in four Eurodollar futures contracts (ED1-ED4) around FOMC announcements. The surprises are derived from 322 FOMC announcements between 1988 and 2019, with changes computed over a 30-minute window starting 10 minutes before each announcement and ending 10 minutes afterward.

[5]The variables used to orthogonalize monetary policy surprises include nonfarm payroll surprises, nonfarm payroll employment growth, S&P 500 stock market index growth, the slope of the yield curve, commodity price growth, and Treasury skewness.

[6]It is worth noting that approach of **?** involves "cleaning" the surprises by regressing them on the right-hand side variables of the VAR and using the residuals from this regression as z_t. Therefore, by using orthogonalized monetary policy surprises, I effectively "clean" the surprises twice, once at FOMC dates using data that predates the announcements, and again after aggregating the surprises at a monthly frequency and using the VAR variables. I find that "cleaning" the surprises by regressing them on the right-hand side variables of the VAR does not affect the results. The irrelevance of orthogonalization with respect to the VAR variables is unsurprising and aligns with findings in **?** that using non-orthogonalized monetary policy surprises as internal instruments in a VAR does not eliminate the endogeneity in the surprises that biases the effects of monetary policy in VAR models.

$(n \times k)$ matrix $\mathbf{X}_t'$:

$$\underset{n\times k}{\mathbf{X}_t'} = \left(\mathbf{I}_n \otimes \underset{1\times(np+1)}{\left[1, z_t, \mathbf{y}_{t-1}', \mathbf{y}_{t-2}', \ldots, \mathbf{y}_{t-p}'\right]} \right). \tag{5}$$

The state-space representation of the TVP-VAR model is:

$$\underset{n\times 1}{\mathbf{y}_t} = \underset{n\times k}{\mathbf{X}_t'}\ \underset{k\times 1}{\boldsymbol{\beta}_t} + \underset{n\times 1}{\mathbf{u}_t} \quad \text{with} \quad \mathbf{u}_t \sim \mathcal{N}\left(\underset{n\times 1}{\mathbf{0}}, \underset{n\times n}{\boldsymbol{\Omega}}\right) \tag{6}$$

$$\underset{k\times 1}{\boldsymbol{\beta}_t} = \underset{k\times 1}{\boldsymbol{\beta}_{t-1}} + \underset{k\times 1}{\boldsymbol{\zeta}_t} \qquad \text{with} \quad \boldsymbol{\zeta}_t \sim \mathcal{N}\left(\underset{k\times 1}{\mathbf{0}}, \underset{k\times k}{\mathbf{Q}}\right). \tag{7}$$

Since **?**, a popular specification for $\boldsymbol{\beta}_t$ is the drift-less random walk with innovations $\boldsymbol{\zeta}_t$. The innovations have zero mean and a time-varying variance-covariance matrix $\mathbf{Q}$ which elements govern the rate of drift in the parameters. The random walk specification is desirable as it assumes that parameters evolve in a gradual but unpredictable manner.[7] The model innovations are assumed to be jointly normally distributed with zero mean and variance-covariance matrix in block diagonal form:

$$\mathbf{V} = \text{Var}\left(\begin{bmatrix}\mathbf{u}_t \\ \boldsymbol{\zeta}_t\end{bmatrix}\right) = \begin{bmatrix}\boldsymbol{\Omega} & 0 \\ 0 & \mathbf{Q}\end{bmatrix}. \tag{8}$$

The model is estimated using Markov chain Monte Carlo (MCMC) methods, as is standard with TVP-VAR models (**?**). Bayesian estimation of the model requires specifying prior distributions for the hyperparameters, namely all parameters in $\boldsymbol{\beta}^T$ and $\mathbf{V}$, with $\boldsymbol{\beta}^{1:t}$ denoting the history of parameters in $\boldsymbol{\beta}$ up to and including month $t = 1, \ldots, T$. I follow **?** and **?**, with slight modifications given the application.

The prior distributions are calibrated based on a constant parameter VAR estimated over a training sample of around 13 years (September 1976 to December 1990). For a significant part of the training sample, the series of monetary policy surprises is unavailable. Thus, I set the surprises to zero for periods with no available data, as in other applications of the exogenous variable approach (**?**). The OLS estimates for the training sample are then used to calibrate the prior distributions, which are assumed to be normal for the unobserved parameters and inverse-Wishart for the covariance matrices of the state

[7] The random walk allows for permanent shifts, but it can also smooth over genuinely discrete changes if time variation is driven by a few abrupt structural breaks. In Appendix B, I use the Chow test and the **?** test to analyze structural breaks. Both identify multiple breaks with some linked to major economic events (e.g., the onset of the Great Recession, the start of QE) and others coinciding with turning points in the time-varying effects of monetary policy or developments in housing credit policy (e.g., the 1995 Affordable Housing Credit Goals). The presence of numerous breaks, including some unrelated to major economic events, reinforces the choice of a general nonlinear model with parameters that evolve smoothly over time.

equations:

$$\boldsymbol{\beta}_0 \sim \mathcal{N}\left(\hat{\boldsymbol{\beta}}_{\text{OLS}}, 4 \cdot V\left(\hat{\boldsymbol{\beta}}_{\text{OLS}}\right)\right) \tag{9}$$

$$\boldsymbol{\Omega} \sim \mathcal{IW}\left(\mathbf{I}_n, n+1\right) \tag{10}$$

$$\mathbf{Q} \sim \mathcal{IW}\left(\kappa_Q^2 \cdot \tau \cdot V\left(\hat{\boldsymbol{\beta}}_{\text{OLS}}\right), \tau\right) \tag{11}$$

where $\hat{\boldsymbol{\beta}}_{\text{OLS}}$ collects the OLS estimates from the training sample, $V\left(\hat{\boldsymbol{\beta}}_{\text{OLS}}\right)$ is their variance, and $\tau = 169$ is the size of the training sample. The parameter κ_Q specifies the prior belief about the amount of time variation in $\boldsymbol{\beta}_t$ and is set to 0.015. The simulation of the model is based on 5000 iterations of the Gibbs sampler, with the first 2000 discarded for convergence. The lag length is set to $p = 3$ to reduce the dimensions of both $\boldsymbol{\beta}_t$ and $\mathbf{Q}$, ensuring convergence. The estimation sample runs from January 1991 to December 2014, due to limited availability of monthly mortgage market data. Appendix C provides a detailed explanation of the estimation method.

2.4. Model specification

The vector of endogenous variables is given by:

$$\mathbf{y}_t = \left[R_t, EBP_t, CPI_t, CRB_t, IP_t, H_t\right]' \tag{12}$$

where R_t denotes the shadow federal funds rate (**?**), EBP_t the excess bond premium (**?**), CPI_t the consumer price index, CRB_t the commodity price index, IP_t the industrial production index. The variable H_t is alternatively an indicator capturing residential mortgage credit, GSEs' mortgage purchases, and housing market activity. To keep the model parsimonious, H_t is added one at a time. All mortgage credit variables are available until 2014 and are sourced from **?**. For the TVP-VARX, quantities and prices enter the VAR in first differences of their natural logarithms, while the policy rate, the excess bond premium, and mortgage purchases enter in levels (percent). The consumer price index is used to deflate nominal variables. Appendix A provides further details on all variables used in the article.[8]

3. Evidence from constant-parameter VAR models

The presentation of the results starts by examining the effects of monetary policy using constant-parameter VAR models. Next, I use the TVP-VARX model introduced in the

[8] In specifying the VAR models, I follow the "best practices" of **?**, which recommend including a commodity price index to ensure reliable estimates of the effects of monetary policy. A commodity price index is generally included to avoid the price puzzle (**?**). That said, none of the VAR models estimated in the article exhibit a price puzzle, regardless of the inclusion of a commodity price index. For completeness, Figure E1 in Appendix E shows that the effects of monetary policy remain qualitatively unchanged when commodity prices are excluded.

previous section to study the time-varying interaction between monetary and housing credit policy.

I begin by using a constant-parameter proxy-VAR to assess the relevance of the instrument employed throughout this article. The model includes the vector of endogenous variable $\mathbf{y}_t$ without the indicator H_t and the orthogonalized monetary policy shock z_t as an external instrument. The estimation sample begins in February 1988, and the lag length is set to $p = 3$ as in the TVP-VARX. However, as standard with constant-parameter VARs, all variables enter in log-level, except for interest rates and the excess bond premium. I also estimate a constant-parameter version of the TVP-VARX using the orthogonalized monetary policy shock z_t as an exogenous variable. The variables included, estimation sample, specification, and the method used to construct the confidence bands are the same as those used in the proxy-VAR just mentioned. The size of the shock is normalized to match the initial increase in the shadow federal funds rate to a one-standard-deviation monetary policy shock as obtained with the proxy-VAR. Unlike the TVP-VARX, the estimation of constant-parameter VAR models uses the least squares method.

Figure 2 plots the impulse responses obtained using the proxy-VAR (solid lines) and the VARX (dotted lines) models. The F-statistic calculated from the first-stage regression is 12.63 suggesting that the instrument is relevant according to the threshold recommended by **?**. In both models, a contractionary monetary policy shock immediately raises the shadow federal funds rate and the excess bond premium. Prices and industrial production fall, and there is no evidence of a price puzzle. After the initial jump, the shadow rate gradually returns to the steady state over the following months. Commodity prices fall considerably in the impact month. Consumer prices also fall on impact, but their response is smaller than that of commodity prices, consistent with models exhibiting inflation inertia.[9] Industrial production falls in the impact month and declines further over the next months. This endogenous persistence of industrial production aligns with predictions from models incorporating consumption habits, staggered wage contracts, and variable capital utilization (**?**).

To better understand the transmission mechanism of monetary policy, I extend the model by including a variable that captures housing market conditions (variable H_t in equation 12). Specifically, I include the 30-year fixed-rate Federal Housing Administration-guaranteed mortgage rate, the real S&P/Case-Shiller national house price index, housing starts, and construction employment. All variables except the mortgage rate enter in

[9] Both the steady decline in the CPI and the delayed reversion are consistent with other studies on the effects of monetary policy. For example, in **?** and **?**, the CPI steadily declines and does not return to baseline within the five-year horizon reported. The slow convergence of the CPI can be explained by a combination of nominal and real rigidities. In models with monopolistic competition, where firms' prices are strategic complements, the staggering of individual price changes delays the adjustment of the aggregate price level. Additionally, the forward-looking nature of menu costs slows the convergence of the price level after a shock, even though adjustment begins as soon as the shock hits. See **?** for a recent survey of nominal and real rigidities affecting the price response to aggregate shocks, including monetary disturbances.

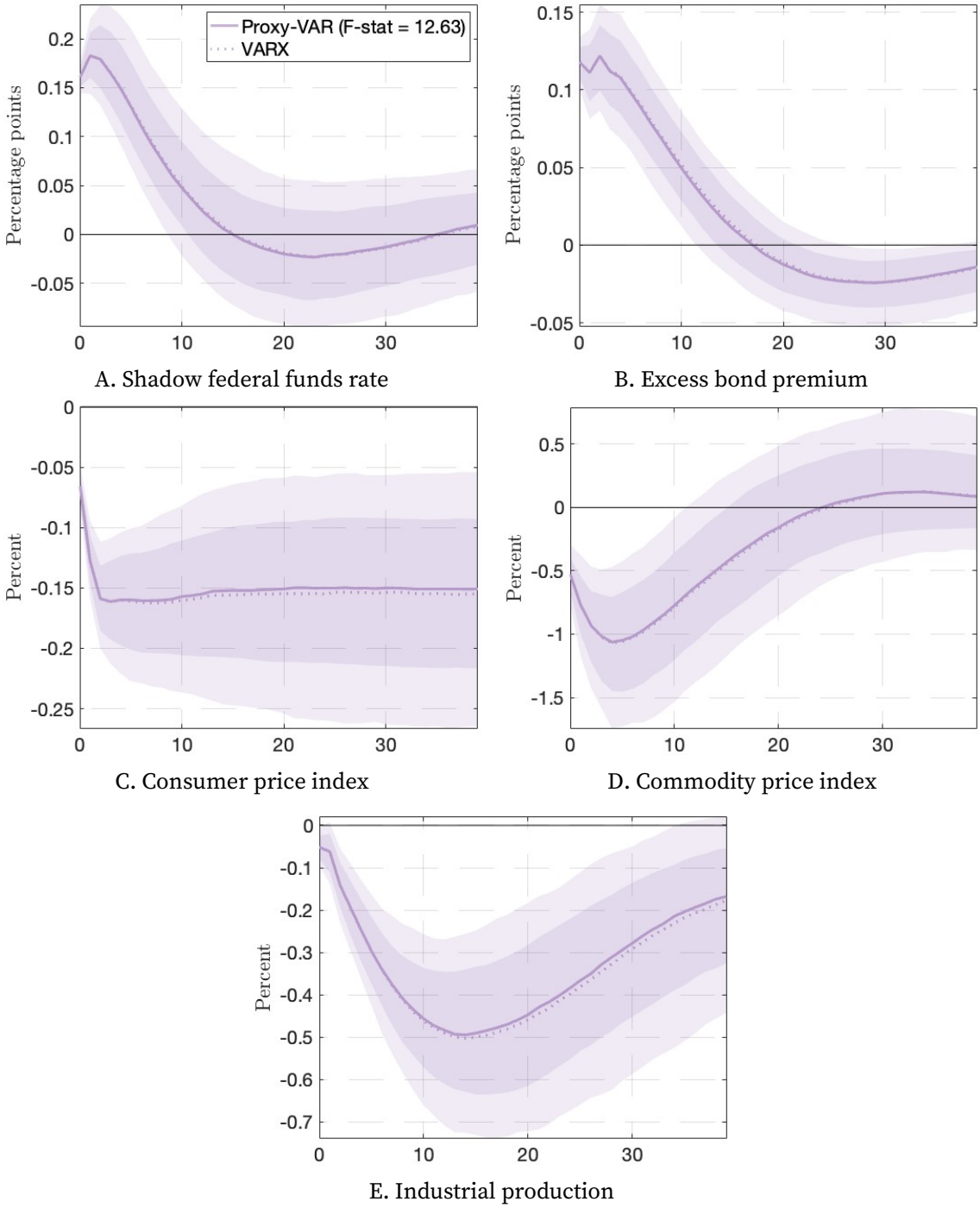


FIGURE 2. Macroeconomic effects of monetary policy

Notes: Impulse responses to a one-standard-deviation contractionary monetary policy shock, median responses along with 68 and 90 percent confidence intervals (proxy-VAR). First-stage regression F-statistics = 12.63. Confidence bands obtained using the recursive wild bootstrap (**?**). For the VARX, the size of the shock is normalized to match the initial increase in the shadow federal funds rate in the proxy-VAR.

log-level. The impulse responses to a one-standard-deviation monetary policy shock from the proxy-VAR are reported in Figure 3. As before, I also report the impulse responses estimated using the VARX (dotted line). A contractionary monetary policy shock raises the cost of mortgage borrowing (panel A) while depressing house prices, which fall persistently after an initial increase (panel B). Housing activity slows down, as indicated by the immediate decline in housing starts (panel C) and construction employment (panel D). The impulse responses are consistent with the credit channel of monetary policy (**???**). A tightening shock worsens the financial position of households, either by increasing the cost of servicing or accessing mortgage credit, or by reducing the value of assets that can be pledged as collateral. The ongoing decline in house prices is consistent with these balance sheet effects of monetary policy. At the same time, the balance sheet effects are reinforced by the increase in the external finance premium triggered by rising interest rates, which discourages housing demand and depresses housing starts and construction employment.

In addition, the credit channel of monetary policy predicts that contractionary monetary policy would reduce credit supply as the external finance premium also rises for financial intermediaries, either by raising deposit rates to avoid disintermediation or by relying on more expensive sources of funding. In Figure 4, I report the impulse responses for residential mortgage debt and mortgage originations. While the stock of residential mortgage debt consistently declines after a contractionary monetary policy shock (panel A), mortgage originations do not (panel B). In fact, originations increase, albeit not significantly, seemingly at odds with the expectation that monetary tightening should contract lending activity.

Mortgage originations occur when borrowers refinance, purchase existing homes, or buy new ones. Without large changes in house prices or homeownership rates, refinancing and purchase originations typically result in small net changes in the stock of mortgage debt. Given that a monetary policy tightening cool down the housing market, changes in originations, although not significant (panel B), are likely driven primarily by increased refinancing activity. Indeed, this is what panel C and D in Figure 4 suggest. Both purchase and refinancing originations respond to monetary policy, but these responses differ in both direction and magnitude. A tightening monetary policy shock reduces purchases while it significantly increases refinancing originations. Interestingly, purchase originations decrease more rapidly than refinancing originations increase, and their decline outpaces the reduction in the stock of mortgage debt. This sharp short-term decline in purchase originations is consistent with monetary policy tightening shocks contracting the housing market and reducing economic activity. In contrast, the increase in refinancing originations is slightly more gradual. Nonetheless, the primary driver of the effects of a monetary tightening on originations is refinancing activity, a finding that aligns with **?**

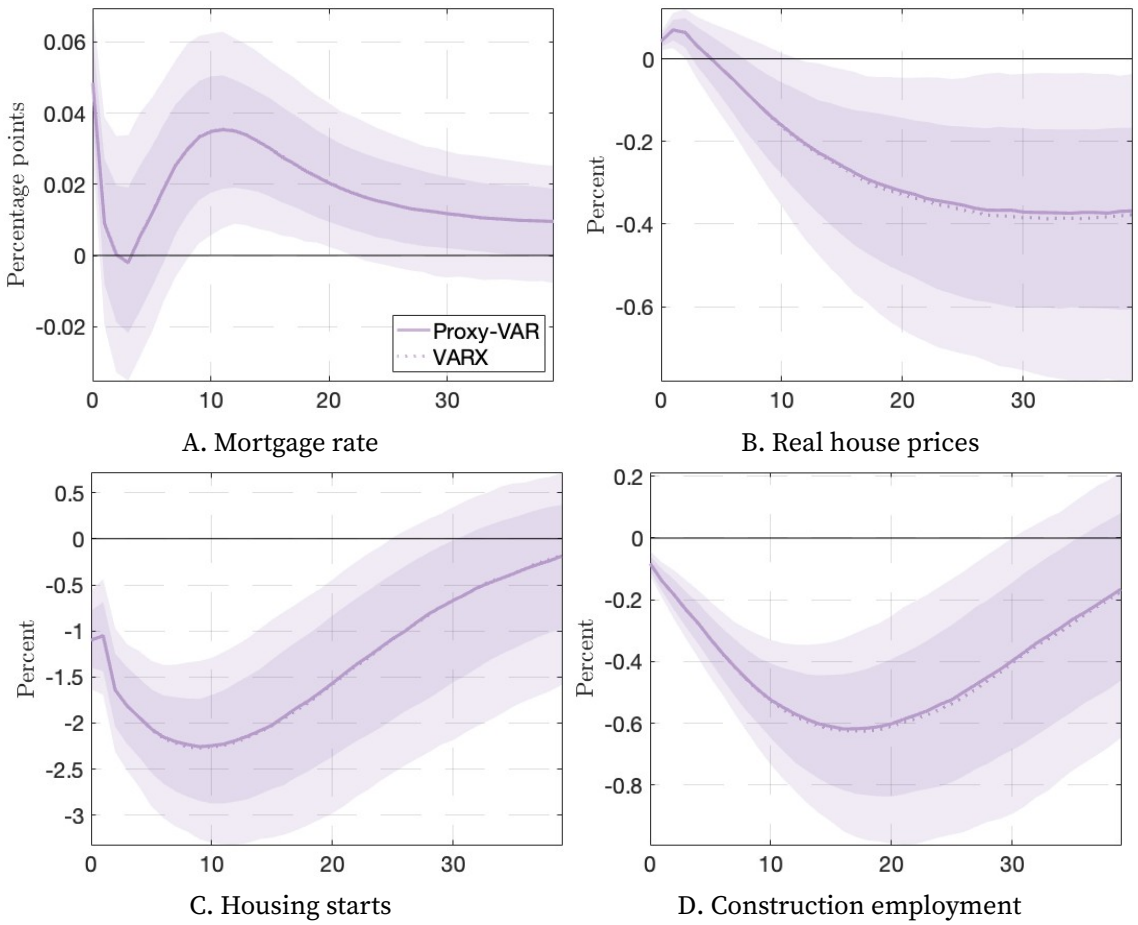


FIGURE 3. Effects of monetary policy on housing activity

Notes: Impulse responses to a one-standard-deviation contractionary monetary policy shock, median responses along with 68 and 90 percent confidence intervals (proxy-VAR). Confidence bands obtained using the recursive wild bootstrap (**?**). For the VARX, the size of the shock is normalized to match the initial increase in the shadow federal funds rate in the proxy-VAR.

on the effects of housing credit policy shocks.

3.1. Monetary policy, refinancing, and housing credit policy

While previous literature has documented the positive response of mortgage originations to monetary policy tightening shocks (**?**), this article highlights a novel finding: this response is primarily driven by refinancing rather than purchase activity. Why does monetary policy tightening increase refinancing originations? One reason is that liquidity-constrained households use refinancing to access accumulated home equity following negative income shocks despite rising interest rates (**??**).[10] A complementary reason,

[10]Aggregate regressions indicate that a 10% decline in real income leads households to increase cash-out refinancing by 1.3% of income to offset the drop (**?**, p. 331). **?** show that the announcement of a reduction

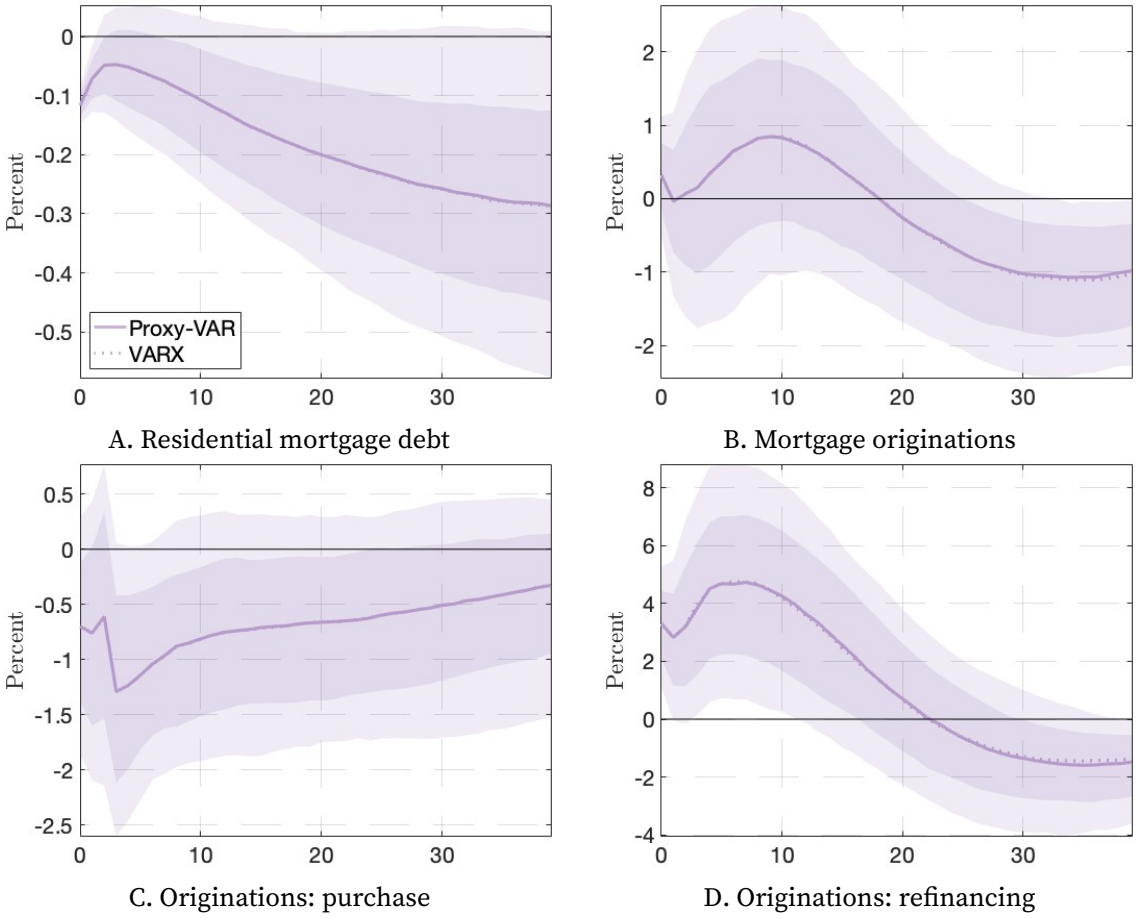


FIGURE 4. Effects of monetary policy on mortgage credit

Notes: Impulse responses to a one-standard-deviation contractionary monetary policy shock, median responses along with 68 and 90 percent confidence intervals. Confidence bands obtained using the recursive wild bootstrap (**?**).

which is the focus of this article, is the interaction between tight monetary policy and housing credit policies, particularly the actions of GSEs.

GSEs purchase eligible mortgages from originators on the secondary market, pool these loans, and create MBSs backed by the cash flows of the underlying mortgages. Some of these MBSs are sold to investors, who acquire interests in the mortgage pool in exchange for cash. The proceeds from MBSs sales provide GSEs with a critical source of liquidity, enabling further mortgage purchases and sustaining the flow of credit in the housing market. These hybrid institutions, which balance private ownership with a public mission, play a stabilizing role by supporting the mortgage market and advancing housing policy objectives.

in the size of the Federal Reserve balance sheet increased refinancing originations in the mortgage jumbo segment, although not significantly.

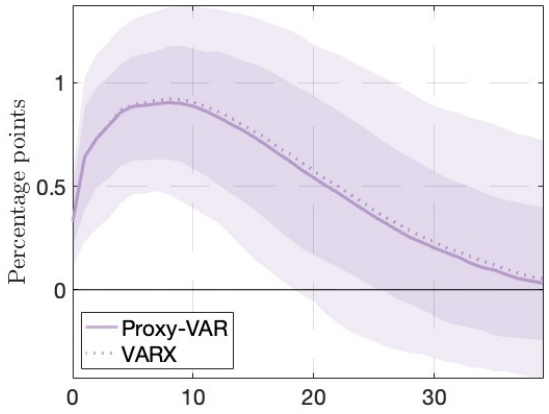


FIGURE 5. Effects of monetary policy on GSEs' mortgage purchases

Notes: Impulse responses to a one-standard-deviation contractionary monetary policy shock, median responses along with 68 and 90 percent confidence intervals (proxy-VAR). Confidence bands obtained using the recursive wild bootstrap (**?**). For the VARX, the size of the shock is normalized to match the initial increase in the shadow federal funds rate in the proxy-VAR. GSEs' mortgage purchases is the cyclical measure of mortgage purchases constructed by **?**, accumulated over time, and expressed as a share of trend total originations.

To investigate the interactions between tight monetary policy and GSEs' mortgage purchases, I consider additional specifications of the constant-parameter proxy-VAR, where the indicator H_t represents GSEs' mortgage purchases as direct proxy for housing credit policy interventions. Specifically, I use a cyclical measure of mortgage purchases constructed by **?**. This measure, based on a narrative analysis of the regulatory history of housing agencies, identifies and quantifies significant policy events affecting agency purchases. The policy events include adjustments to capital requirements, portfolio caps, statutory borrowing authority, and changes to the pools of mortgages eligible for agency purchases. I focus on cyclically motivated purchases and exclude those made by the Fed under the QE program. Cyclical purchases are accumulated over time and expressed as a share of trend total originations. As before, I also estimate a constant-parameter VARX and report both impulse responses in Figure 5.

GSEs' mortgage purchases immediately increase in reaction to a contractionary monetary policy shock and the response remains positive and statistically significant for most of the horizon forecast. Mortgage purchases increase because of the GSEs' statutory mandate to stabilise mortgage markets and ensure their liquidity. Moreover, rising interest rates present profit opportunities for GSEs, whose funding costs are lower than those of banks because of the perception that agency debt is insured by the federal government (**??**). When interest rates rise, GSEs' financing costs relative to Treasuries increase by less than the mortgage spread. This creates a wedge between agency debt rates and mortgage rates, making mortgage purchases profitable. Regulatory constraints on GSEs' asset composition amplify the profit opportunities arising from this wedge. Specifically, GSEs can only invest

in mortgage-related assets, Treasuries, cash, and cash-equivalent assets. When interest rates rise, mortgage-related assets become more attractive due to their higher returns relative to other permissible assets.

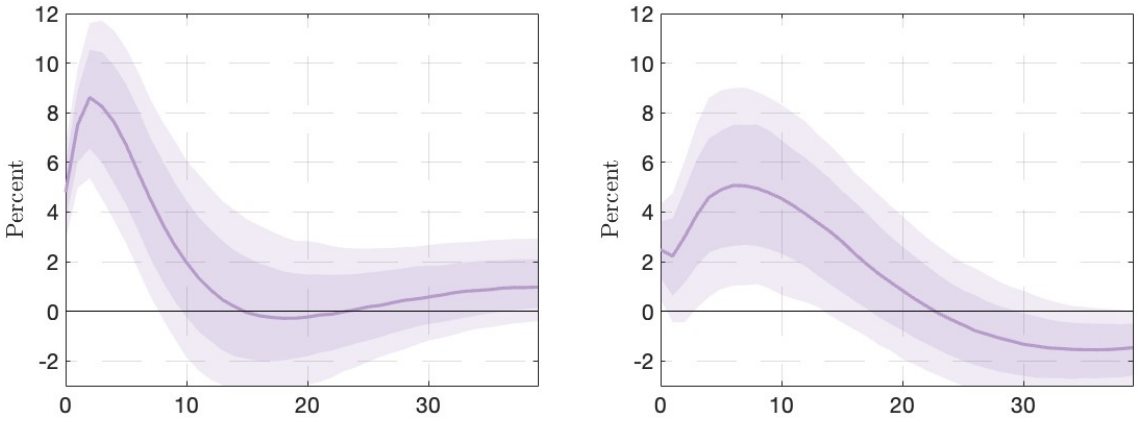
The mechanism of mortgage purchases and their delivery in the secondary market is crucial for understanding the role of GSEs in driving the increase in refinancing originations following a contractionary monetary policy shock. GSEs purchase mortgages from originators by making advanced commitments; that is, they agree to buy a specific amount of mortgages at pre-specified prices with particular characteristics in the coming months. In response, lenders in the primary market originate new mortgages that meet these criteria to ensure they are eligible for delivery to GSEs. Therefore, the mechanism of advanced commitment implies that mortgage purchases in the secondary market affect lending behavior in the primary market through. GSEs' mortgage purchases create an incentive for lenders to originate primarily eligible loans, as this model effectively generates risk-free profits from selling newly originated loans. The strong association between the refinancing originations and GSEs' activity impulse responses suggests that the spillover from mortgage purchases to primary markets operates also in reaction to a monetary tightening shock.[11] I will refer to this mechanism through which monetary policy affects lending behavior in the primary mortgage market via GSEs' intervention as the originate-to-sell channel.

3.2. Asymmetries in the effects of monetary policy on mortgage refinancing

The rise in refinancing activity after a monetary policy tightening can be explained by the presence of liquidity-constrained households and by the originate-to-sell channel, whereby banks actively originate mortgages for sale to GSEs. However, the symmetry of impulse responses in a standard VAR model implies that refinancing would decrease in response to monetary easing, which is unlikely given the strong incentive for homeowners to refinance at lower interest rates.

To explore potential asymmetries in the response of refinancing originations, I estimate two separate proxy-VAR models using transformed versions of the monetary policy surprise series z_t . In the first VAR, contractionary policy surprises are defined as $z_t^+ = \max(0, z_t)$, while in the second VAR, I focus only on expansionary surprises, defined as $z_t^- = \min(0, z_t)$. Each VAR is estimated over the full sample period, using the transformed surprises as the proxy variable. This approach, which follows the method of

[11] **?** argue that the incentive to produce eligible loans may crowd out lending to other sectors, such as commercial and industrial loans. Additionally, GSEs' commitment to purchase at a later date can exacerbate adverse selection problems in lending markets. Lenders might originate more qualifying loans than anticipated sales to GSEs, potentially leading to a situation where they screen new borrowers and end up delivering lower-quality loans to the secondary market while retaining the higher-quality loans. Issues of adverse selection in secondary mortgage markets have been documented in the literature (**?**).



A. Expansionary monetary policy B. Contractionary monetary policy

FIGURE 6. Asymmetric effects of monetary policy on mortgage refinancing originations

Notes: Impulse responses to a one-standard-deviation contractionary monetary policy shock, median responses along with 68 and 90 percent confidence intervals from proxy-VAR. Confidence bands obtained using the recursive wild bootstrap (**?**).

?, allows for an illustrative comparison of impulse response functions and permits the effects of monetary policy shocks on all variables in the VAR system to vary according to the sign of the shock.

Figure 6 illustrates the asymmetric response of mortgage refinancing originations to monetary policy. Regardless of the sign of the shock, refinancing activity increases. However, consistent with the fact that refinancing incentives are stronger during periods of falling interest rates, the response to expansionary shocks is larger than the response to contractionary shocks. A potential explanation for the larger response under expansionary policy lies in the motivations behind refinancing. Abstracting from the originate-to-sell channel, when interest rates fall, indebted households refinance to reduce the cost of servicing their debt. If house prices have been increasing, they may also use cash-out refinancing to extract accumulated home equity, which can then be used to finance consumption or repay other liabilities. Indeed, **?** show that both rate and cash-out refinancing are responsive to potential interest saving opportunities and are important drivers of durable consumption. In contrast, when monetary policy is contractionary, the only reason to refinance is to extract home equity to smooth consumption even if it involves accepting a higher mortgage rate, as shown by **?**. In both cases, the presence of the originate-to-distribute channel (which is arguably stronger during periods of monetary tightening) may amplify the response of refinancing originations by shaping lenders' behavior in the primary market.

4. The time-varying interaction between monetary and housing credit policy

As noted in the introduction, the role of GSEs in housing credit policy has undergone profound changes over time, with significant implications for their response to monetary policy. While their prominence in the housing finance system became evident during the subprime mortgage crisis, their origins date back to the Great Depression, when the federal government first acted to stabilize a paralyzed mortgage market. Key milestones, such as the 1980s Savings and Loan crisis, the rise of securitization, and regulatory reforms, facilitated the expansion of GSEs, including Freddie Mac's transition to a publicly traded company in 1989. During the 1990s, advancements in technology and strong political support positioned GSEs at the center of housing credit policy, enabling them to significantly expand their role. By 2006, Fannie Mae and Freddie Mac were responsible for 40-50% of mortgage originations, with much of this activity involving the securitization of mortgages into MBSs sold to private investors (**?**). However, this rapid growth raised concerns, leading to increased regulatory scrutiny and portfolio caps in the mid-2000s. The subprime mortgage crisis further transformed GSEs' operations, culminating in their Conservatorship and the introduction of federal programs such as the Treasury's MBS purchase program and the Fed's QE. Although GSEs' holdings of residential mortgages declined, federal agency ownership of mortgage debt has remained substantial. These structural and operational changes in the conduct of housing credit policy may have caused the response of mortgage purchases and refinancing originations to monetary policy reported in the previous section to vary over time.[12]

In this section, I use the TVP-VARX model introduced in Section 2 to analyze the time-varying effects of monetary policy and the interaction with housing credit policy. In presenting the results, I normalize the impulse responses following the method used by **?**. To ensure a consistent comparison of impulse responses over time, they are normalized to reflect an immediate increase of 20 basis points in the shadow federal funds rate R in January 1991. This normalization ensures that the impulse responses are always reactions to the same-size structural shock since its relation with z_t is constant (Equation 4).[13] For the variables that enter TVP-VARX in first differences of the logarithm, I report cumulative impulse responses, i.e. the level effect.

Figure 7 presents the time-varying responses of various mortgage credit variables to a same-size monetary policy shock. These impulse responses are obtained by adding the

[12] To my knowledge, the role of mortgage credit policy in altering the impact of monetary policy shocks has been studied only by **?** and **?**. However, there is still no empirical evidence on how the effect of monetary policy on mortgage credit has evolved alongside these institutional changes intervened in the housing finance system.

[13] This normalisation of the time-varying impulse responses implies that they are not directly comparable in magnitude to the impulse responses estimated using the constant-parameter proxy-VAR. In this case, the impulse responses are responses to a one-standard-deviation monetary policy shock, whereas for the VARX the size of the shock is normalised to the initial increase in the shadow federal funds rate in the proxy-VAR.

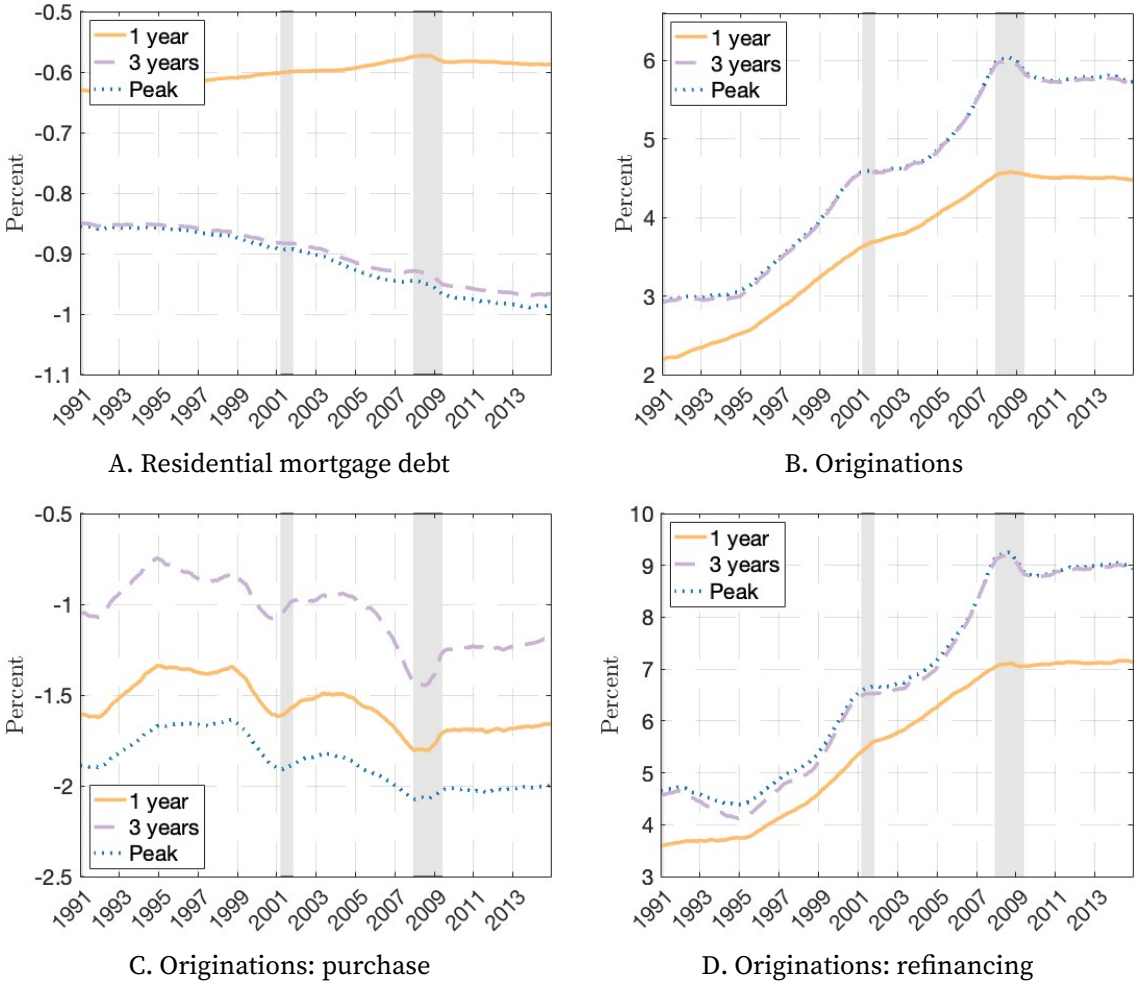


FIGURE 7. Time-varying effects of monetary policy on mortgage credit

Notes: Cumulative median impulse responses to a monetary tightening obtained using the TVP-VARX model.

indicator H_t to the baseline TVP-VARX model. To better illustrate time variation, I report the median responses at one year (short term) and three years (medium term) after the shock. The figure includes the peak response, although its relevant horizon may vary across the estimation period.[14]

A monetary policy tightening shock consistently reduces the stock of residential mortgage debt (Figure 7, panel A). The short-term reduction fluctuates around 0.6% and has slightly decreased over time. In contrast, the medium-term and peak reductions are larger, slightly increasing from 0.85% in 1991 to nearly 1% by the end of the sample period. However, the overall time-variation in the effects of monetary policy on residential mortgage debt remains relatively small, consistently with previous research using constant-

[14]For a more detailed view, Figure E4 and E5 in Appendix E plot the short- and medium-term impulse responses together with credibility intervals, while Figure E3 plots the responses at all horizons.

parameter VAR models and sample splits (**?**). In contrast, a monetary policy tightening increases residential mortgage originations, with originations becoming increasingly sensitive to monetary policy shocks over time (Figure 7, panel B). While the positive response of mortgage originations has been noted in previous literature (**?**), the finding that it has intensified over time is new.

As with the constant-parameter VAR models, the effect of monetary policy shocks on purchase and refinancing originations differ in direction and magnitude (Figure 7, panel B and C). A tightening monetary policy shock reduces purchases, with the peak response ranging between -1.5% and -2%, although the reduction is not statistically significant within conventional credibility intervals. Conversely, refinancing originations increase following a monetary tightening, with the effect becoming significant since the mid-2000s. The medium-term and peak response of refinancing originations increased dramatically from about 4.5% in the early 1990s to 9% at the onset of the Great Financial Crisis.

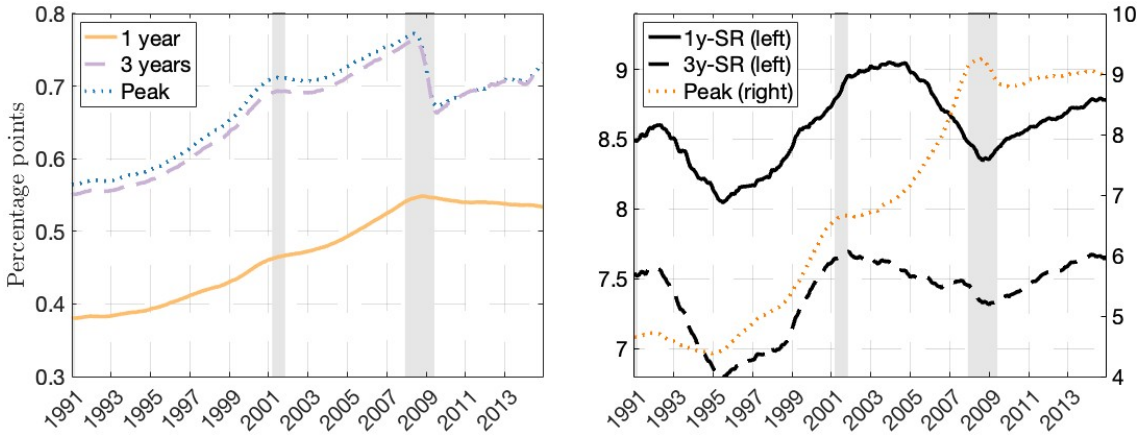
4.1. Relative time-variation and regulatory changes in housing credit policy

Next, I examine the role of housing credit policy and GSEs' mortgage purchases in shaping the time-varying effects of monetary policy on mortgage refinancing originations. I corroborate the main findings using historical evidence on the regulatory changes in housing credit policy from **?** and by using a state-dependent local projections approach.

I begin by demonstrating that the impact of a monetary policy tightening shock on GSEs' mortgage purchases has grown over time. Panel A of Figure 8 displays the time-varying impulse responses from a TVP-VARX model, where H_t is the cyclical measure of mortgage purchases, constructed following **?**, and consistent with the approach used for the impulse response in Figure 5. As in the constant-parameter case, mortgage purchases rise in response to a contractionary monetary policy shock, with the effect intensifying over time.[15] As previously noted, the endogenous intervention of GSEs in secondary mortgage markets influences lending behavior in the primary market. Indeed, a visual inspection of the time-varying effects of monetary policy reveals that the response of refinancing originations closely mirrors that of GSEs' mortgage purchases (see peak effect in Figure 8, panel B).

One challenge with interpreting impulse responses in time-varying parameter models is that they may capture a stronger reaction of the shadow rate to a same-sized monetary policy shock. To address this, I examine relative impulse responses, or *sacrifice ratios*, between refinancing originations and industrial production. Specifically, I define the sacrifice ratio as the percent change in mortgage refinancing originations relative to a one percent change in industrial production, both changes resulting from a monetary

[15] Appendix E provides additional details: Figure E8 show the short- and medium-term impulse responses with credibility intervals, while Figure E6 plots the responses across all horizons.



A. GSEs' mortgage purchases

B. Originations: refinancing

FIGURE 8. Time-varying effects of monetary policy and sacrifice ratios

Notes: Panel A: cumulative median impulse responses to a monetary tightening obtained using the TVP-VARX model. GSEs' mortgage purchases is the cyclical measure of mortgage purchases constructed by **?**, accumulated over time, and expressed as a share of trend total originations. Panel B: SR are sacrifice ratios (absolute value of ratio between the response of refinancing mortgage originations and industrial production). In both panels, the peak is the median peak response obtained using the TVP-VARX model.

policy tightening shock. Because the response of industrial production is always negative throughout the sample and to emphasize the trend in relative time-variation, I take the absolute value of the ratio and focus on two horizons, one and three years.[16]

The historical evidence on regulatory changes in housing credit policy presented by **?** offers a valuable context for interpreting the sacrifice ratios and impulse responses. A notable turning point in Figure 8, panel B, occurs around 1995, marking the beginning of an increase in the responsiveness of mortgage refinancing originations to monetary policy relative to that of industrial production. This turning point is likely to be the result of policy interventions that deepened GSEs' involvement in the secondary mortgage market, particularly in advancing housing policy objectives that could be challenged during periods of monetary tightening. Already in 1992, the statutory purposes of Fannie Mae and Freddie Mac were revised to explicitly strengthen their role in promoting affordable housing and providing liquidity to the secondary mortgage market. The national effort to increase homeownership launched by President Clinton in 1994 was another major policy shift that helped accelerate the GSEs' involvement in affordable housing goals. The growing pressure on GSEs to meet housing policy targets likely increased their sensitivity to monetary

[16] Figure E2 in Appendix E illustrates the time-varying effects of monetary policy shocks on the broader economy, using a model where the vector of endogenous variables $\mathbf{y}_t$ excludes the indicator H_t. In the impact month, the shadow rate increases in response to a contractionary monetary policy shock, though its magnitude has fluctuated over time and declined since 1991. During the effective lower bound period, the model incorporates monetary policy shocks via shadow rates, while responses of the shadow rate and other variables remain constant. Commodity prices and industrial production have become increasingly sensitive to monetary policy shocks.

policy shocks (panel A). Consistent with GSEs' increased sensitivity affecting the primary mortgage market through the originate-to-sell channel, both the sacrifice ratios and the peak response of refinancing originations show a marked increase since 1995.

The housing policy measures adopted in the early 1990s and a number of other policy changes underpinned the rising sensitivity of mortgage purchases and, in turn, of refinancing originations until the early 2000s. For example, a further acceleration in the impulse responses and sacrifice ratios can be observed from 1999 onwards, when new and more ambitious affordable housing targets were adopted. Between 2001 and 2003, however, housing policy changes of opposite sign may have helped to stabilise the effects of monetary policy. These policies included new capital requirements for the GSEs and limits on mortgage purchase activity.

Between 2003 and 2005, the peak response of mortgage refinancing originations and of GSEs' mortgage purchases increased. The sacrifice ratios for refinancing originations, however, started to stagnates and, later, decrease as the effect of monetary policy on industrial production grew stronger until the Great Recession. Nevertheless, housing policy underwent major changes between the early 2000s and the crisis. In April 2004, new ambitious housing goals were announced. The goals significantly increased mortgage purchase targets for GSEs, specifically to support first-time homebuyers. The higher targets significantly affected Fannie Mae's purchasing behavior, and likely contributed to increase the sensitivity of mortgage purchases. In 2005 and 2006, concerns and political pressures mounted to limit GSEs' growth, particularly their retained portfolios. Refinancing originations and GSEs' mortgage purchases became more reactive to monetary policy shocks as GSEs faced growing public scrutiny and a decline in their market share. **?** document that rising concerns over GSEs coincided with several housing credit policy decisions aimed at stimulating purchasing activity, including increases or the removal of mortgage portfolio limits and reductions in capital surcharges.

The highest sensitivity of refinancing originations to monetary policy is reached by the end of 2008. The peak may reflect the central role of housing credit policy within the policy measures enacted during the recession. In 2008, the Economic Stimulus Act further raised conforming loan limits to enhance the reach of GSEs' purchases and securitization. Additionally, the Treasury purchased approximately $200 billion in agency MBSs between 2008 and 2009. At the end of 2009, Fannie Mae and Freddie Mac were placed under the Conservatorship and directed to expand their mortgage portfolios before gradually reducing them. Figure 8, panel B, suggests that a strengthening of the originate-to-sell channel since the Conservatorship period with the impact of monetary policy shocks on mortgage refinancing activity increasing over time. Indeed, the Conservatorship marked a period of intensive mortgage market intervention, with agency net portfolio purchases and pool issuance accounted for all US mortgage originations (**?**).

The previous analysis focuses primarily on the role of GSEs' purchases in shaping the time-varying response of mortgage refinancing to monetary policy. It is important, however, to acknowledge that this channel has not evolved in isolation. Over the past three decades, the US mortgage market has undergone significant structural transformations, notably the rise of non-bank lenders and the adoption of technology-driven underwriting. Non-bank lenders, who originated more than 60% of US mortgages in 2020, tend to specialize in conforming loans eligible for GSEs' purchase and typically operate under an originate-to-distribute model. Because of their dominant position in this segment, the entire GSEs' pipeline has arguably become more responsive to interest rate movements. Recent evidence (**?**) shows that non-banks respond less procyclically to monetary tightening than traditional banks, often continuing to expand credit even when policy tightens. A second major development is the rise of FinTech lenders which reduce processing times and respond more elastically to changes in mortgage demand than traditional lenders (**?**). Together, these findings suggest that the observed increase in refinancing responsiveness may also reflect a structural shift in the composition of originators active in primary mortgage markets. Non-bank and FinTech lenders, by promptly originating refinance mortgages for sale to the GSEs, contribute to the heightened sensitivity of mortgage refinancing to monetary policy shocks. However, the state-dependent local projections analysis in the next section suggests that the differences in refinancing activity responses can be explained by the housing credit policy stance, which affects GSEs' responses to monetary policy.

5. A state-dependent local projections approach

The historical interpretation of the time-varying impulse responses suggests that the effects of monetary policy on mortgage credit are influenced by the stance of housing credit policy. In the originate-to-sell channel, GSEs intervene in response to monetary policy, both to address disruptions in housing markets and to exploit profit opportunities arising from the differential between their cost of issuing debt and the returns on the mortgages purchased. However, the importance of the channel may be larger during periods of expansionary housing credit policy, as suggested by the sacrifice ratios.

In this section, I test the hypothesis that the effects of monetary policy depend on the stance of housing credit policy using a state-dependent local projections approach (**??**). Specifically, I estimate the following set of regressions:

$$\Delta y_{t+h} = I_{t-1}\left[\alpha_E^h + \gamma_E^h(L)\mathbf{x}_t + \beta_E^h z_t\right] + (1 - I_{t-1})\left[\alpha_{NE}^h + \gamma_{NE}^h(L)\mathbf{x}_t + \beta_{NE}^h z_t\right] + u_t, \tag{13}$$
$$\Delta y_{t+h} = y_{t+h} - y_{t-1}$$

where y is an outcome variable of interest (e.g., log of real residential mortgage debt),

$\mathbf{x}_t$ is a vector of control variables, $\gamma^h(L)$ is a polynomial in the lag operator with $L = 3$ as in the VAR, α^h is a constant, z_t is the orthogonalized monetary policy shock of **?**, and h identifies the horizon of the local projection. The vector $\mathbf{x}_t$ includes lags of the outcome variables and of all variables used in the VAR models, that is the shadow interest rate, excess bond premium, consumer price index, commodity price index, and industrial production. The indicator variable I_t identifies the stance of housing credit policy at the time of the monetary policy shock z_t. Specifically, $I_t = 1$ indicates an expansionary stance (E), while $I_t = 0$ corresponds to a non-expansionary stance (NE). To account for serial correlation in the errors of the local projections, I use Newey-West corrected standard errors (**?**). Equation 13 is used to estimate impulse responses (series of $\hat{\beta}$ coefficients) that vary based on the stance of housing credit policy. Because the local projection approach does not necessitate of a training sample like the TVP-VAR, I estimate the model on a slightly larger sample starting in 1988M2.

The indicator I_t is constructed using monthly data on GSEs' mortgage purchases activity. Following **?**, I define an index of GSEs' flow market share as the annualized net portfolio commitments, p_t, over an eight-month interval, expressed as ratio of the long-run trend in annualized mortgage originations, $\tilde{x}_t$.[17] However, the GSEs' flow market share is endogenous to the state of the economy, as GSEs respond to shifts in housing market conditions and macroeconomic shocks. To address this problem, I use the following regression to remove the influence of macroeconomic and financial variables:

$$\frac{12}{8} \times \frac{\sum_{j=0}^{7} p_{t+j}}{\tilde{x}_t} = \mu + \delta_E^h(L)\mathbf{z}_t + \xi_t. \tag{14}$$

In the regression, $\mathbf{z}_t$ is a vector of control variables, $\delta^h(L)$ is a polynomial in the lag operator with $L = 11$, and μ is a constant. Following a similar specification by **?**, the control variables include measures of credit and housing markets conditions, macroeconomic indicators, and interest rates. These are all proxies for the factors affecting GSEs' purchases.[18] The residuals, $\hat{\xi}_t$, from this regression are taken as the orthogonalized measure of GSEs' flow market share.

The stance of housing credit policy, I_t, is then defined as a dummy variable equal to 1 when $\hat{\xi}_t > 0$ and 0 otherwise. This indicator captures shifts in housing credit policy that are

[17] Net portfolio commitments refer to the difference between commitments for mortgage purchases and those for mortgage sales in a given month. I focus on net commitments rather than actual purchases because GSEs often purchase mortgages through advance commitments, agreeing to buy specific amounts of mortgages at pre-determined prices and characteristics in the future. Commitments under the Federal Reserve's QE program are excluded.

[18] This endogeneity arises from the GSEs' statutory mandate to stabilise the housing market as well as from profit opportunities that would be immediately exploited by the GSEs. The control variables $\mathbf{z}_t$ are: nominal house prices, real residential mortgage debt, real mortgage originations, housing starts, unemployment rate, real personal consumption expenditure (PCE) growth rate,core PCE price index growth rate, 3-moth T-bill rate, 10-year Treasury rate, conventional mortgage rate, and the BAA-AAA corporate bond spread.

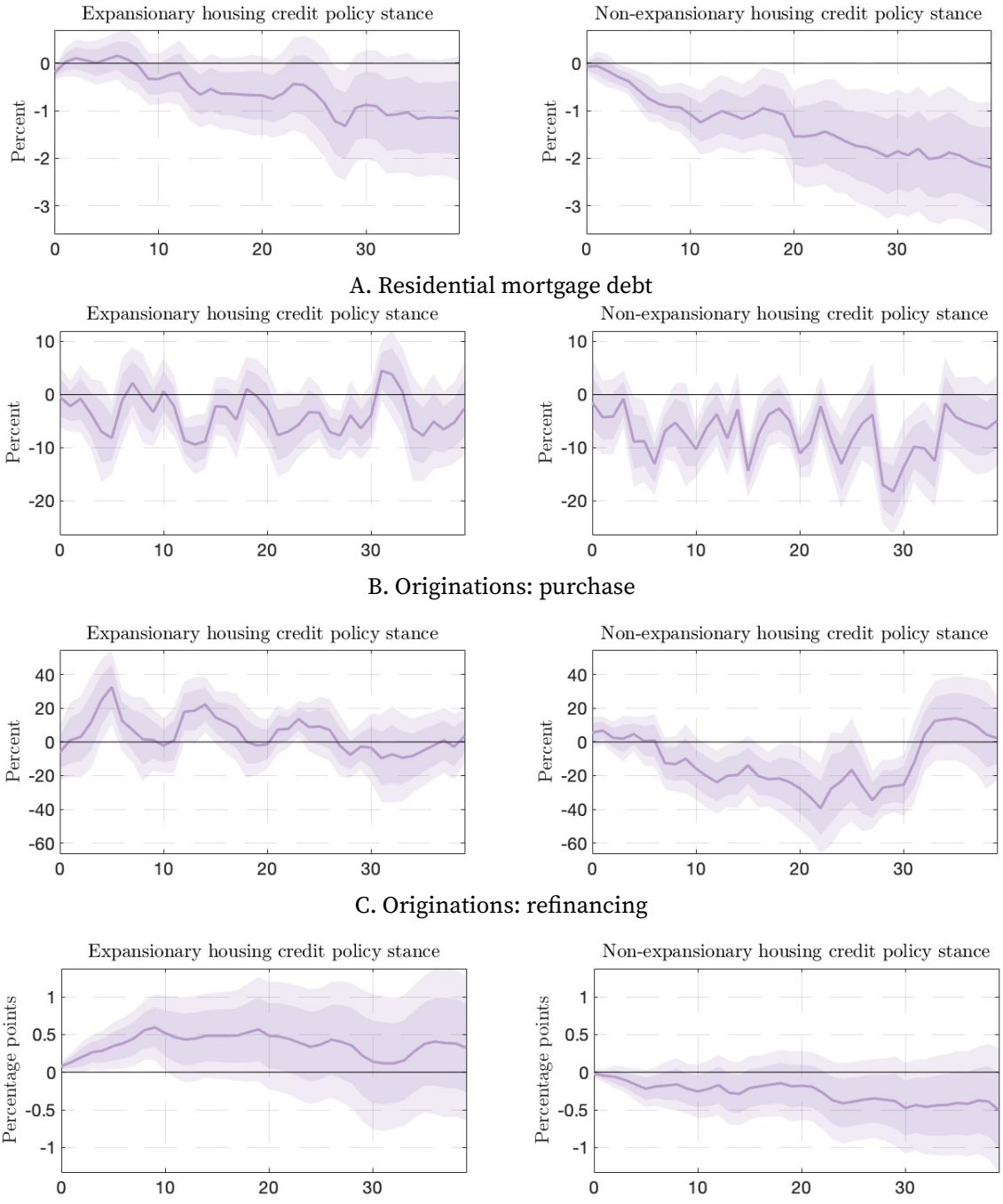


FIGURE 9. State-dependent effects of monetary policy I

Notes: State-dependent local projections impulse responses to a monetary policy shock that increases the shadow federal funds rate by 0.16 percentage points, as in the macroeconomic proxy-VAR model. Bands are 68 and 90 percent confidence intervals. The left column shows the response in the expansionary housing credit policy stance state, while the right column shows the response in the non-expansionary housing credit policy stance state.

exogenous to housing market, credit market, and macroeconomic conditions. Such policy shifts are more likely to reflect changes in GSEs' statutory mandates, federal initiatives to promote homeownership, and ambitious housing goals targeting low- and middle-income households. As noted by **?**, these changes are often motivated by longer-term social policy objectives aimed at increasing homeownership rates.

One limitation of the regression-based approach in equation 14 is that it may not fully isolate policy-driven changes in GSEs' mortgage purchases. To assess the effectiveness of the regression-based approach, I compare it with non-cyclically motivated policy events identified by **?**. These events are defined as "interventions motivated by social policy, budgetary, or other more ideological objectives [...] provided historical sources do not at the same time indicate significant short-term economic or financial market concerns" (ibid., p. 1524). In what follows, I examine the behavior of the regression-based policy stance (i.e., $I_t = 1$ or $\hat{\xi}_t > 0$) around all policy events between 1988 and 2014.[19]

a. **Freddie Mac public listing.** Between March and April 1989, the housing credit policy stance turns expansionary, likely due to Freddie Mac's January 1989 public listing, which was perceived to improve its balance sheet ahead of future privatization. This followed a prior tightening phase after the 1987 imposition of mortgage purchase caps (Freddie Mac) and debt ratio limits (Fannie Mae). The regression-based indicator remains expansionary for most of 1989, likely driven by the effect of public listing and the enaction of Financial Institutions Reform, Recovery, and Enforcement Act which rechartered Freddie Mac, explicitly extending its mission to supporting housing for low- and moderate-income families.
b. **Affordable Housing Goals of 1992.** From late 1991 to October 1992, the stance is expansionary, likely reflecting the 1992 Affordable Housing Goals. The goals were enacted within the Financial Safety and Soundness Act, which greatly affected the scale and scope of mortgage purchases by Freddie Mac and Fannie Mae. Although they became effective in January 1993, the goals had been largely anticipated at least since July 1991 when both GSEs started negotiating with Congress the content of the Act. The regression-based indicator turns non-expansionary before the goals' implementation in January 1993, possibly because their impact on net commitments had been absorbed in early, while tighter oversight and capital rules contained in the Act offset further stimulus.
c. **Affordable Housing Goals of 1995.** The stance is expansionary ahead of the 1995 goals, most likely due to the temporary extension of 1994 goals into 1995 (November 1994) and HUD's May 1995 National Homeownership Strategy, which responded to the Clinton administration's push to raise homeownership. The stance remained expansionary

[19] Figure E10 in Appendix E plots the timing of these policy events against the regression-based stance of housing credit policy ($\hat{\xi}_t > 0$). The events correspond to those listed in Table 4 of **?**, along with the detailed historical discussion therein. I focus on events that positively affected GSEs' mortgage purchases.

throughout 1995 and 1996, reflecting the issuance of new housing goals for the period 1996–1999. These goals directly affected Freddie Mac's purchases, which had missed the targets imposed by previous goals.

d. **Affordable Housing Goals of 2000.** In October 2000, the stance is expansionary, consistent with the launch of ambitious housing goals for the period 2000-2004 (effective January 2001), though the regression-based indicator lags the July 1999 news date when financial markets had already reacted.
e. **Affordable Housing Goals of 2004.** The 2005–2008 affordable housing goals, proposed in April and officially issued in November 2004, aimed to expand access for first-time buyers. The regression-based indicator turns expansionary in August 2004, thus reacting to the news date with a lag, but capturing the issue and effective date of January 2005.
f. **Removal of Portfolio Limit.** In March 2008, portfolio limits on Fannie Mae and Freddie Mac were officially lifted after earlier news in February. The stance indicator reacts with a lag of two months relative to the effective date but remains expansionary thereafter, consistent with efforts by GSEs to support mortgage markets during the unfolding financial crisis.

The regression-based indicator of housing credit policy aligns broadly with the narrative approach of **?**. However, my indicator often lags their reported news dates. This discrepancy may stem from differences in construction. The narrative indicator captures housing credit interventions which can be used as news shock about pending agency purchases and balance sheet expansions or contractions. Actual purchases tend to lag both the news date and the issuance of commitments to purchase mortgages from originators. Moreover, **?** date policy shocks to when they became public (via leaked information, statements, or market reactions) regardless of implementation timing, and they exclude extensions of existing policies or non-binding measures. In contrast, my regression-based approach can capture such events if they generate unexpected shifts in net commitments unexplained by controls in equation 14. These methodological differences likely explain the observed timing gaps.

Figure 9 presents the impulse responses estimated using the state-dependent model, distinguishing between expansionary (left column) and non-expansionary (right column) stances of housing credit policy. Consistent with the time-varying impulses responses from the TVP-VAR model, the effects of monetary policy on mortgage credit variables depend on the stance of housing credit policy. These state-dependent local projections provide a further evidence of an originate-to-sell channel.

When housing credit policy is expansionary, the decline in the stock of residential mortgage debt following a monetary policy tightening is less pronounced compared to the non-expansionary state (panel A). Similarly, panel C shows that mortgage originations for

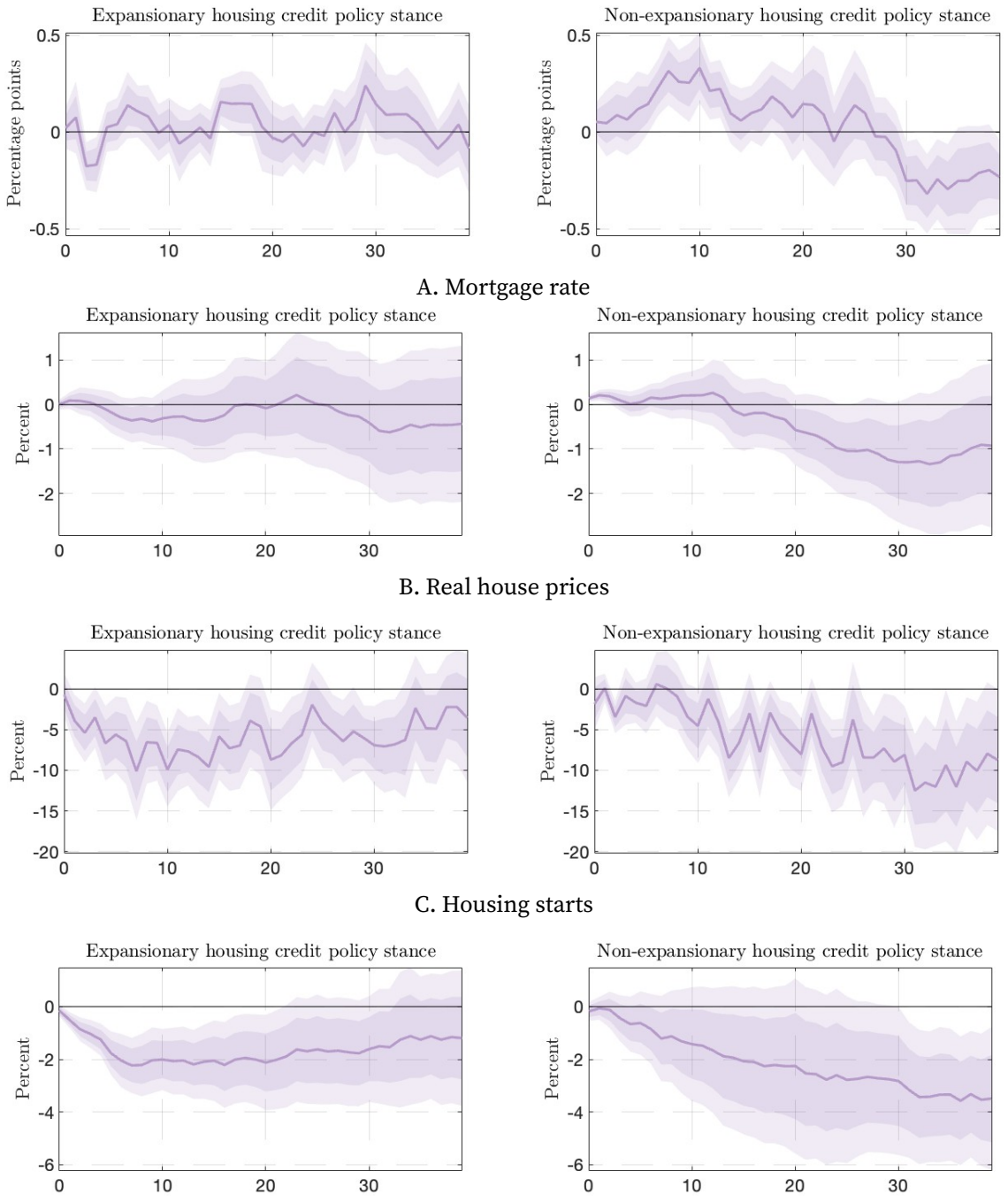


FIGURE 10. State-dependent effects of monetary policy II

Notes: State-dependent local projections impulse responses to a monetary policy shock that increases the shadow federal funds rate by 0.16 percentage points, as in the macroeconomic proxy-VAR model. Bands are 68 and 90 percent confidence intervals. The left column shows the response in the expansionary housing credit policy stance state, while the right column shows the response in the non-expansionary housing credit policy stance state.

refinancing rise in response to a monetary policy tightening shock under an expansionary housing credit policy stance, while they decline in the non-expansionary state. This asymmetric response of refinancing originations aligns with the historical interpretation of the sacrifice ratios and time-varying impulse responses discussed earlier (see also Figure 8). In contrast, panel B indicates that the response of mortgage originations for home purchases remains consistently contractionary across both policy stances, reflecting the relative stability of the time-varying impulse responses shown in Figure 7 (see also Figure E7 in Appendix E).

The observed increase in mortgage refinancing originations during an expansionary housing credit policy stance supports the hypothesis that GSEs counteract monetary policy by ramping up mortgage purchases (**?**). Panel D of Figure 9 further corroborates this mechanism, showing that GSEs' share of mortgage holdings rises in response to a monetary policy tightening shock under an expansionary policy stance, while it declines in the non-expansionary state.

How does the GSEs' reaction to a monetary policy tightening affect housing activity? Figure 10 illustrates that the negative effects of a monetary policy tightening shock on housing activity are more pronounced when housing credit policy is non-expansionary. For instance, the responses of mortgage rates (panel A) and house prices (panel B) are more muted under the expansionary state compared to the non-expansionary state. Similarly, the declines in housing starts (panel C) and construction employment (panel D) are smaller and less persistent in the expansionary state.

These state-dependent effects are consistent with the evidence from counterfactual VAR model scenarios provided by **?**. A plausible interpretation, as proposed by **?**, is that without GSES' intervention, lenders fully pass through the higher funding costs for mortgage originations to borrowers, leading to higher mortgage rates (panel A). Rising borrowing costs reduce housing demand, triggering a contraction in construction activity and employment. Conversely, when the stance of housing credit policy is expansionary, mortgage originators can partially offset increased funding costs by selling illiquid assets (old and newly originated conventional mortgages) to GSEs. This mitigates the rise in the external finance premium induced by tighter monetary policy, dampening its adverse effects on housing activity.

5.1. Refinancing and home equity extraction

At first glance, the rise in refinancing following a tightening of monetary policy is puzzling: households typically refinance when interest rates fall, to take advantage of lower mortgage rates. However, interest savings are not the only motive for refinancing. Even when interest rates are rising, liquidity-constrained households may refinance to smooth consumption, since labour income is not tradable and home equity constitutes a source

of liquidity, albeit a costly one (**?**). The variety of motives for refinancing is visible in aggregate data: according to the FHFA National Mortgage Database, between 1998 and 2024, roughly 50% of refinancing originations were cash-out refinances, while the other half were rate-and-term refinances. If home equity extraction is the primary reason behind the rise in refinancing observed after a monetary tightening, then such an increase should be driven specifically by cash-out refinancing. In the originate-to-sell channel, demand for cash-out refinancing by liquidity-constrained homeowners is met by originators who can sell eligible loans to GSEs, provided they meet underwriting requirements. This channel supplies originators with liquidity, enabling continued lending even during monetary tightening. Spillovers from secondary-market purchases by GSEs into primary-market lending are likely to be stronger when housing credit policy is expansionary.

In this section, I test the hypothesis that the increase in refinancing following a monetary tightening is driven by households extracting home equity through cash-out refinancing. Using the state-dependent local projections model (equation 13), I assess whether the effect of monetary tightening on cash-out refinancing depends on the stance of housing credit policy. I consider two dependent variables: the mortgage spread (conventional mortgage rate less the 10-year Treasury yield) and cash-out refinancing originations. The latter are retrieved from the FHFA National Mortgage Database (NMDB), a nationally representative sample of mortgages based on first-lien, closed-end loans reported to one of the three national credit bureaus. Cash-out refinancing loans are those used to access home equity through refinancing; they replace an existing first-lien mortgage and include additional borrowed funds extracted from home equity. Because NMDB data are available only since 1998, models using cash-out refinancing as the dependent variable are estimated on a restricted sample. Following the standard definition in the literature (**?**), the NMDB classifies a refinancing loan as "cash-out" when the new loan amount (including both first-lien and second-lien balances) exceeds 5% of the outstanding balance at the time of refinancing. I focus on cash-out refinancing in the conventional conforming segment, which consists of loans eligible for GSEs' purchase and excludes government-backed and jumbo loans.

Figure 11 provides evidence on home equity extraction and the role of housing credit policy. A monetary tightening increases cash-out refinancing initially (line with circles, panel A), regardless of the stance of housing credit policy.[20] When housing credit policy is expansionary, a monetary tightening reduces mortgage spreads, although with a lag and not significantly, and increases cash-out refinancing more than in the linear model. By contrast, under a non-expansionary stance, the effects of monetary policy

[20]The linear local projection estimate is based on the following model: $\Delta y_{t+h} = \alpha^h + \gamma^h(L)\mathbf{x}_t + \beta^h z_t + u_t$, which corresponds to the state-dependent local projections model without distinguishing between housing credit regimes. A monetary tightening also increases cash-out refinancing in VARX and proxy-VAR models. These results are not shown in the text but are available upon request.

are consistent with the financial accelerator mechanism: mortgage spreads increase more persistently, suggesting a rise in borrowers' external finance premium, and lending activity declines. Therefore, under an expansionary housing credit policy, the rise in refinancing originations following a monetary tightening is linked to households tapping home equity via cash-out refinancing. The increase in cash-out refinancing secured by first-lien, GSE-eligible loans confirms that interest savings are not the only reason to refinance. **?** show that households to use refinancing of senior-lien mortgages primarily for consumption smoothing. GSEs' mortgage purchases may facilitate such smoothing in response to aggregate shocks such as a monetary tightening.

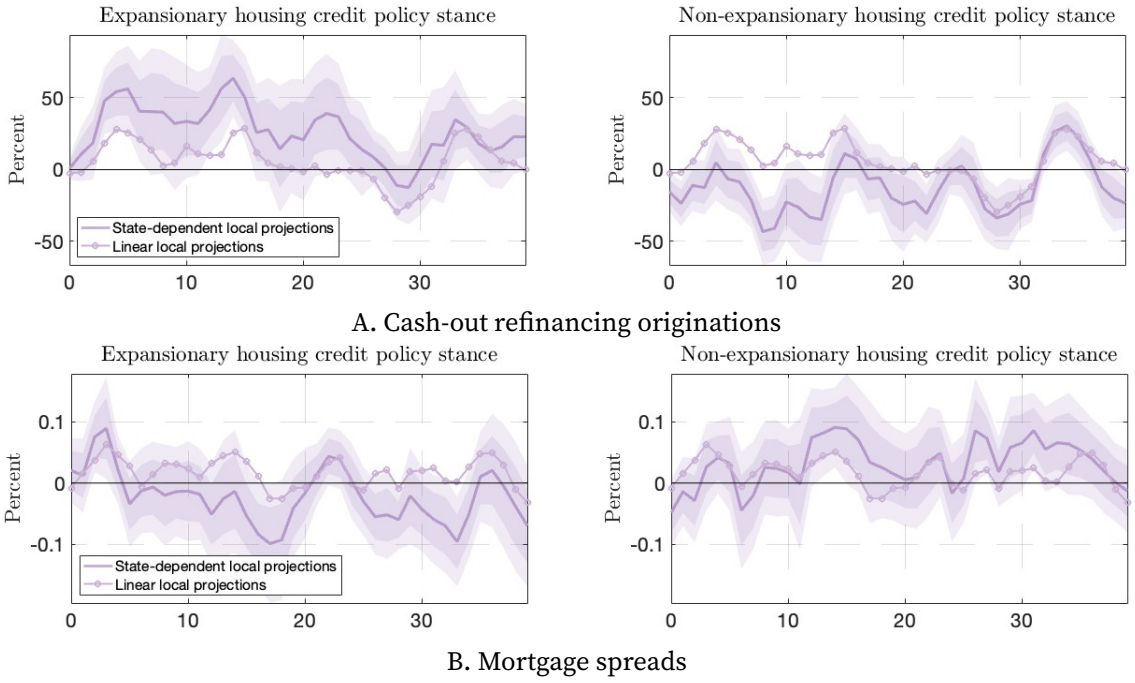


FIGURE 11. State-dependent effects of monetary policy III

Notes: State-dependent local projections impulse responses to a monetary policy shock that increases the shadow federal funds rate by 0.16 percentage points, as in the macroeconomic proxy-VAR model. Bands are 68 and 90 percent confidence intervals. The left column shows the response in the expansionary housing credit policy stance state, while the right column shows the response in the non-expansionary housing credit policy stance state.

5.2. The role of house price cycles

A necessary condition for households to extract home equity via cash-out refinancing after a monetary policy tightening is that house prices have increased since the origination of the mortgage. **?** show that the share of cash-out refinancing tends to rise toward the end of an expansion, when interest rates are also typically increasing due to inflationary pressures. Households refinance even when new mortgage rates are higher than the

original ones, and this behavior coincides with periods of rising house prices, not only during the early 2000s housing boom.

In this section, I explore the role of past house price appreciation in driving refinancing activity after a monetary tightening. I estimate a state-dependent model, as in equation 13, but substitute the state variable with a new indicator that captures whether house prices have been increasing in the recent past. To identify periods of sustained house price growth during which indebted households may accumulate equity for future extraction, I begin by applying a Hodrick–Prescott filter to the national house price index to extract the cyclical component. Then, using a turning point identification algorithm (**?**), I detect house price booms and busts. A boom is defined as the period between a local trough and the subsequent peak of the cyclical component.[21] I use this house price boom indicator to estimate the effects of monetary policy during periods of sustained house price growth. In a separate regression, I then interact this indicator with the housing credit policy stance indicator to evaluate the effects of monetary policy when both house prices and housing credit policy are expansionary. I focus on two dependent variables: aggregate refinancing originations and cash-out refinancing originations. As before, the latter refers to the conventional conforming segment and is available only from 1998. Figure 12 reports the impulse responses to a monetary tightening when all states (house prices, housing credit policy, and their interaction) are expansionary.

Under a housing boom regime, refinancing originations increase immediately in response to a monetary tightening shock (panel A, left). This initial rise is likely driven by households tapping into accumulated home equity, but the effect is short-lived and followed by a decline in refinancing activity. In contrast, when house prices are booming and housing credit policy is expansionary, the increase in refinancing originations is more persistent and similar in magnitude to the case where housing credit policy is the sole state variable (panel A, right). It is important to note that refinancing originations include a variety of loan types and lien structures, including rate-and-term refinancing, which may not become more desirable simply because house prices are rising, particularly given the higher cost of refinancing during tightening periods.

Turning to cash-out refinancing, we observe a different pattern (panel B). Under a housing boom regime, cash-out refinancing increases persistently in response to a monetary tightening shock, closely mirroring the response observed under an expansionary housing

[21] A clarification is in order regarding the construction of the house price boom indicator. First, house prices exhibit an upward trend over the sample period. Applying a turning point algorithm to the raw series would therefore classify most observations as part of a boom. Second, house price booms that enable households to extract equity are best understood as periods of sustained appreciation in collateral values, rather than short-lived spikes (as would be captured by simple growth rates). By focusing on booms identified in the cyclical component, regardless of whether prices are above or below trend, I capture two types of households potentially interested in cash-out refinancing: (1) households that purchased during a downturn and gained equity as prices recovered, even if still below trend, and (2) households whose homes appreciated above their purchase price, approximated by the trend.

credit policy (panel B, left). This suggests that households use cash-out refinancing as a form of liquidity access, akin to using their homes as ATMs, when broader financing and economic conditions deteriorate, as is typically the case following a monetary policy tightening. This finding extends the descriptive evidence in **?** by highlighting the specific role played by monetary policy.

When both house prices are booming and housing credit policy is expansionary, the increase in cash-out refinancing is substantially larger than when either condition holds in isolation (panel B, right). This amplification is consistent with a view of GSEs facilitating equity extraction when both borrower demand and institutional support (captured by the stance of housing credit policy) are strong. If households refinance to tap into accumulated home equity, what role does housing credit policy play? By funding mortgage originations, GSEs' purchases provide originators with liquidity, which can then be used to fund additional loans. In this sense, expansionary housing credit policy, by freeing up originators' capital, may enable them to meet increased refinancing demand and, in doing so, help alleviate household liquidity constraints.

Another factor likely contributing to the large response of cash-out refinancing when both house prices are booming and housing credit policy is expansionary relates to the profitability of GSEs' activity. As previously discussed, purchasing mortgages during periods of rising interest rates can be a profitable strategy for GSEs. The wedge between mortgage rates and GSE funding costs implies that profits from mortgage purchases are likely higher during house price booms. This is because rising house prices stimulate household demand for cash-out refinancing, as more borrowers gain the equity needed to access this form of credit.

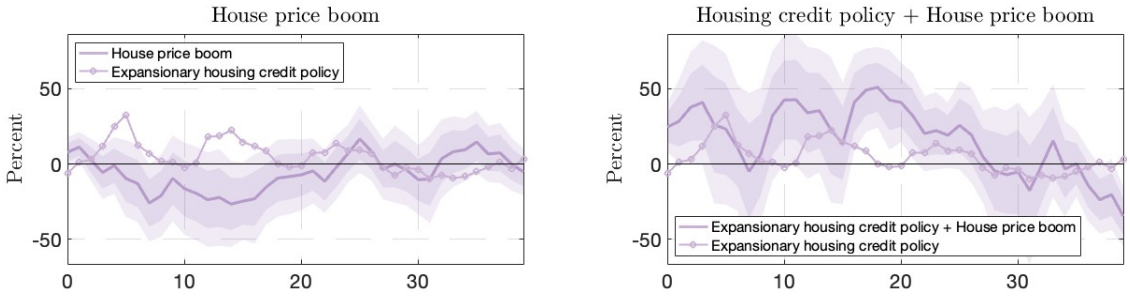
5.3. Robustness checks

In Appendix D, I replicate the main findings of the article using an alternative prior specification and a different monetary policy shock. Additionally, I provide estimates of the state-dependent effects of monetary policy using a narrative-based classification from **?** as an alternative indicator of housing credit policy stance.

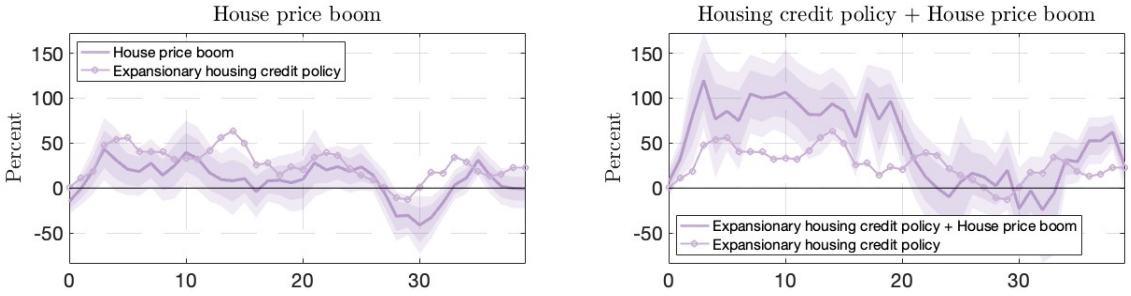
6. Recent developments and policy implications

6.1. The stability of the originate-to-sell channel after 2014: a qualitative assessment

Due to data limitations, the analysis concludes in 2014. Following the government bailout and the placement of the GSEs into Conservatorship in 2008, the GSEs significantly reduced their portfolios of retained mortgages to levels comparable to those before the 1990s. However, the issuance of MBSs has continued to grow, essentially without limit (**?**). This trend parallels the large-scale purchases of MBSs by the Fed under QE, which made the



A. Refinancing originations



B. Cash-out refinancing originations

FIGURE 12. State-dependent effects of monetary policy IV

Notes: State-dependent local projections impulse responses to a monetary policy shock that increases the shadow federal funds rate by 0.16 percentage points, as in the macroeconomic proxy-VAR model. Bands are 68 and 90 percent confidence intervals.

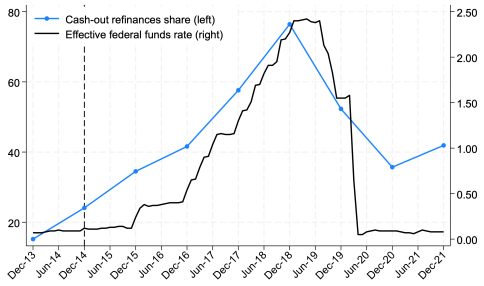
Fed the primary holder of agency MBSs. Despite increased regulatory scrutiny after 2008, the GSEs remain essential actors in the mortgage market. Indeed, the share of first-lien mortgage originations securitized by the GSEs remained stable at approximately 45% between 2014 and 2020 (**?**). This section provides a qualitative assessment of the stability of the originate-to-sell channel during the monetary policy cycle that preceded the COVID-19 pandemic. Given changes in the conduct of monetary policy and the Conservatorship of the GSEs, it is pertinent to ask whether these new conditions altered the functioning of the originate-to-sell channel.[22]

Figure 13 plots the dynamics of the effective federal funds rate alongside selected variables capturing mortgage purchased by Freddie Mac and retrieved from the April 2022 Freddie Mac Economic & Housing Research Note "Trends in Mortgage Refinancing Activity". The figure suggests that the main mechanism underlying the originate-to-sell channel persisted throughout the Conservatorship. As interest rates began rising at the end of 2015, the incidence of cash-out refinancing (the share of refinances that are cash-out) increased from 24.1% in 2015 to 76.4% in 2018 (panel A). This rise is consistent with the originate-to-distribute channel: demand for refinancing by liquidity-constrained homeowners is met by originators who can sell eligible loans to GSEs, provided they meet underwriting standards. The increase in cash-out refinances share is also driven by the reduced attractiveness of rate refinancing, since when interest rates rise, the primary reason for refinancing becomes accessing accumulated home equity. Between 2012 and the onset of the pandemic, house prices steadily increased. Indeed, conditional on obtaining a cash-out refinance, the average equity cashed out rose during the period of rising interest rates, both in absolute terms (panel B) and relative to property value (panel C).

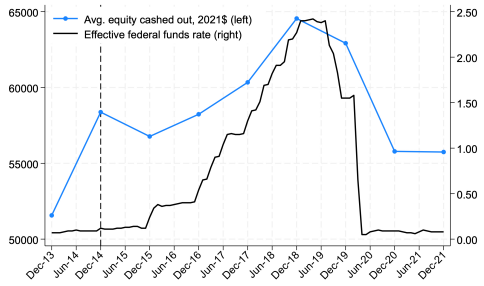
This evidence indicates that the originate-to-sell channel remained active during the rise in interest rates at the end of the long expansion preceding the pandemic recession. One important difference from the pre-2014 period is the role of the Fed. Since the launch of QE, the Fed's purchases of MBSs have had a significant impact on the MBS market, which is the largest source of mortgage financing (**?**). In principle, the Fed's purchases and sales of agency MBSs may affect the originate-to-sell channel, as purchases affect mortgage spreads. When the Fed reduces its holdings of MBSs, their prices decline, and mortgage spreads increase, making GSEs' mortgage purchases more profitable. As **?** report, when the Fed sells MBSs, private investors become net purchasers of MBSs. If the Fed's reduced demand for MBSs is offset by private investors, the originate-to-sell channel would be largely unaffected, representing a substitution in buyers of agency MBSs. In this case, GSEs' mortgage purchases would only be affected by the rise in mortgage spreads

[22] I intentionally excluded the post-pandemic cycle from the qualitative assessment because fiscal policy may have directly impacted mortgage markets through the CARES Act and the American Rescue Plan Act, both of which included measures aimed at helping indebted homeowners, such as mortgage forbearance and grants.

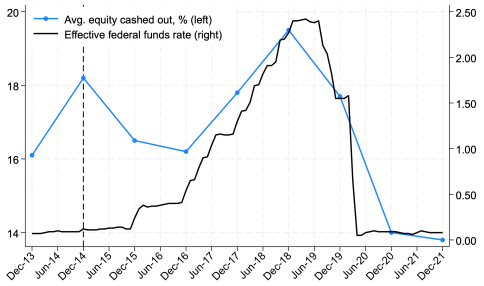
following the Fed cutting holdings of MBS. A quantitative assessment of the effects of the Fed's MBS purchases on the GSEs' is beyond the scope of this article but remain an important question for future research.



A. Cash-out refinance share



B. Home equity extracted



C. Home equity extracted, % property value

FIGURE 13. Post-2014 monetary policy cycle

Notes: Data on refinancing are retrieved from April 2022 Freddie Mac Economic & Housing Research Note "Trends in Mortgage Refinancing Activity" which can be accessed here. The data refers to mortgages purchased by Freddie Mac. The figure shows monthly values obtained by interpolating the annual observations reported in the Freddie Mac report with the dots representing the original yearly data points.

6.2. Policy implications of the monetary and housing credit policy interactions

The findings of this article suggest that GSEs' mortgage purchases mitigate the effects of a monetary policy tightening on both mortgage and housing market activity. This interaction between monetary and housing credit policy has important implications for monetary policymakers and for future reforms of GSEs and housing policy.

6.2.1. Monetary policy and financial stability

Evidence that GSEs can dampen the effects of monetary policy and influence credit supply in ways that diverge from standard channels, such as the financial accelerator, is highly relevant for understanding the real effects of monetary policy. Previous research shows that without GSEs' intervention, a monetary tightening would raise the unemployment

rate more sharply, with little effect on the inflation response (**?**). Given the interest-rate sensitivity of housing activity, policymakers should account for the endogenous response of GSEs, and housing credit policy more broadly, when forecasting policy effects. Ignoring the originate-to-sell channel could lead to overestimating the impact of interest rate increases on housing and residential mortgage markets.

By subsidizing a specific segment of credit markets, GSEs' purchases can reallocate credit away from commercial mortgages and loans (**?**). My findings suggest that a monetary tightening, by stimulating GSEs' activity, may amplify this reallocation effect, potentially reducing credit available to businesses. This would add a crowding-out effect to the conventional channels through which monetary policy raises the external finance premium for businesses. Although assessing this unintended effect lies beyond the scope of this article, it represents a promising area for future research with important implications for the monetary policymakers' assessment of the real effects of monetary policy.

Financial stability considerations provide another reason for policymakers to account for housing credit policy when forecasting the effects of their policies. After a tightening, lenders may strategically originate large volumes of mortgages, retaining higher-quality loans while selling riskier ones in the secondary market (**?**). This spillover from housing credit policy to primary market originations could be reinforced during a tightening, when GSEs increase purchases both to stabilize the mortgage market and to exploit profit opportunities from rising mortgage rates. More research is needed to quantify the importance of these effects which, however, warrant close monitoring by policymakers, as the quality of credit could deteriorate when monetary policy tightens.

6.2.2. The future of GSEs and housing credit policy

The 2008 crisis revealed a fundamental problem with GSEs: capital markets expected federal support in the event of financial distress. The 2008 bailout and the subsequent Conservatorship under direct regulatory control confirmed this perception. Since then, the main legislation governing GSEs has remained largely unchanged. Under Conservatorship, three main changes occurred. First, GSEs' balance sheets were reduced. Second, credit risk on GSE-owned mortgages was lowered by purchasing insurance and issuing catastrophe bonds, effectively privatizing some of the risk and marking a departure from the pre-2008 model of privatized gains and socialized losses. Third, guarantee fees charged to mortgage originators were increased, raising compensation for the risks associated with purchased loans. **?** identify several factors explain why regulation, and housing credit policy more broadly, have remained unchanged since Conservatorship began. With the crisis passed, GSEs are much more solid and profitable. Moreover, subsidizing homeownership remains a cornerstone of US housing policy and carries strong political support. Reforming GSEs or reducing government involvement in mortgage provision could raise borrowing costs

for homeowners.

Recently, the Trump administration expressed interest in re-privatizing GSEs, with the Treasury planning to sell part of its stake. Past Republican administrations have also tried privatizing GSEs. For example, Freddie Mac's 1989 public listing was seen as a step toward privatization, and subsequent ambitious housing policy goals fueled extraordinary GSEs growth. Coupled with the perception of an implicit federal backstop, this expansion increased both their systemic importance and risk, ultimately leading to the crisis and Conservatorship. Regardless of the details of GSEs privatization, many observers expect capital markets to continue viewing them as "too big to fail" (**?**). The structure of the U.S. mortgage market, with its dominant 30-year fixed-rate loans and extensive securitization, requires entities such as GSEs to ensure adequate financing conditions. Based on my findings, policymakers should recognize that privatization could heighten GSEs' responsiveness to market conditions, including monetary policy changes, particularly if profit opportunities arise from the gap between agency funding costs (likely still reflecting an implicit guarantee) and mortgage rates. Privatization could therefore spur renewed GSEs' growth and rekindle the financial stability concerns that led to Conservatorship. Conversely, fully privatizing GSEs might end their housing policy role, leaving households fully exposed to monetary policy shocks without the liquidity and affordability support currently provided. Assessing these effects remains an important avenue for future research.

7. Concluding remarks

Housing credit policy in the United States has long exerted a significant influence on mortgage markets, particularly through GSEs. These entities purchase residential mortgages from originators and pool them into mortgage-backed securities, which are sold to private investors and, more recently, to the Federal Reserve. At the same time, mortgage markets are a central component of the monetary policy transmission mechanism. This article examines the time-varying effects of monetary policy on mortgage markets, with a particular focus on the role of housing credit policy.

I show that GSEs' purchases in the secondary mortgage market have shaped the response of mortgage credit to monetary shocks from the early 1990s to 2014. When monetary policy tightens, refinancing activity increases, consistent with the presence of liquidity-constrained households who use cash-out refinancing to tap into accumulated home equity and smooth consumption. The demand for refinancing loans is met by originators, who can sell eligible loans to GSEs, provided they meet underwriting requirements. The prompt reaction of GSEs aligns with their statutory mandate to ensure liquidity and affordability of mortgages, and exploit profit opportunities arising from the wedge between mortgage rates and their own financing costs, which benefit from an implicit federal

guarantee. Favorable institutional conditions for GSEs, combined with house price booms, amplify the responses of GSEs' activity and cash-out refinancing. This suggests that households often treat their homes as ATMs to access accumulated equity, with GSEs playing a facilitating role in this process.

These findings have important policy implications. GSEs' actions can mitigate the contractionary effects of monetary policy, potentially weakening traditional transmission channels. The results also speak to ongoing debates over the future of GSEs, particularly considering a potential future privatization, which could alter their role in the housing finance system. Moreover, they open avenues for further research on the interaction between monetary and housing credit policy. Future work could investigate the effects of monetary policy on adverse selection in the origination of GSE-eligible mortgages (**?**) or examine whether GSEs' responses to monetary shocks amplify or mitigate the distributional consequences of monetary policy, which are known to operate through household borrowing (**?**).

Online Appendix

Supplementary Material for

Time-varying interactions between monetary and housing credit policy

Giacomo Rella

October 3, 2025

A. Data appendix

The following variables are used in the article (see also Table A.1):

- Shadow federal funds rate:
  - Units: percent.
  - Frequency: monthly.
  - Source: **?**.
- Excess bond premium:
  - Units: percent.
  - Frequency: monthly.
  - Source: **?**.
- Consumer price index:
  - Units: index (1984=100).
  - Frequency: monthly.
  - Source: **?** (FRED code: CPIAUCSL).
- Commodity price index: all items:
  - Units: index.
  - Frequency: monthly.
  - Source: **?**.
- Industrial production index:
  - Units: index (2012=100).
  - Frequency: monthly.
  - Source: **?** (FRED code: INDPRO)
- Residential mortgage debt:
  - Units: millions of 1984 dollars (deflated using the consumer price index).
  - Frequency: monthly
  - Source: **?**.
- Mortgage originations:
  - Units: millions of 1984 dollars (deflated using the consumer price index), seasonally adjusted.
  - Frequency: monthly
  - Source: **?**.
- Purchase originations:
  - Units: millions of 1984 dollars (deflated using the consumer price index), seasonally adjusted.
  - Frequency: monthly
  - Source: **?**.
- Refinancing originations:
  - Units: millions of 1984 dollars (deflated using the consumer price index), sea-

sonally adjusted.
    - Frequency: monthly
    - Source: **?**.
- Agency purchases as share of originations:
    - Units: millions of 1984 dollars (deflated using the consumer price index), seasonally adjusted.
    - Frequency: monthly
    - Source: **?**.
- Housing starts: total new privately owned:
    - Units: thousands of units, seasonally adjusted annual rate.
    - Frequency: monthly.
    - Source: **?** (FRED code: HOUST)
- New one family homes for sale:
    - Units: thousands of units, seasonally adjusted.
    - Frequency: monthly.
    - Source: US Department of Housing and Urban Development (FRED code: HNFSEPUSSA)
- New one family houses sold:
    - Units: thousands of units, seasonally adjusted annual rate.
    - Frequency: monthly.
    - Source: US Department of Housing and Urban Development (FRED code: HSN1F)
- Construction employment:
    - Units: thousands of persons, seasonally adjusted.
    - Frequency: monthly.
    - Source: US Bureau of Labor Statistics, Employment Situation (FRED code: USCONS)

TABLE A.1. Dataset

Series	Units	T	Source
A. Macroeconomic and financial variables			
Shadow federal funds rate	Percent	1	?
Excess bond premium	Percent	1	?
Consumer price index	1984=100	5	?
Commodity price index	Index	5	?
Industrial production	2012=100	5	?
B. Mortgage credit variables			
Residential mortgage debt	Mil. of 1984$	5	?
Mortgage originations	Mil. of 1984$	5	?
Purchase originations	Mil. of 1984$	5	?
Refinancing originations	Mil. of 1984$	5	?
Mortgage purchases as share of originations	Percent	1	?
C. Housing variables			
Housing starts	1000 units	5	?
Homes for sale	1000 units	5	FRED-HUD
Houses sold	1000 units	5	FRED-HUD
Construction employment	1000 units	5	FRED-BLS

Notes: Residential mortgage debt includes single-family (1-to-4) home mortgages and multifamily residential mortgages. Mortgage origination is total originations of long-term mortgage loans for 1-to-4 nonfarm homes and multifamily residential properties. T stands for Transformation code. T = 1 means no tran=sformation (levels), T = 5 means first difference of logarithm, T = 6 means second difference of logarithm. FRED = Federal Reserve Economic Data, HUD = US Department of Housing and Urban Development, BLS = US Bureau of Labor Statistics.

B. Tests for structural change

This Appendix report the results of two structural break tests. The first is a Chow test for breaks at two key dates: the onset of the Great Recession (2007M12) and the start of the QE program (2008M11). The second is the **?** test for multiple structural changes at unknown dates. All structural break tests are conducted, separately, on the following two regressions:

$$y_t = \alpha + \gamma(L)\mathbf{x}_t + \beta z_t + u_t, \tag{B15}$$

$$\Delta y_t = \alpha + \gamma(L)\Delta\mathbf{x}_t + \beta z_t \quad \text{with} \quad \Delta y_t = y_t - y_{t-1} \tag{B16}$$

where y is one of the mortgage credit variables studied in the paper (mortgage debt, mortgage originations, purchase originations, refinancing originations, and GSEs' mortgage purchases as a share of originations). The vector **x** includes all other variables used in the VAR (shadow federal funds rate, excess bond premium, consumer price index, commodity price index, and industrial production) with $L = 3$ lags, consistent with the VAR specification, while z are monetary policy surprises. I conduct the texts on the specification in levels and first differences. I test for the structural stability of all parameters in the regression, including the constant term. Each regression represents a mortgage credit variable equation in the VAR models. All tests are implemented using the **xtbreak** command by **?**.

Table B.1 reports the results of the Chow test. The **?** results are shown in Table B.2 and Table B.3. Table B.2 reports the test of the null hypothesis of no breaks against the alternative of an unknown number of breaks (between 1 and s_{max}). To ensure sufficient subsample length, I allow for a maximum of five breaks. The test statistic (UDmax) is compared with the 5% critical value provided by **?**. Table B.3 reports the results of the sequential procedure applied to the multiple breaks identified in Table B.2. The procedure works as follows:

a. The null hypothesis of no breaks is tested against the alternative of a single break. If the null cannot be rejected, the search for further breakpoints stops.
b. If the null is rejected, the breakpoint is estimated and the sample is split into two at the estimated breakpoint.
c. For each subsample, the null of no breaks is tested against the alternative of a single break. If no further break is found, the process stops with the existing breaks. Otherwise, new breakpoints are estimated, and the sample is split again.
d. This process continues until the null cannot be rejected.

Accordingly, Table B.2 reports the number and location of breakpoints, when found. Figure B1 plots the peak impulse responses together with any detected break dates.

According to the Chow test, both the onset of the Great Recession and the introduction

of QE are structural breaks in the mortgage credit equations in the VAR. This is especially true for purchase originations and GSEs' mortgage purchases. The detection of these structural breaks is consistent with the importance of these events. The **?** test, however, suggests that the Great Recession and the introduction of QE are not the only events driving structural change in the mortgage credit equations in the VAR. For all equations tested, structural breaks cluster around specific intervals: 1994–95, 1998–99, 2002–03, 2005–07, and 2009–11. This suggests that time variation is driven by more than just a few major breaks, such as the mortgage debt crisis, the Great Recession, and the introduction of QE. Still, these events are all detected by the **?** test, confirming their role as important sources of structural change, albeit not the only ones. The fact that numerous structural breaks are identified, with some not directly linked to major economic events, reinforces the choice of using a general nonlinear model, such as a TVP-VAR with parameters that change smoothly over time. Several other breaks align with turning points in the time-varying effects of monetary policy and, in some cases, with notable developments in housing credit policy. For instance, one factor likely contributing to the breaks in 1994–95 is the introduction of the 1995 Affordable Housing Credit Goals.

TABLE B.1. Chow test

Equation	Date	T	F-statistics	P-value	Decision
Mortgage debt	2007M12	L	1.54	0.07	Cannot reject H_0
	2007M12	D	2.33	0.00	Reject H_0
	2008M11	L	0.97	0.50	Cannot reject H_0
	2008M11	D	1.28	0.19	Cannot reject H_0
Mortgage originations	2007M12	L	1.60	0.05	Reject H_0
	2007M12	D	0.96	0.52	Cannot reject H_0
	2008M11	L	0.70	0.82	Cannot reject H_0
	2008M11	D	0.60	0.92	Cannot reject H_0
Purchase originations	2007M12	L	2.72	0.00	Reject H_0
	2007M12	D	1.82	0.02	Reject H_0
	2008M11	L	3.01	0.00	Reject H_0
	2008M11	D	1.73	0.03	Reject H_0
Refinancing originations	2007M12	L	1.28	0.19	Reject H_0
	2007M12	D	0.72	0.80	Cannot reject H_0
	2008M11	L	0.60	0.91	Cannot reject H_0
	2008M11	D	0.39	0.99	Cannot reject H_0
Mortgage purchases (%, originations)	2007M12	L	15.04	0.00	Reject H_0
	2007M12	D	12.66	0.00	Reject H_0
	2008M11	L	5.35	0.00	Reject H_0
	2008M11	D	3.38	0.00	Reject H_0

Notes: H_0: no break at date τ, H_1: s breaks at date τ. Test executed using Stata command **xtbreak** (**?**).

TABLE B.2. Test for multiple breaks at unknown break dates

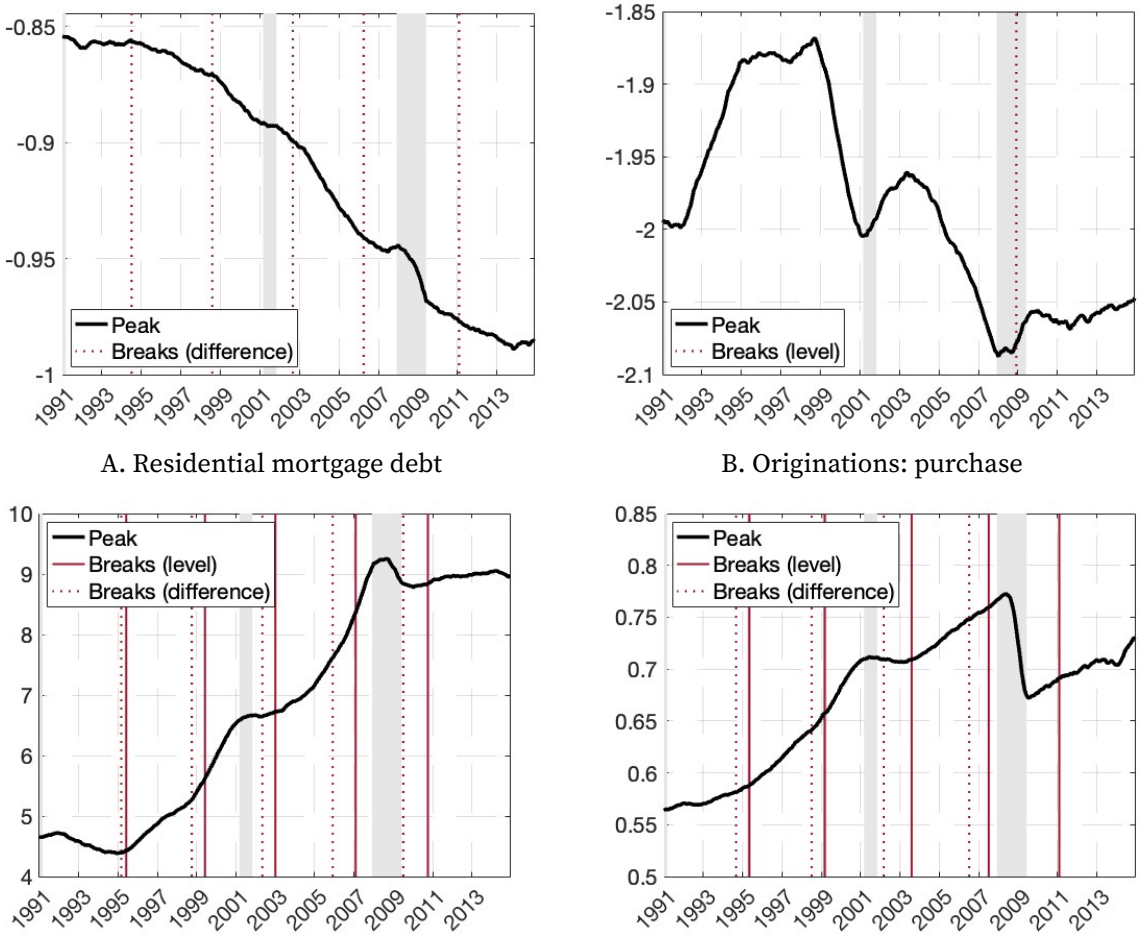
Equation	T	Test statistics	5% c.v.	Decision
B. Augmented models				
Mortgage debt	L	2.40	2.72	Cannot reject H_0
	D	3.29	2.72	Reject H_0
Mortgage originations	L	2.64	2.72	Cannot reject H_0
	D	1.76	2.72	Cannot reject H_0
Purchase originations	L	3.20	2.72	Reject H_0
	D	2.07	2.72	Cannot reject H_0
Refinancing originations	L	3.61	2.72	Reject H_0
	D	3.12	2.72	Reject H_0
Mortgage purchases (%, originations)	L	68.27	2.72	Reject H_0
	D	18.79	2.72	Reject H_0

Notes: H_0: no breaks, H_1: between 1 and s_{max} breaks, with s_{max} break. Implementation of **?** test using Stata command **xtbreak** (**?**).

TABLE B.3. Sequential test for multiple breaks at unknown break dates

Equation	T	Breaks	Break dates
Mortgage debt	L	0	Cannot estimate breakpoints
	D	5	1994M7, 1998M8, 2002M9, 2006M4, 2011M2
Mortgage originations	L	0	Cannot estimate breakpoints
	D	0	Cannot estimate breakpoints
Purchase originations	L	1	2008M12
	D	0	Cannot estimate breakpoints
Refinancing originations	L	5	1995M6, 1999M6, 2003M1, 2007M2, 2010M10
	D	5	1995M3, 1998M10, 2002M5, 2005M12, 2009M7
Mortgage purchases (%, originations)	L	5	1995M5, 1999M3, 2003M8, 2007M7, 2011M2
	D	6	1994M9, 1998M7, 2002M3, 2005M7, 2011M2

Notes: H_0: s breaks, H_1: $s+1$ breaks. Test executed using Stata command **xtbreak** (**?**).



A. Residential mortgage debt

B. Originations: purchase

C. Originations: refinancing

D. GSEs' mortgage purchases

FIGURE B1. Structural break tests

Notes: Cumulative impulse responses to a monetary tightening obtained using the TVP-VARX model.

C. Estimation

The model is estimated using Markov chain Monte Carlo (MCMC) methods, as is standard with TVP-VAR models **?**. Let $\boldsymbol{\beta}^{1:t}$ denote the history of parameters in $\boldsymbol{\beta}$ up to and including month $t = 1, \ldots, T$, Gibbs sampling is employed to evaluate the posterior distribution of $\boldsymbol{\beta}^{T}$ and the elements of $\mathbf{V}$. Bayesian estimation of the model requires specifying prior distributions for the hyperparameters, namely all parameters in $\boldsymbol{\beta}^{T}$ and $\mathbf{V}$. I follow **?** and **?**, with slight modifications given the data.

The prior distributions are calibrated based on a constant parameter VAR estimated over a training sample of around 13 years (from September 1976 to December 1990). For a significant part of the training sample, the series of monetary policy surprises is unavailable because the futures market started trading in 1988. Thus, I set the surprises to zero for periods with no available data, as in other applications of the exogenous variable approach (**?**). The OLS estimates for the training sample are then used to calibrate the prior distributions, which are assumed to be normal for the unobserved parameters and inverse-Wishart for the covariance matrices of the state equations:

$$
\begin{aligned}
\boldsymbol{\beta}_0 &\sim \mathcal{N}\left(\hat{\boldsymbol{\beta}}_{\text{OLS}}, 4 \cdot V\left(\hat{\boldsymbol{\beta}}_{\text{OLS}}\right)\right) \\
\boldsymbol{\Omega} &\sim \mathcal{IW}\left(\mathbf{I}_n, n+1\right) \\
\mathbf{Q} &\sim \mathcal{IW}\left(\kappa_Q^2 \cdot \tau \cdot V\left(\hat{\boldsymbol{\beta}}_{\text{OLS}}\right), \tau\right)
\end{aligned}
$$

where $\hat{\boldsymbol{\beta}}_{\text{OLS}}$ collects the OLS estimates from the training sample, $V\left(\hat{\boldsymbol{\beta}}_{\text{OLS}}\right)$ is their variance, and $\tau = 169$ is the size of the training sample. The parameter κ_Q specifies the prior belief about the amount of time variation in $\boldsymbol{\beta}_t$ and is set to 0.015. The simulation of the model is based on 5,000 iterations of the Gibbs sampler, with the first 2,000 discarded for convergence. The lag length is set to $p = 3$ to reduce the dimensions of both $\boldsymbol{\beta}_t$ and $\mathbf{Q}$, ensuring convergence, as in other application of the external variable approach in a time-varying setting **??**. The estimation sample runs from January 1991 to December 2014, due to limited availability of monthly mortgage market data.

Once the prior distributions are calibrated, the following steps of the Gibbs sampler are implemented to evaluate the posterior distributions:

a. Initialize $\mathbf{V}$,
b. Sample $\boldsymbol{\beta}^{1:T}$ from $p(\boldsymbol{\beta}^{1:T}|\mathbf{y}^{1:T}, z^{1:T}, \mathbf{V})$,
c. Sample $\mathbf{V}$ by sampling $\boldsymbol{\Omega}$ and $\mathbf{Q}$ from $p(\boldsymbol{\Omega}, \mathbf{Q}|\mathbf{y}^{1:T}, z^{1:T}, \boldsymbol{\beta}^{1:T})$,
d. Repeat step 2,

where $p(\cdot|\cdot)$ denotes the conditional density, $\mathbf{y}^{1:T} = [\mathbf{y}_1, \ldots, \mathbf{y}_T]'$ and $z^{1:T} = [z_1, \ldots, z_T]'$ are the histories of $\mathbf{y}_t$ and z_t for $t = 1, \ldots, T$, respectively.

D. Sensitivity analysis and further results

In this section, I replicate the main findings of the article using an alternative prior specification and a different monetary policy shock. Moreover, I present further results on time variation and sign-dependent effects of monetary policy.

Priors. In time-varying parameter models, **?** notes that the results may be sensitive to different values of κ_Q. In the sensitivity analysis, I slightly lower κ_Q to 0.01, which reduces the amount of time variation and makes the impulse response functions smoother relative to the baseline results. Figure D1 in Appendix E shows the medium-term response of residential mortgage debt, originations, agency pool issuance, and mortgage purchases to a different value of the parameter κ_Q, which controls the prior belief in the time variation of the model parameters. Overall, the results are qualitatively unchanged and the time variation and magnitude of the effects of monetary policy remain largely the same.

Monetary policy shocks. Throughout the paper, I use the orthogonalized monetary surprise series from **?** to address the predictability issue in high-frequency monetary policy surprises. **?** propose an alternative approach to correct for this predictability issue by separating surprises into two components: a pure monetary policy shock and an information shock. The pure monetary policy shock is identified by the negative co-movement between interest rate and stock price changes around policy announcements. Figure D2 in Appendix E shows the medium-term response of residential mortgage debt, originations, and mortgage purchases when using the monetary policy shocks from **?**. The results remain qualitatively similar but the magnitude of the impulse responses is smaller compared to the baseline model. For mortgage purchases, the responses even fall outside the credibility intervals of the baseline estimates. These size differences arises from the differences in how the instruments are constructed and from using orthogonalized surprises which produce estimates of monetary policy effects that are purged of attenuation biases.

Uncertainty. To emphasize the trend in the time-varying impact of monetary policy, the main text presents only the median impulse response. However, to fully acknowledge the uncertainty surrounding these time-varying effects, Figures E4 and E5 in Appendix E display the short- and medium-term impulse responses of mortgage credit variables, accompanied by 68% credibility intervals. It's noteworthy that for some variables, despite the lower bound of the chosen interval, zero is often encompassed within the credibility band. Furthermore, Figure D3 illustrates the median differences in impulse responses between the initial period (January 1991) and the final period (December 2014) of the sample. This figure also includes 38%, 68%, and 90% credibility intervals derived from

the posterior distribution. Also for the differences, statistical significance often emerges at lower confidence levels than conventionally employed. This characteristic is common to TVP-VAR models, as documented in previous literature (**??**).

State-dependent local projections. To identify episodes of expansionary housing credit policy, I purge GSEs' net commitments of the influence of credit, housing, and macro-financial indicators. As a robustness check, I re-estimate the state-dependent effects of monetary policy using an indicator that captures the stance of housing credit policy according to the narrative approach of **?**. More specifically, if a non-cyclically motivated housing credit policy intervention occurs in month t, then the stance of housing credit policy is classified as expansionary in that month and over the subsequent 12 months. I use a full-year interval following each event to account for implementation delays. Since these events are rare, the narrative-based state variable is extremely sparse. Therefore, I adopt a simpler local projections specification, in which the monetary policy shock is interacted directly with the state variable, rather than allowing all model coefficients to vary by state, as in the main specification (equation 13). This approach reduces the number of state-dependent parameters to estimate. The local projection model I estimate is:

$$\Delta y_{t+h} = \alpha^h + \gamma^h(L)\mathbf{x}t + \beta^h zt + \delta^h z_t I_{t-1} + u_t^h, \tag{D17}$$

where the state-dependent effect is captured by the interaction between the shock and the narrative-based housing credit policy stance indicator. When the stance of housing credit policy is expansionary ($I_{t-1} = 1$), the impulse response function is given by the sum of the linear and interaction terms, i.e., $\beta^h + \delta^h$. Figures D5 and D4 in Appendix E present the results of this robustness check. Each plot reports four impulse responses, derived from different specifications and definitions of the state variable: (1) baseline specification with regression-based state, (2) baseline specification with alternative (narrative-based) state, (3) interaction specification with regression-based state, and (4) interaction specification with alternative state. The baseline specification corresponds to the main state-dependent local projections model (equation 13). In most cases, the result that the effects of monetary policy on mortgage credit variables depend on the stance of housing credit policy is robust to using an alternative approach for identifying policy stance, as well as to a different modeling of state dependence in local projections. When the regression-based indicator is used, the state-dependent effects of monetary policy are qualitatively similar across models. However, there are notable exceptions in which the baseline impulse responses diverge from those in the robustness checks. For example, the impulse responses of mortgage debt, refinancing, house prices, and housing starts diverge across specifications at longer horizons, with the responses based on the narrative-based indicator exhibiting

erratic jumps.

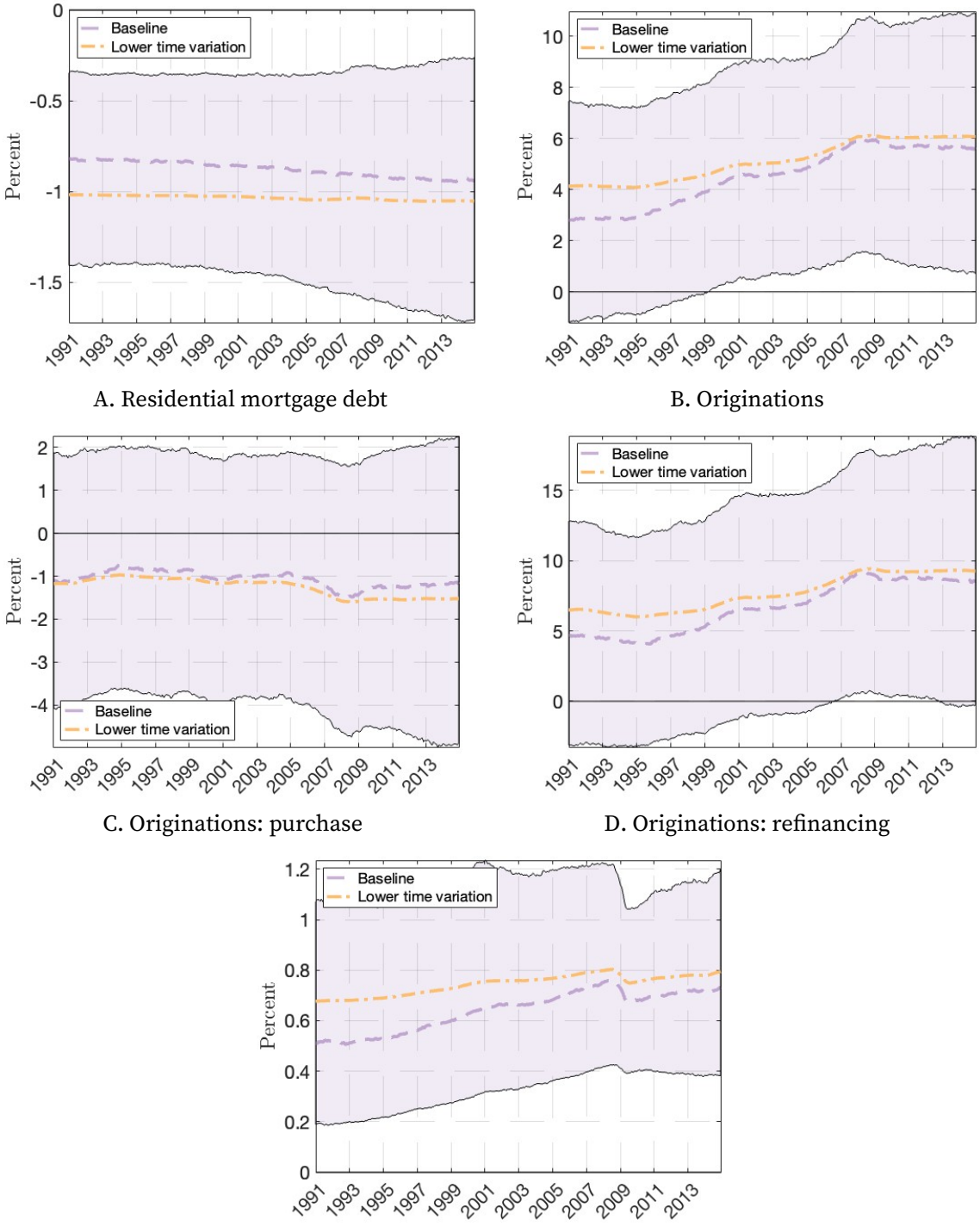


FIGURE D1. Time-varying effects of monetary policy: robustness to priors

Notes: Cumulative impulse responses to a monetary tightening obtained using the TVP-VARX model. Median impulse responses along with 68 percent credibility intervals from the posterior distribution. Prior belief about time variation is $\kappa_Q = 0.015$ in Baseline and $\kappa_Q = 0.01$ in Lower time variation.

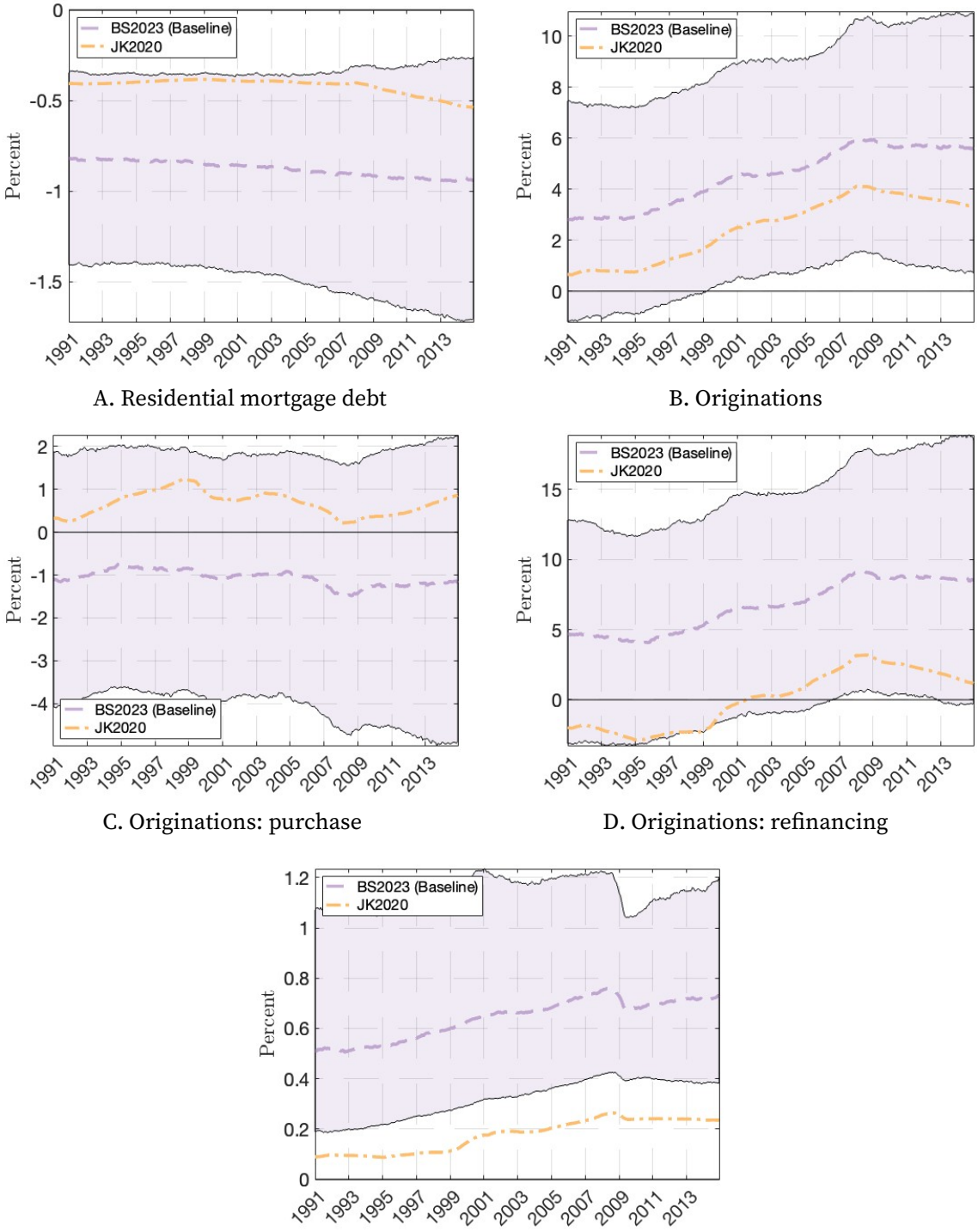
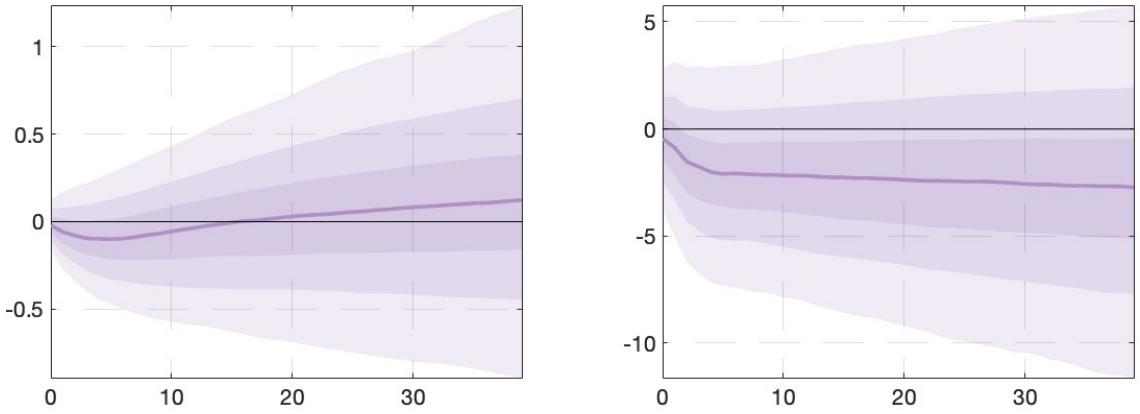


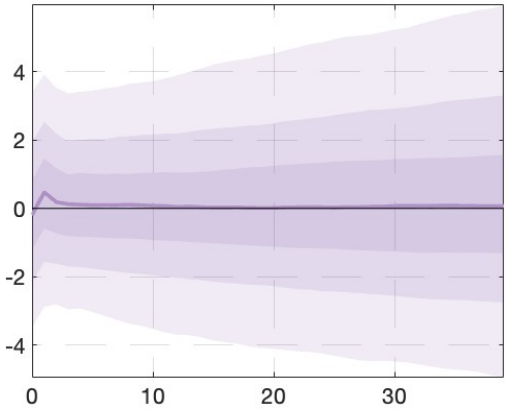
FIGURE D2. Time-varying effects of monetary policy: robustness to shock

Notes: Cumulative impulse responses to a monetary tightening obtained using the TVP-VARX model. Median impulse responses along with 68 percent credibility intervals from the posterior distribution. BS2023 is **?**, JK2020 is **?**.

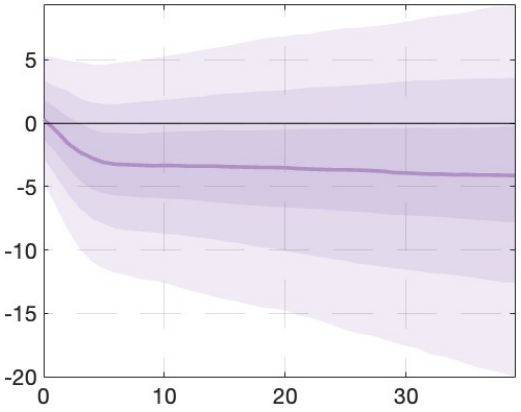


A. Residential mortgage debt

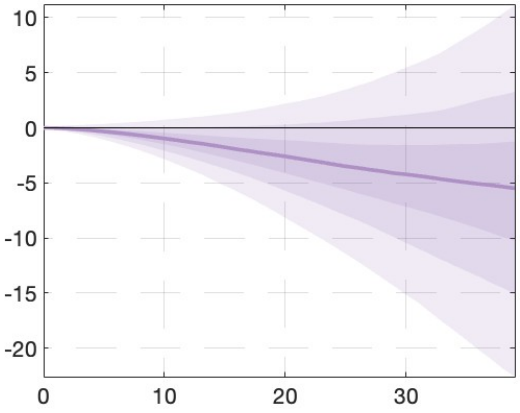
B. Originations



C. Originations: purchase



D. Originations: refinancing



E. Mortgage purchases

FIGURE D3. Differences in impulse responses (1991M1 - 2014M1)

Notes: Median differences in cumulative impulse responses from TVP-VARX model together. Credibility intervals (38, 68, and 90 percent) based on iterations of the Gibbs sampler.

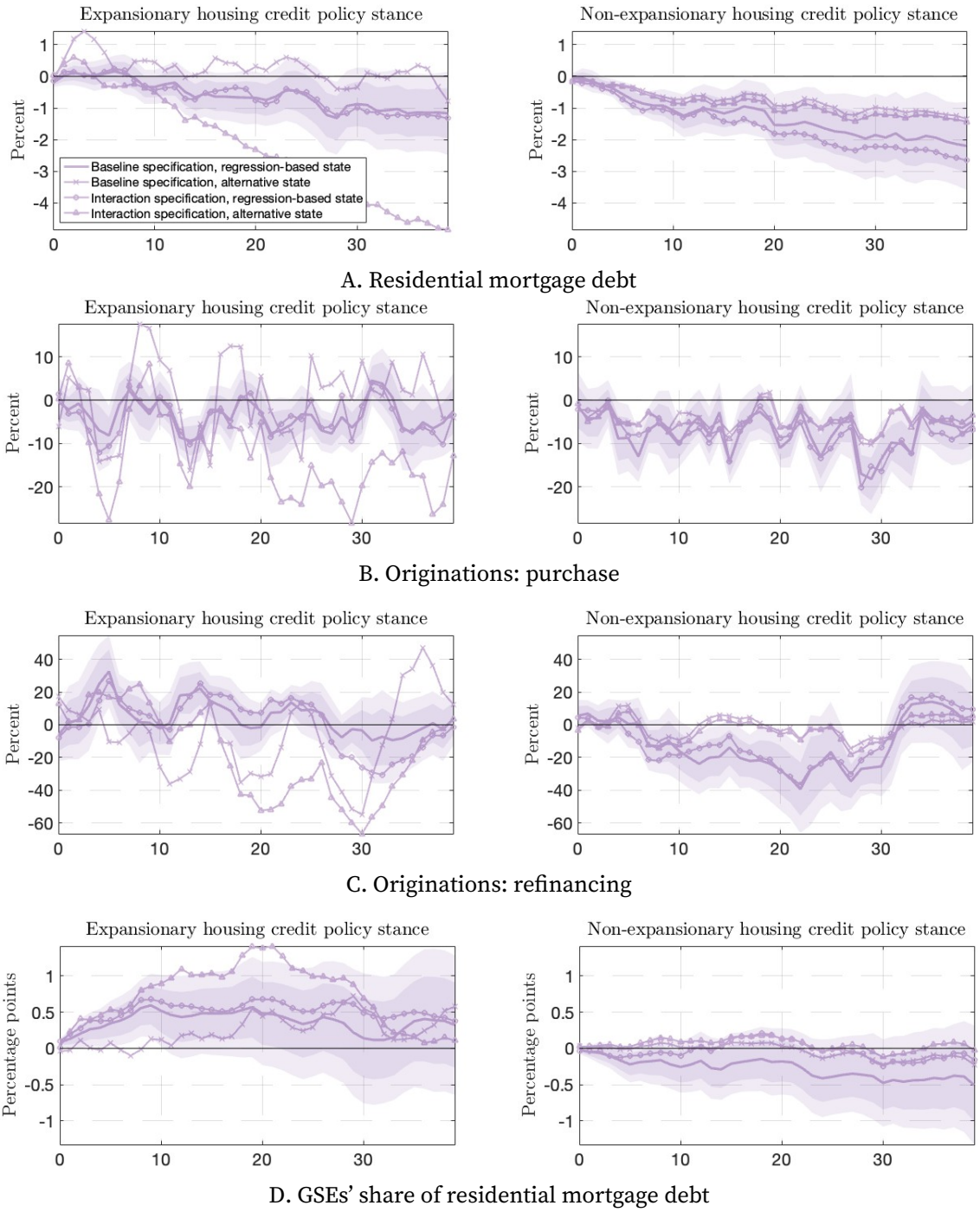


FIGURE D4. State-dependent effects of monetary policy I - robustness

Notes: State-dependent local projections impulse responses to a monetary policy shock that increases the shadow federal funds rate by 0.16 percentage points, as in the macroeconomic proxy-VAR model. Bands are 68 and 90 percent confidence intervals. The left column shows the response in the expansionary housing credit policy stance state, while the right column shows the response in the non-expansionary housing credit policy stance state.

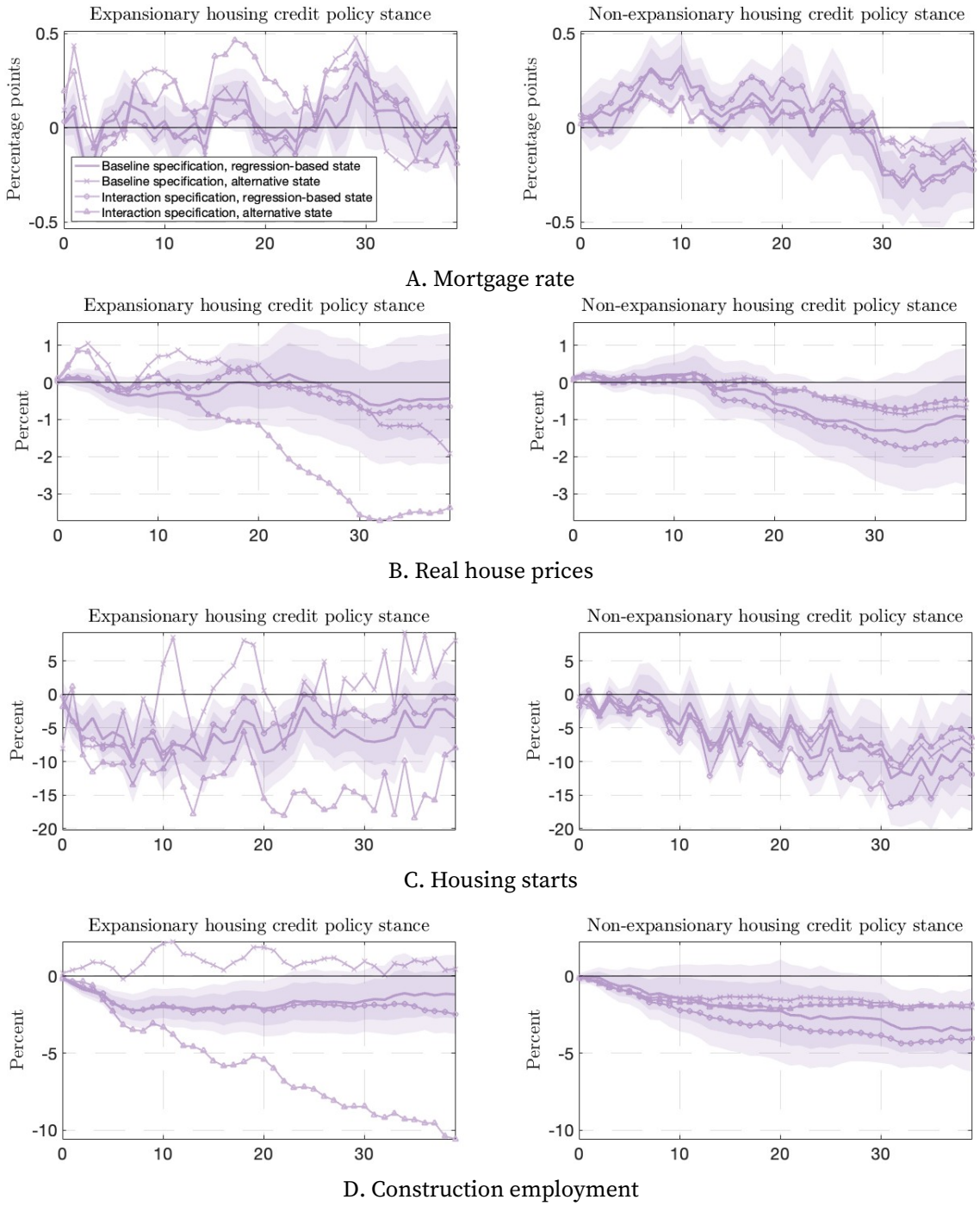


FIGURE D5. State-dependent effects of monetary policy II - robustness

Notes: State-dependent local projections impulse responses to a monetary policy shock that increases the shadow federal funds rate by 0.16 percentage points, as in the macroeconomic proxy-VAR model. Bands are 68 and 90 percent confidence intervals. The left column shows the response in the expansionary housing credit policy stance state, while the right column shows the response in the non-expansionary housing credit policy stance state.

E. Additional figures

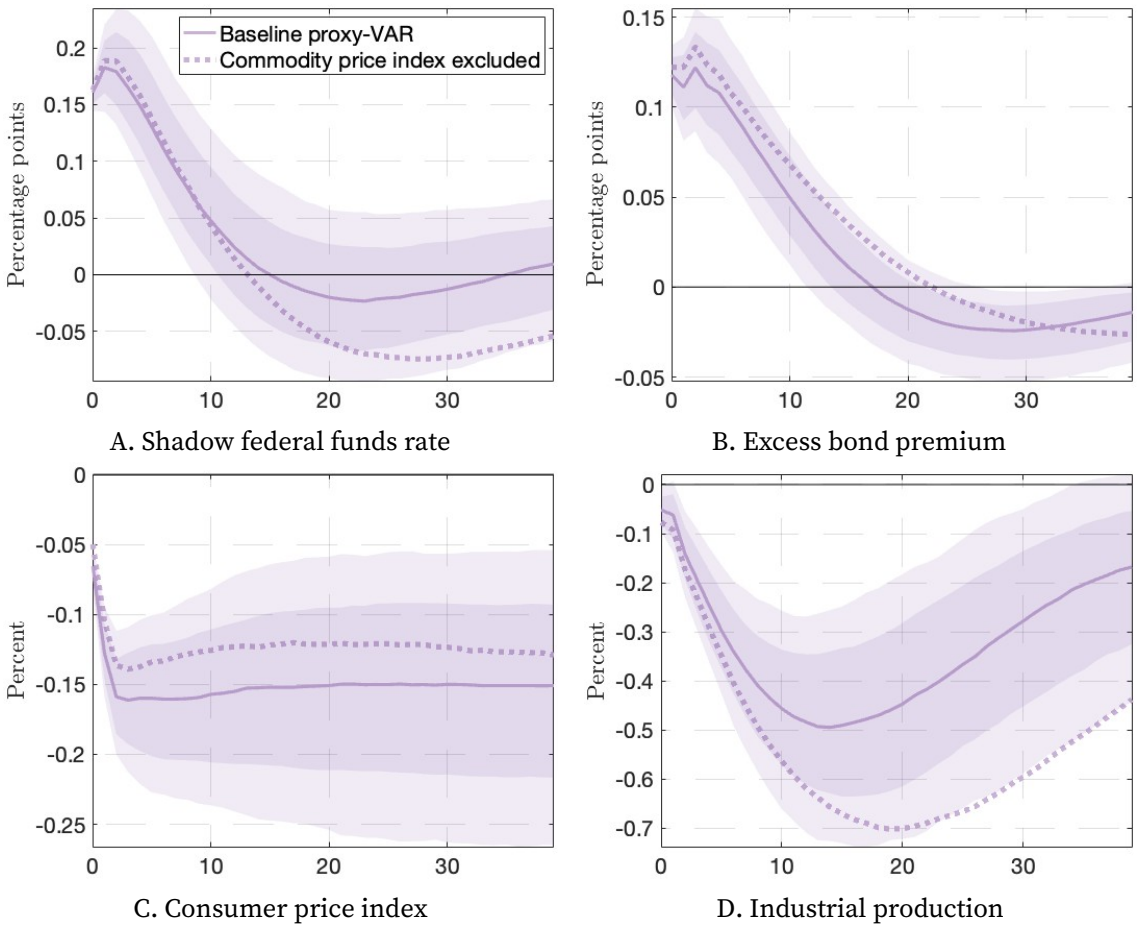
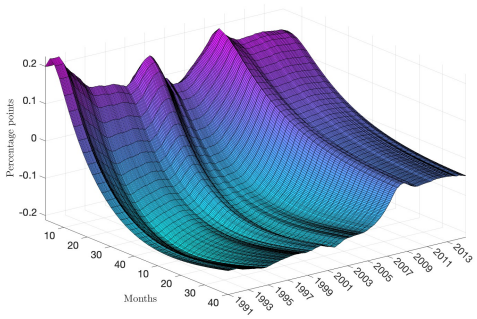
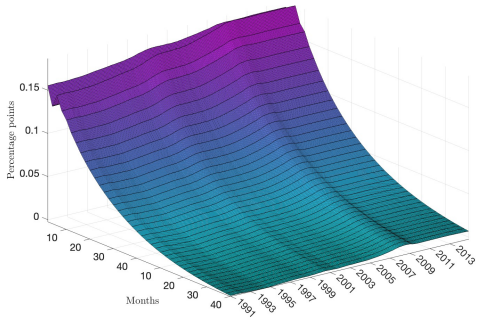


FIGURE E1. Macroeconomic effects of monetary policy

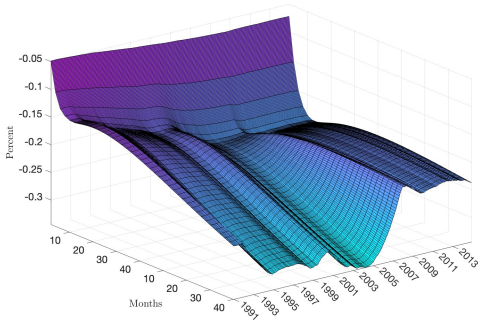
Notes: Impulse responses to a one-standard-deviation contractionary monetary policy shock, median responses along with 68 and 90 percent confidence intervals (proxy-VAR). Confidence bands obtained using the recursive wild bootstrap (**?**). For the VARX, the size of the shock is normalized to match the initial increase in the shadow federal funds rate in the proxy-VAR.



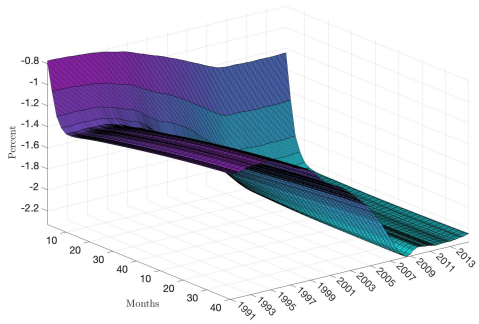
A. Shadow federal funds rate



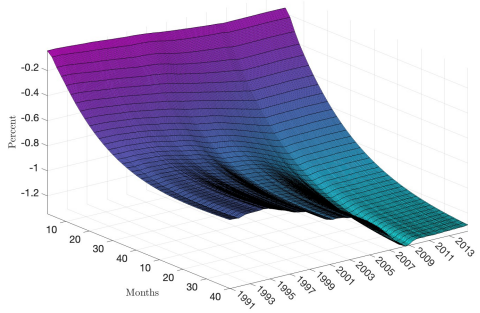
B. Excess bond premium



C. Consumer price index



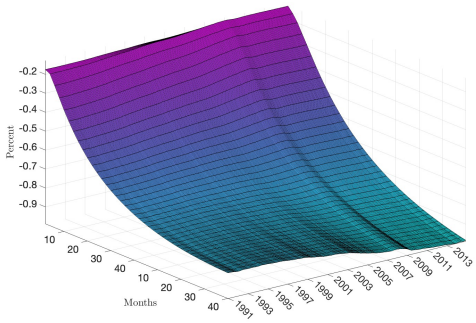
D. Commodity price index



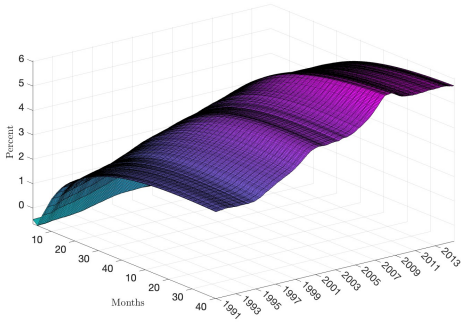
E. Industrial production

FIGURE E2. Time-varying effects of monetary policy on macroeconomic aggregates

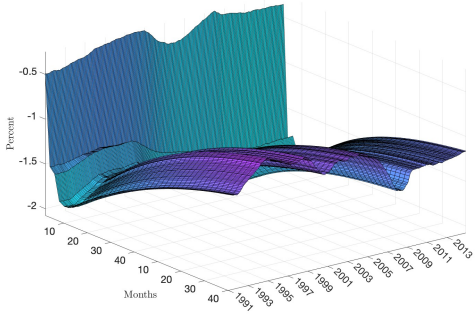
Notes: Cumulative impulse responses to a monetary tightening obtained using the TVP-VARX model.



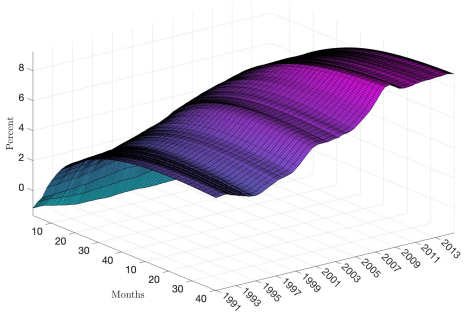
A. Residential mortgage debt



B. Originations



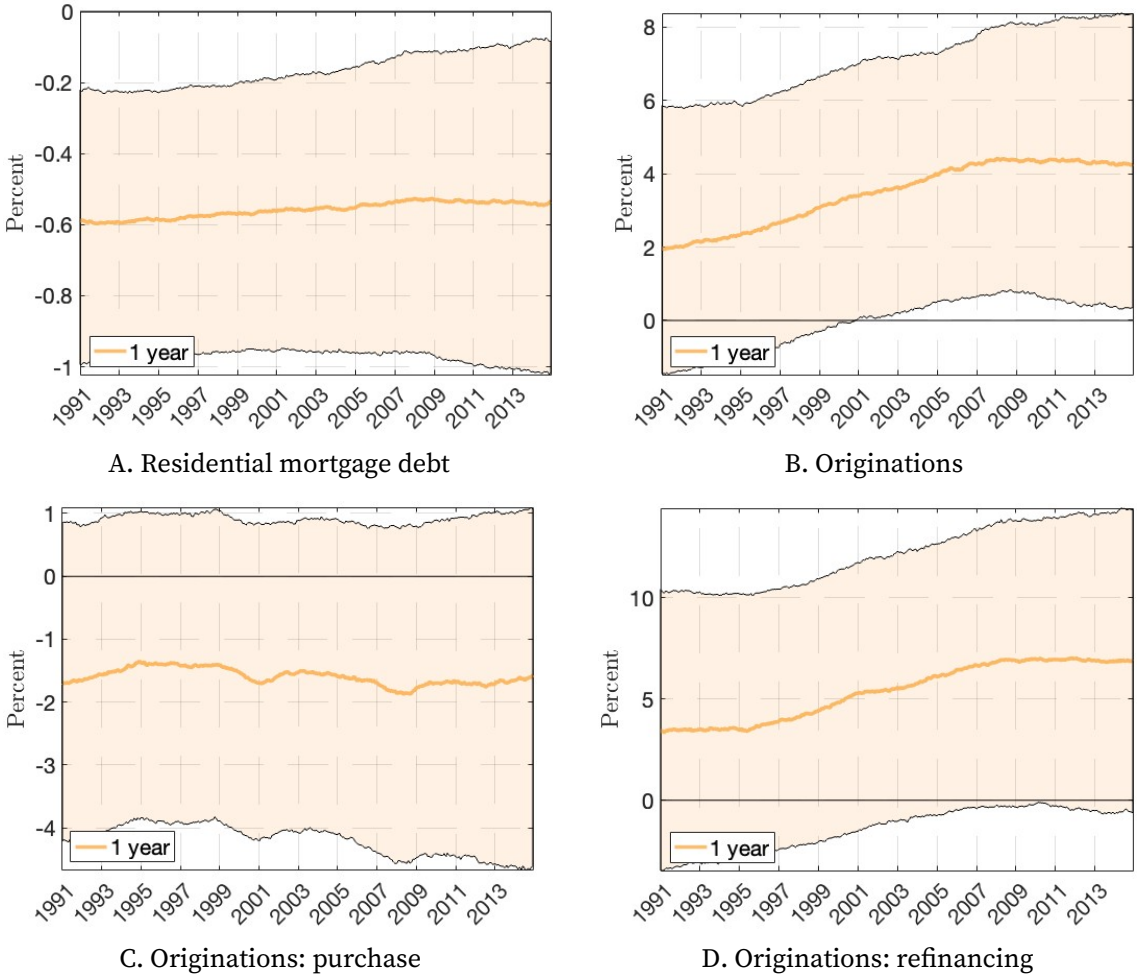
C. Originations: purchase



D. Originations: refinancing

FIGURE E3. Time-varying effect of monetary policy on mortgage credit: full impulse responses

Notes: Cumulative impulse responses to a monetary tightening obtained using the TVP-VARX model.



A. Residential mortgage debt

B. Originations

C. Originations: purchase

D. Originations: refinancing

FIGURE E4. Time-varying effects of monetary policy on mortgage credit: short term

Notes: Cumulative impulse responses to a monetary tightening obtained using the TVP-VARX model. Median impulse responses along with 68 percent credibility intervals from the posterior distribution.

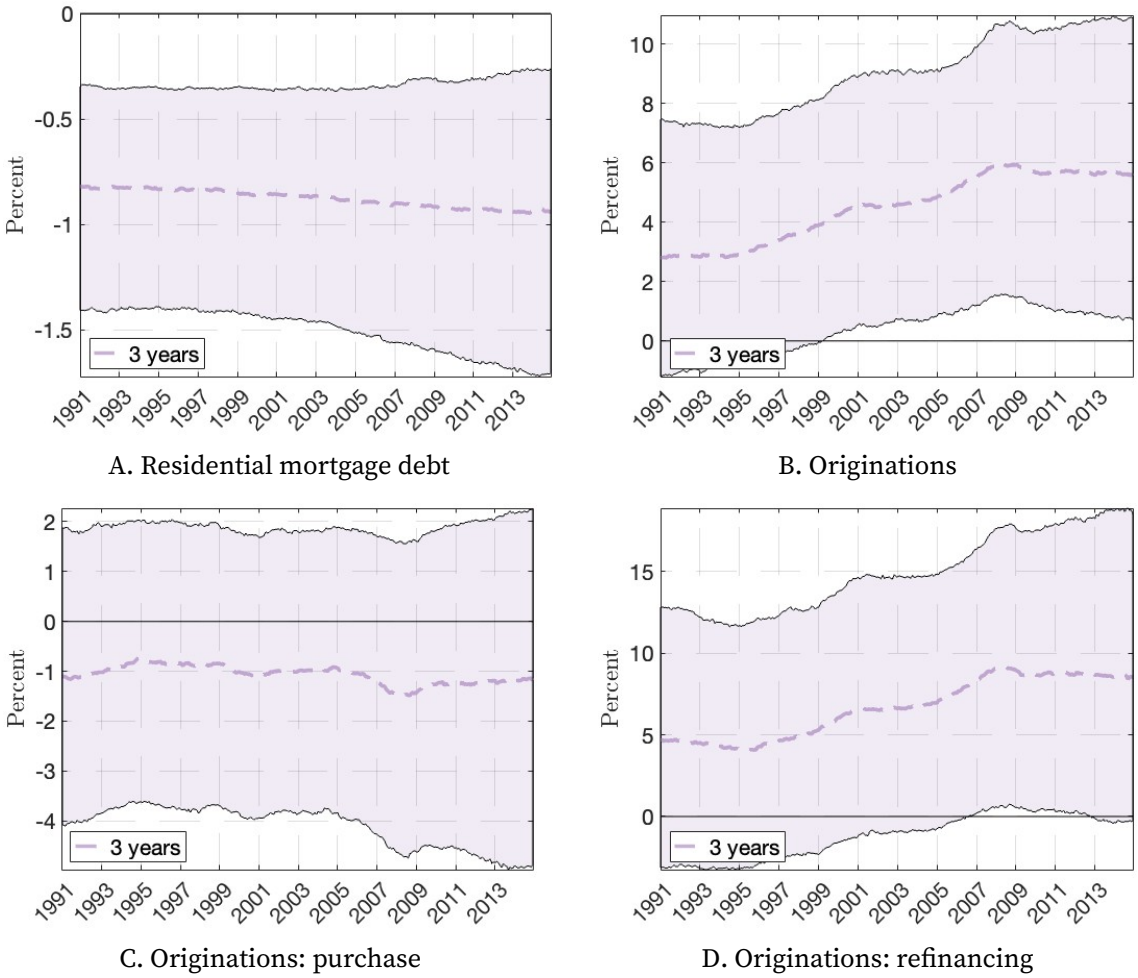


FIGURE E5. Time-varying effects of monetary policy on mortgage credit: medium term

Notes: Cumulative impulse responses to a monetary tightening obtained using the TVP-VARX model. Median impulse responses along with 68 percent credibility intervals from the posterior distribution.

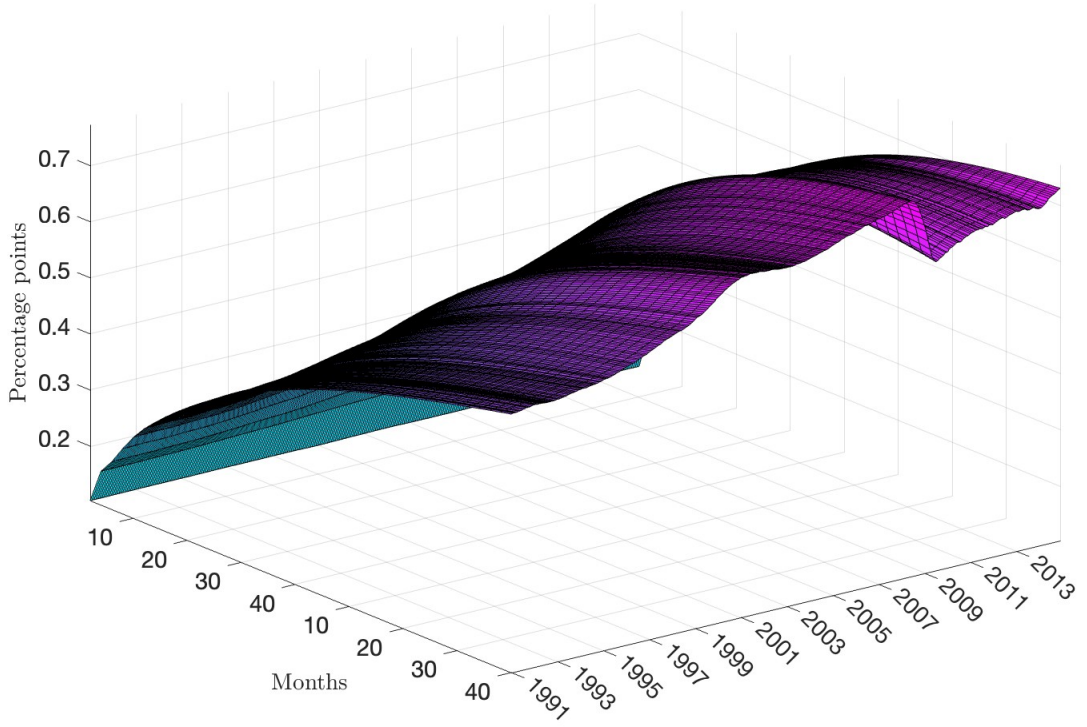
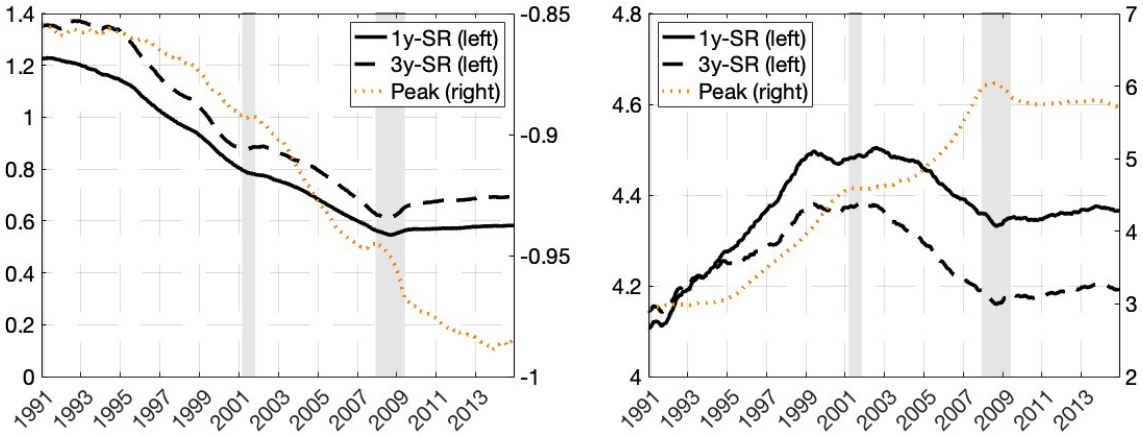


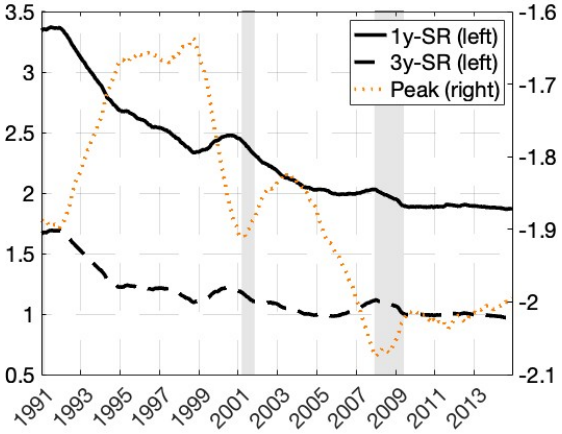
FIGURE E6. Time-varying effects of monetary policy on GSEs' mortgage purchases: full impulse responses

Notes: Cumulative impulse responses to a monetary tightening obtained using the TVP-VARX model.

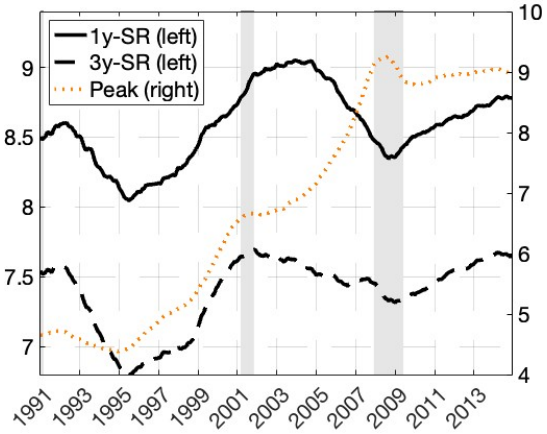


A. Residential mortgage debt

B. Originations



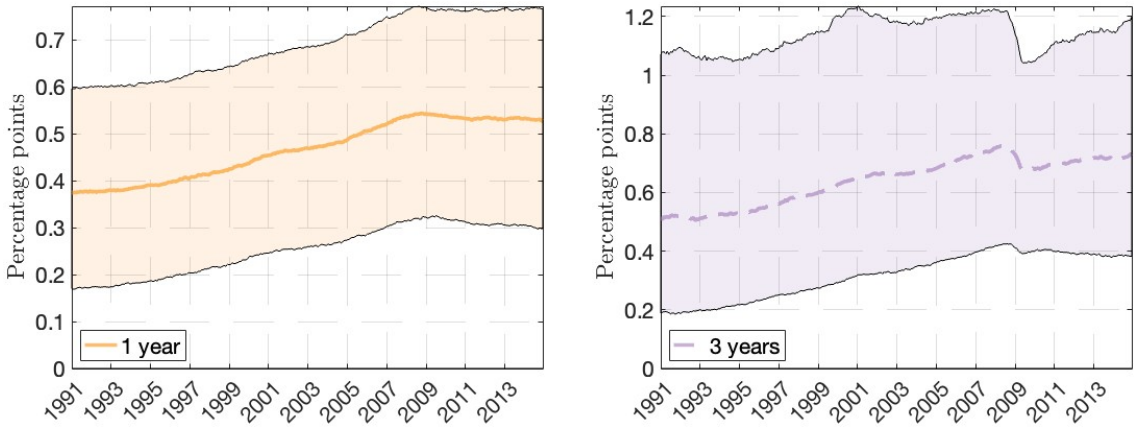
C. Originations: purchase



D. Originations: refinancing

FIGURE E7. Relative impulse responses (sacrifice ratios)

Notes: Cumulative impulse responses to a monetary tightening obtained using the TVP-VARX model.

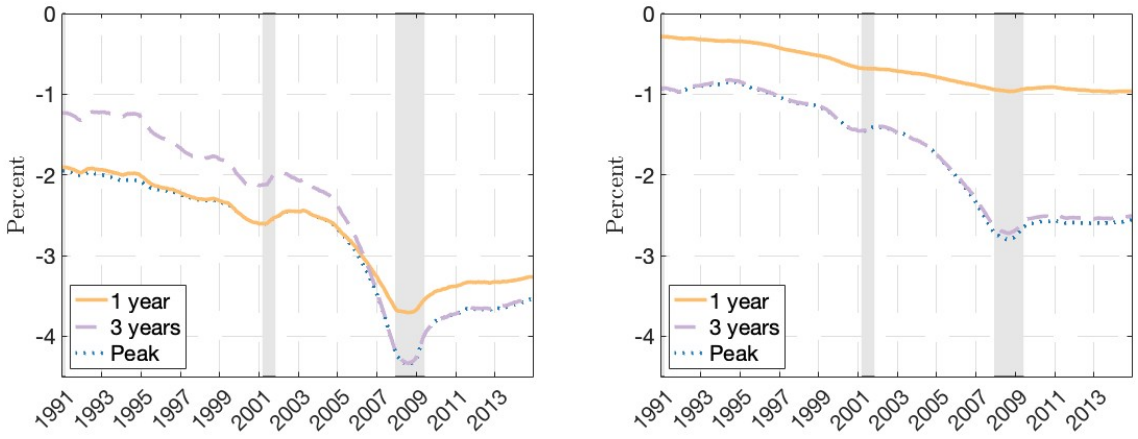


A. Short-term impulse response

B. Medium-term impulse response

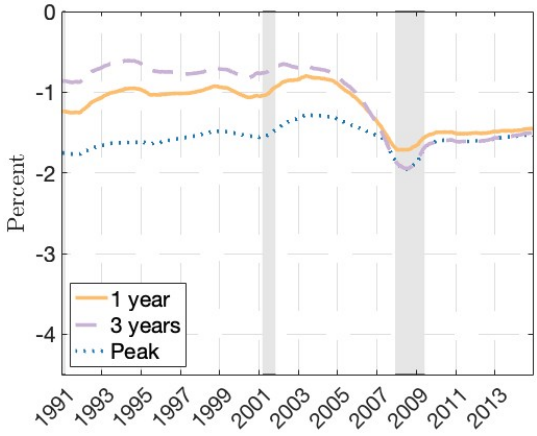
FIGURE E8. Time-varying effects of monetary policy on GSEs' mortgage purchases

Notes: Cumulative impulse responses to a monetary tightening obtained using the TVP-VARX model. Median impulse responses along with 68 percent credibility intervals from the posterior distribution.

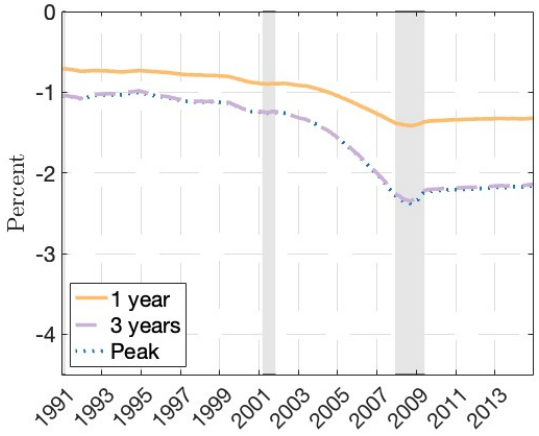


A. Housing starts

B. Houses for sale



C. Houses sold



D. Construction employment

FIGURE E9. Time-varying effects of monetary policy on housing activity: selected horizons

Notes: Cumulative impulse responses to a monetary tightening obtained using the TVP-VARX model. Median impulse responses from the posterior distribution.

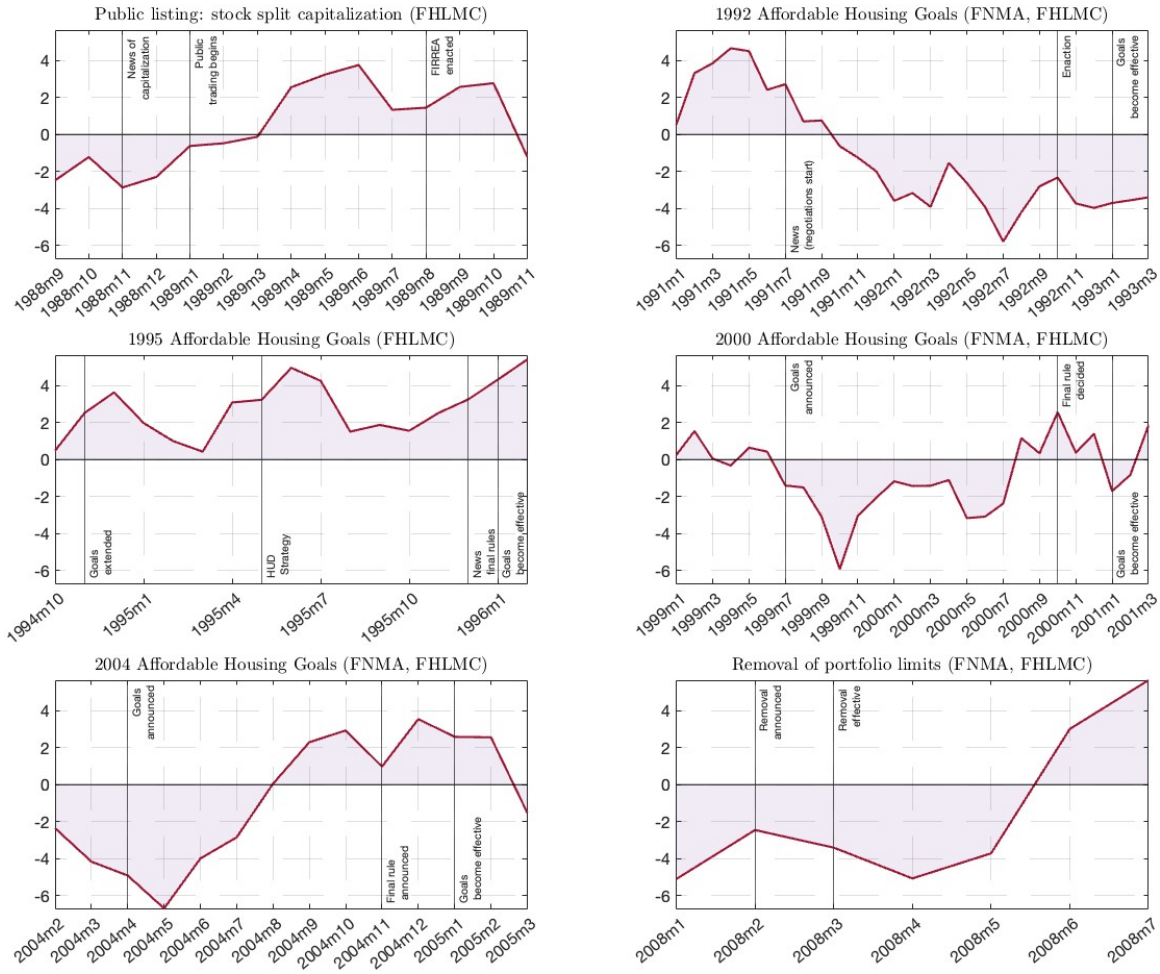


FIGURE E10. Cross-referencing the stance of housing credit policy

Notes: Solid red line is the stance of housing credit policy, $\hat{\xi}_t$. The stance is expansionary when $\hat{\xi}_t > 0$ and non-expansionary otherwise. Vertical lines capture policy events from **??**. FHMLC = Freddie Mac, FNMA = Fannie Mae, HUD = U.S. Department of Housing and Urban Development, FIRREA = Financial Institutions Reform, Recovery, and Enforcement Act.