

Re-examining the Framework for Macro Modeling of Monetary Policy and Regional Housing

Daniel Centuriao* Michael Duncan[†] Scott Schuh[‡]

October 21, 2026

Abstract

This paper re-examines the aggregate modeling framework that captures both national markets (monetary and financial) and heterogeneous regional housing markets by re-specifying the macro-housing VAR in the HAVAR model of Fratantoni and Schuh (2003). Both the original (levels) and revised (rates) specifications of the 6-variable model affirm that housing remains more cyclically and interest sensitive than non-housing activity and capture the major developments in monetary policy and housing that altered timing and transmission since 1998. However, the rates specification is preferable on several dimensions and is consistent with an SVAR specification of a New Keynesian model with two heterogeneous sectors. An expanded macro VAR model that adds a financial variable and two more housing variables also fits the data well, thereby providing a solid foundation for an updated, revised, and expanded HAVAR model in future research.

Keywords: Monetary policy, housing, regional, mortgage rate, HAVAR model

JEL Classification: E3, E4, E5, R3

*Post Doctoral Scholar, Northeast Regional Center for Rural Development, Penn State University. Email: dfc5823@psu.edu

[†]Visiting Assistant Professor, Illinois Wesleyan University. Email: mduncan@iwu.edu.

[‡]*Corresponding Author.* Associate Professor, West Virginia University. Email: scott.schuh@mail.wvu.edu

1 Introduction

Following the 1970s demise of large-scale macroeconometric models with a housing market, early stages of modern macroeconomic theory omitted an explicit, separate role for housing. During the 21st century, housing re-emerged as a key part of macroeconomics and finance (Piazzesi and Schneider, 2016). Much of this resurgence was driven by the housing boom-bust of the 2000s and Global Financial Crisis (GFC) in 2007-2009. An early contribution was Fratantoni and Schuh (2003), henceforth “FS,” which built a heterogeneous agent VAR (HAVAR) model of monetary policy and housing with 50 states. The HAVAR model uses exact aggregation to integrate national monetary policy with heterogeneous regional goods and housing markets. A key feature of HAVAR models is that responses to monetary policy shocks exhibit endogenous “long and variable lags”—time-varying and state-dependent dynamics due to widespread cross-section diversity in state Gross Domestic Product (GDP) and house prices. Thus, the efficacy and impact of monetary policy varies each period.

Since then, detailed economic features of housing markets have diffused to multiple dimensions of macro and financial research. For examples, Iacoviello (2005) and Piazzesi and Schneider (2016) emphasized the role of housing in portfolios, investment, and asset pricing; Iacoviello and Neri (2010) and Iacoviello (2010) focused on the role of housing in aggregate Dynamic Stochastic General Equilibrium (DSGE) models; and Cooper et al. (2022) extend regional analysis of heterogeneity to monetary policy differences arising in state-level real interest rates estimated from New Keynesian IS curves. However, none of the resurgence in macro housing-monetary policy research has continued the exact-aggregation micro-macro approach advocated by Fratantoni and Schuh (2003), so the literature lacks a comparable update of macro and housing developments since the late 20th century.¹

Nevertheless, recent developments and the literature highlight aspects of the FS HAVAR model that merit updating and warrant revisions. Most obviously, the massive boom-bust in home sales, prices, and ownership during the 2000s begs for inclusion and comparison with the earlier period. The unique state-level diversity of this particularly boom-bust period (Aastveit et al., 2023) provides further motivation for doing this within a HAVAR model. The central importance of mortgages, securitization, shadow banking, and asset product innovations leading up to the Global Financial Crisis (GFC) strongly suggests including a financial variable(s) (for examples, see Keys et al., 2010; Mian and Sufi, 2011; Meeks et al., 2017; Calza et al., 2013; Justiniano et al., 2019; Kim and Lim, 2020; Greenwald and Guren, 2025). Also, a deposit channel for monetary policy (Drechsler et al., 2017) and a bank-level

¹A recent exception is Cooper et al. (2022), whose results “...show larger effects of monetary policy on house prices during the housing boom (2000–06) than during the non-boom period” (p. 176) in a model *without* exact aggregation.

correlation between deposit types and real estate loans across states (Minuci and Schuh, 2025) amplify the need to connect regional housing and banking further.

In addition, modern macro theory has moved toward structural DSGE models with micro foundations that have a restricted VAR representation of the observable structure. Taking this approach would improve the unrestricted HAVAR. A calibrated DSGE model with 50 states and an aggregate resource constraint is becoming technically feasible; Duncan (2026) takes a step in that direction by constructing a DSGE model of regional housing markets with population growth. However, it is still true that, “To our knowledge, no structural dynamic general equilibrium model with optimizing behavior exists that satisfactorily represents our housing-monetary framework.” (Fratantoni and Schuh, 2003, page 564.). Estimation of that complex macro model still would be extraordinarily difficult. And identified VARs remain useful, although subsequent models have incorporated larger and richer information sets, high-frequency surprises, external instruments, and financial variables to identify monetary transmission (Bernanke et al., 2005; Gertler and Karadi, 2015; Stock and Watson, 2018; Caldara and Herbst, 2019; Jarociński and Karadi, 2020).²

Instead, this paper takes a first step toward an updated and expanded housing-monetary HAVAR model by re-examining and improving the macro VAR block of Fratantoni and Schuh (2003). The model is based on vector $X_t = [X_t^m \ X_t^a]'$. The macro (m) vector, $X_t^m = [P_t \ M_t \ R_t]'$, represents the aggregate price, P_t , short-term monetary interest rate, M_t , and mortgage rate, R_t , that are determined in the national market. The aggregated (a) vector $X_t^a = [Q_t \ Y_t \ H_t]'$, represents the real regional house price, Q_t , non-housing output, Y_t , and housing output (residential investment), H_t , that are determined in regional markets. The two-sector HAVAR framework is consistent with structural multi-sector models (Davis and Heathcote, 2005; Kydland et al., 2016) emphasizing housing production dynamics and time-to-build frictions, which show residential investment differs from ordinary capital and reproduce its high volatility and business cycle co-movement.

Subsequent research also uses VAR models to study monetary policy and housing from macro (Jarociński and Smets, 2008; Vargas-Silva, 2008) and regional (Del Negro and Otrok, 2007; Owyang and Wall, 2009; Furceri et al., 2019; Beraja et al., 2019; Fischer et al., 2021) perspectives. Two papers perhaps closest to the HAVAR framework are Cooper et al. (2022), which shows monetary accommodation raises state-level house-price growth more during the early-2000s in supply-constrained locations, and Chen et al. (2024), which shows that housing-market quantities (faster sales and lower inventories) amplify house-price responses to monetary easing. However, none of the VAR models impose the exact aggregation essential

²Note that VAR dynamics generally are consistent with local projections estimates (Plagborg-Møller and Wolf, 2021).

to the HAVAR model.

The remainder of this paper reports the results of a first step toward updating, revising, and expanding the FS HAVAR model by re-examining the specification of the macro VAR block. Results are reported for four key comparisons. First, we use the updated original FS macro VAR in levels (non-stationary) to compare macro-housing dynamics in the early (1966-1998) and late (1999-2019) samples consistently. Second, we use a revised FS macro VAR in rates (stationary) to compare with the dynamics of the original levels (non-stationary) specification to assess the effects of macro data transformations on the model. The rates model improves the mixed treatment of the nominal aggregate price with the real price of housing, and it resolves the collinearity between the levels of interest rates that obscured pass-through from monetary policy to liquidity-, credit-, and financial-market conditions (Iacoviello and Minetti, 2008; Cooper et al., 2025). Third, we successfully estimate a structural VAR (SVAR) specification to show the macro VAR is consistent with a basic three-variable New Keynesian model with two sectors (housing and non-housing) to compare recursive and structural identification of shocks. And fourth, we use an expanded macro VAR that includes a financial variable (loan-to-deposit ratio) and housing variables (home ownership and rent price inflation) with substantial cross-section heterogeneity to assess their suitability for the macro VAR model to set up the second step toward a new HAVAR model in the future.

Early versus late sample. Re-estimating the original FS levels VAR over the late sample reveals substantial continuity but important changes in monetary and mortgage-finance transmission. Federal funds rate shocks generally have smaller and less persistent effects on output and prices after 1998 and normalizing the shocks to the same impact change in the policy rate leaves this qualitative contrast intact. In contrast, mortgage-rate shocks have larger negative effects on housing output and prices in the late sample, suggesting a greater role for mortgage-finance conditions. Private-sector output and price shocks also produce larger and more persistent housing responses in the late sample, consistent with stronger interaction between the housing and non-housing sectors. The central FS result nevertheless survives: housing remains more responsive than non-housing activity, while the timing, persistence, and propagation of shocks change across the two periods.

Levels versus rates specification. Replacing output and price levels with sectoral output gaps and inflation rates, and replacing the mortgage rate with the mortgage spread, produces more concentrated short-run dynamics while preserving the central housing sensitivity of the FS framework. Following a contractionary policy shock, housing activity responds faster and more strongly than non-housing activity in the rates specification, while housing-price and housing-output shocks reveal substantial differences in sectoral propagation relative to the levels specification. The largest change appears in the financial block: mortgage-

spread innovations do not reproduce the dynamics of federal funds rate shocks, and the variance decomposition shows a strongly asymmetric relationship in which policy shocks account for a substantial share of spread variation while spread shocks explain little policy-rate variation. These results suggest that separating cyclical activity, sectoral inflation, and mortgage-finance conditions provides a more informative representation of short-run housing-monetary transmission than the original levels specification.

Recursive versus structural identification. An SVAR specification of the revised macro VAR is estimated successfully. The coefficients are roughly consistent with the standard New Keynesian 3-variable system of an IS curve, Phillips curve, and Taylor Rule. However, the estimates also reveals some intriguing statistically and economically significant heterogeneity in the coefficients. In particular, the 3-variable model implicitly imposes symmetry conditions on coefficients across sectors, many of which are rejected by the data. Nevertheless, the impulse responses of the SVAR model are broadly similar to those of the recursive VAR model. The main differences arise in the responses to a monetary policy shock, where the SVAR model exhibits smaller and opposite-signed responses due to the long-run restrictions.

6- versus 9-variable model. The revised macro VAR model with three new variables reveals an economically and statistically important role for the loan-to-deposit ratio, but more limited roles for home ownership and rental prices—at least at the macro (aggregate) level. Most significantly, the new variables greatly attenuate the responses of monetary policy and both sectors’ output to shocks in housing appreciation in the smaller 6-variable model. A few individual responses of the new variables have some mild interest, especially a decline in rent inflation to a shock in non-housing inflation. However, the much larger impact of these new variables is likely to emerge when extended to a HAVAR framework with state-level data.

Overall, the results in this paper offer sound evidence for the updated, revised, and expanded macro VAR model to serve as the foundation for a second step toward a new housing-monetary HAVAR model in future research. Although home ownership and rental prices are not particularly important at the macro VAR level, the heterogeneity in regional data and related prior research suggest they will likely be important for the non-linear dynamics of a HAVAR model. If so, an updated, revised, and extended HAVAR model should provide a richer assessment of the housing boom-bust and GFC, and perhaps new insights about monetary and housing policies.

2 Context and Motivation

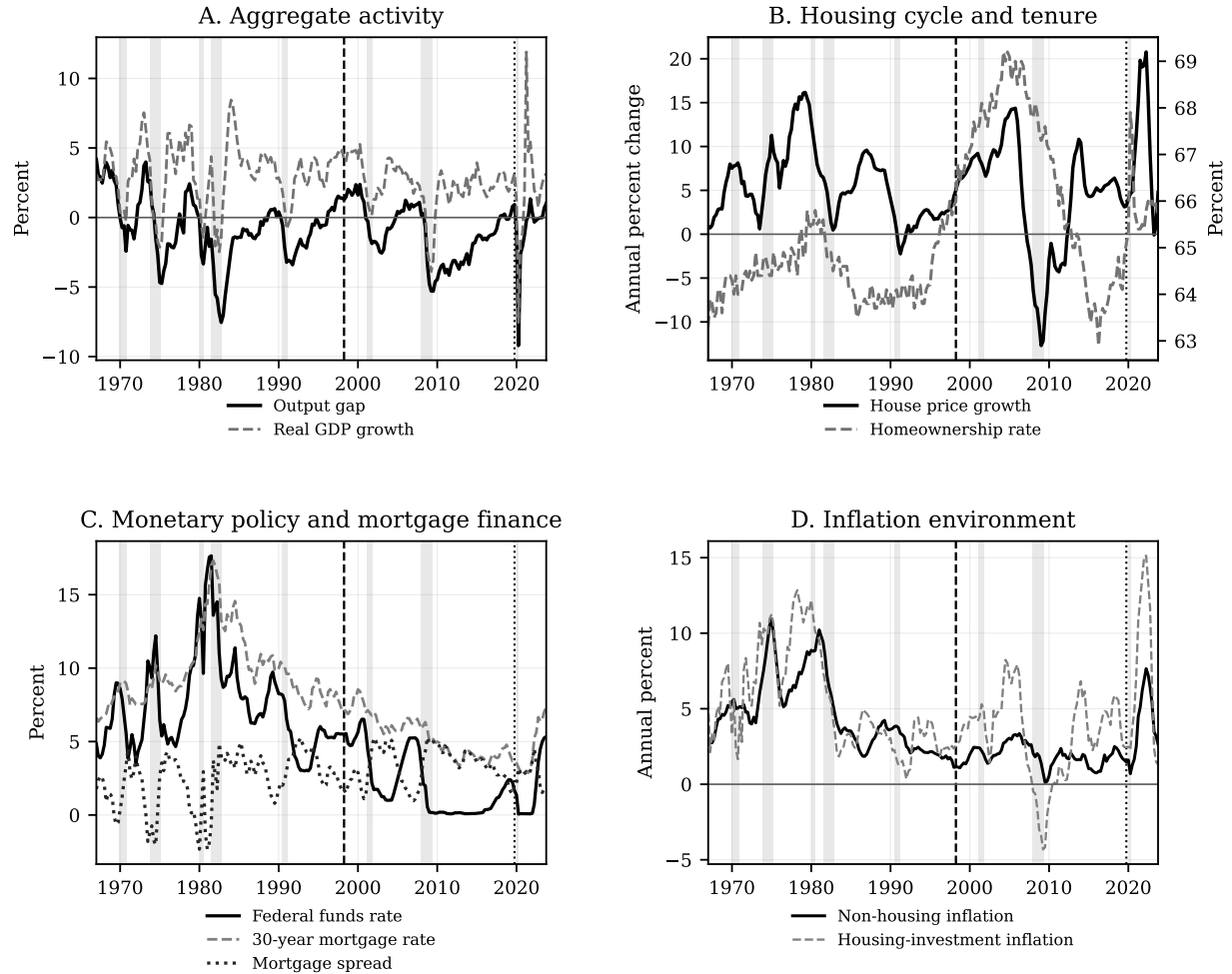
Major developments have transpired in the U.S. macroeconomy since 1998, as illustrated in Figure 1. The vertical dashed lines mark the ends of the original FS sample (1998Q2) and our estimation sample (2019Q4); shaded areas denote NBER recessions. Although some series continue beyond 2019, we exclude 2020–present from estimation to abstract from the extraordinary disruptions associated with the COVID-19 period. The recent (post-1998) period differs from the early along several key dimensions relevant to the housing-monetary macro HAVAR model: the nature of the business cycle (panel A); housing markets dynamics (panel B); financial markets, including monetary policy (panel C); and inflation (panel D). This section summarizes the macroeconomic developments that motivate and guide the revisions and expansion of the macro VAR block.

The U.S. business cycle (panel A) in the late period is characterized by lower volatility and more persistence—at least prior to 2020. The Great Moderation, which began in 1984 (McConnell and Pérez-Quirós, 2000), continued until the sharp and highly transitory recession during the COVID-19 Pandemic and recovery. Lower volatility is better seen in the growth of real GDP. Greater persistence, also called “jobless (or job-loss) recoveries”, is better seen in the output gap. The macro literature already incorporates these changes, as will the macro VARs.

The housing market (panel B) sustained relatively high and, in at least one respect, unprecedented volatility. Much attention focused on the dramatic housing boom of the early-2000s, when house prices grew 15 percent per year at their peak in 2005 for diverse reasons (Eickmeier and Hofmann, 2013; Adelino et al., 2018). House-price appreciation was similar during the 1970s for different reasons, especially the reduction in the real value of mortgage debt stemming from the persistent Great Inflation. However, housing appreciation collapsed and prices even fell during the Great Financial Crisis, whereas they did not decline after the Volker disinflation in 1980-82. Also unique to the later sample was a historically large swing in home ownership (about 5 percentage points). The regional concentration of house-price appreciation also changed—Fratantoni and Schuh (2003) focused on coastal housing booms, whereas the 2000s boom-bust was concentrated in AZ, NV, CA, and FL.

Relatedly, financial markets (panel C) also changed remarkably in two main ways. First, the housing boom was fed by large and rapid changes in banking—greater mortgage securitization and the emergence of shadow banking—and housing-related assets—sub-prime and Alt-A mortgages, mortgage-backed securities (MBS) collateralized debt obligations (CDO) and credit default swaps (CDS). Second, the collapse of these housing-related asset prices produced a liquidity crisis that pushed the fed funds rate to its zero lower bound (ZLB),

Figure 1: U.S. Macroeconomic Developments, 1966-2026



Notes: The vertical dashed line marks 1998Q2, the end of the original Fratantoni and Schuh (2003) sample. Shaded areas denote NBER recessions. The dotted vertical line marks 2019Q4, the end of our estimation sample. Series are plotted beyond 2019 for descriptive context, but the 2020–present period is excluded from estimation. The figure summarizes aggregate activity, the housing cycle, monetary policy and mortgage finance, and sectoral inflation dynamics.

prompting the Federal Reserve to adopt unconventional monetary policies (UMP).³ In particular, the ZLB alters the role of the short-term interest rate, and central balance sheet operations introduced new roles for long-term (mortgage) rates in counter-cyclical monetary policy. The shadow fed funds rate (Wu and Xia, 2016, not pictured) provides a measure of monetary policy at the ZLB but is not appropriate to use directly in VAR models (Mavroeidis, 2021). However, the shadow fed funds rate is derived from the relationship between long- and short-term rates, so the mortgage spread (mortgage rate minus fed funds rate) provides an approximate measure of the effects of UMP. In the later period, the spread is more persistent and less correlated with the fed funds rate.

Finally, inflation dynamics (panel D) changed in ways that will affect model estimation. In the early sample, both non-housing price growth (goods and services inflation) and house-price appreciation declined similarly after the 1970s, remaining positively correlated. In the later sample, however, the volatility of housing appreciation rose dramatically relative to non-housing inflation, reducing the correlation between the two price growth rates. On average, house prices appreciated faster than inflation in the later period, so real house prices increased as well.

3 Models

This section describes the three macro VAR models based on $X_t = [X_t^m \ X_t^a]'$ with the original six variables in the FS HAVAR model that are estimated and simulated. The levels (original) and rates (revised) VAR models are unrestricted and reduced-form. The SVAR model imposes some long-run restrictions consistent with the basic New Keynesian model.

3.1 Original VAR (levels)

The original VAR model specification includes the six variables of the FS monetary VAR with housing (Fratantoni and Schuh, 2003, Figure 1 p. 561) in levels:

$$X_t^{FS} = [P_t, P_t^H, Y_t^N, Y_t^H, M_t, R_t]'$$

where P_t is the aggregate price level, P_t^H is the house price, Y_t^N is non-housing output, Y_t^H is housing-related output (residential investment), M_t is the monetary policy instrument

³UMP includes large-scale asset price (LSAP) purchases held on the Fed's balance sheet (also known as Quantitative Easing, QE); interest on reserve balances (IOR); and forward guidance (FG) about future fed funds rates.

(federal funds rate), and R_t is the mortgage interest rate (30-year fixed).⁴ Prices and output are in log levels. Variables in X_t^{FS} are listed in their original FS ordering for identification via the Cholesky decomposition to facilitate replication of the model.

Specifying the VAR in levels avoids imposing explicit long-run restrictions on the non-stationary variables (prices and output), such as unit roots and co-integration. Instead, the levels specification allows the unrestricted model to estimate these relationships from the data. Thus, VARs specified in levels can remain informative in systems with unit roots and cointegration (Sims et al., 1990), but may fail to identify them exactly when they exist. Subsequent work on business-cycle measurement emphasizes that empirical transformations should match the theoretical object being studied (Canova and Paustian, 2011; Canova and Ferroni, 2011).

3.2 Revised VAR (rates)

The revised VAR retains the original six variables but transforms the non-stationary I(1) levels into stationary I(0) rates:

$$X_t^{new} = [x_t^N, x_t^H, \pi_t^N, \pi_t^H, M_t, S_t]',$$

where x_t^N and x_t^H are real sectoral output gaps, π_t^N and π_t^H are the growth of non-housing prices (inflation) and housing-investment price inflation. M_t remains the federal funds rate, but $S_t = R_t - M_t$ is the mortgage rate spread. The sectoral real output gaps are based on GDP growth contributions and thus aggregation-consistent: $x_t = x_t^N + x_t^H$. The corresponding GDP-based price indexes provide non-overlapping price measures.⁵ Variables in X_t^{new} are ordered with output gaps before growth rates of prices because the gaps are more persistent over the business cycle.

The revised specification with I(0) variables serve three purposes. First, output gaps replace log activity levels so that the real variables correspond more closely to cyclical deviations from potential. Second, inflation rates replace price levels, separating non-housing price pressure from residential-investment price pressure. Both changes eliminate the role of stochastic trends, so long-run relationships are not imposed at all (even implicitly). Third, the mortgage spread, S_t , better isolates mortgage-finance conditions not captured by the policy rate.

⁴The actual FS HAVAR model includes the real house price, $Q_t = P_t^H/P_t$, rather than P_t^H .

⁵Housing services are excluded from the VAR models because housing output is residential investment in *new* homes and thus excludes the larger stock of existing homes. This specification is necessary due to data limitations, NIPA account conventions, and the need to link housing activity directly to GDP. Rent and tenure measures also are excluded but examined later as extensions.

Both the original (levels) and revised (rates) model specifications use a recursive Cholesky decomposition to identify orthogonalized innovations in the six-variable quarterly VARs.

3.3 Structural VAR (SVAR)

We also estimate a structural VAR specification using the same core variables, lag length, and sample. This exercise does not replace the recursive benchmark. Instead, it asks whether the central housing–monetary transmission patterns are an artifact of the recursive ordering or whether they also emerge when contemporaneous relationships are disciplined by macroeconomic theory.

For both the levels and rates systems, $j \in \{FS, new\}$, the SVAR specification is

$$B_0^j X_t^j = K^j + \sum_{\ell=1}^L B_\ell^j X_{t-\ell}^j + U_t^j, \quad (1)$$

where B_0^j summarizes contemporaneous relationships, B_ℓ^j summarizes lag dynamics, K^j is a vector of constants, and U_t^j is a vector of mutually orthogonal structural innovations. Premultiplying by $(B_0^j)^{-1}$ gives the reduced-form VAR,

$$X_t^j = \Pi_0^j + \sum_{\ell=1}^L \Pi_\ell^j X_{t-\ell}^j + V_t^j, \quad (2)$$

where $\Pi_0^j = (B_0^j)^{-1} K^j$, $\Pi_\ell^j = (B_0^j)^{-1} B_\ell^j$, and $V_t^j = (B_0^j)^{-1} U_t^j$. Thus, the VAR estimates reduced-form dynamics, while the SVAR imposes long-run restrictions in B_0^j .

The 6-variable SVAR model is a disaggregated version of the simple 3-variable New Keynesian (NK) SVAR model without rational expectations and constants suppressed (e.g., Clarida et al., 2000):

$$x_t = \alpha(\pi_t - M_t) + \varepsilon_{xt} \quad (3)$$

$$\pi_t = \gamma x_t + \varepsilon_{\pi t} \quad (4)$$

$$M_t = \theta_x x_t + \theta_\pi \pi_t + \varepsilon_{Mt} \quad (5)$$

where equation (3) is the IS curve, (4) is the Phillips curve, and (5) is the Taylor Rule. Expected parameter signs are as follows: $\alpha < 0$ and $\gamma, \theta_x, \theta_\pi > 0$.

Implicitly, the 3-variable SVAR model imposes symmetry on the underlying sector-specific coefficients. The less-restricted 6-variable SVAR model decomposes the 3-variable NK model into two sectors, non-housing (N) and housing (H), and adds a mortgage-spread

equation:

$$x_t^N = \alpha^N(\pi_t^N - M_t) + \varepsilon_{xt}^N \quad (6)$$

$$x_t^H = \alpha^H(\pi_t^H - M_t) + \varepsilon_{xt}^H \quad (7)$$

$$\pi_t^N = \gamma_{\pi x}^{NN} x_t^N + \gamma_{\pi x}^{NH} x_t^H + \varepsilon_{\pi t}^N \quad (8)$$

$$\pi_t^H = \gamma_{\pi x}^{HN} x_t^N + \gamma_{\pi x}^{HH} x_t^H + \varepsilon_{\pi t}^H \quad (9)$$

$$M_t = \theta_{Mx}^N x_t^N + \theta_{Mx}^H x_t^H + \theta_{M\pi}^N \pi_t^N + \theta_{M\pi}^H \pi_t^H + \varepsilon_{Mt} \quad (10)$$

$$S_t = \rho_{Sx}^N x_t^N + \rho_{S\pi}^N \pi_t^N + \rho_{SM} M_t + \varepsilon_{St}. \quad (11)$$

where, equations (6) and (7) are components of the IS curve, and (8) and (9) are components of the Phillip curve. Equation (10) is the Taylor Rule with potentially heterogeneous effects of output and inflation.⁶ Expected parameter signs for these five equations are the same as in the 3-variable model. (11) is a new equation for the Mortgage Spread. Based on the expectations theory of the term structure, R_t and M_t should be positively correlated in the long run, but the sign of ρ_{SM} is less clear *a priori*. R_t includes term and risk premia, so S_t includes them as well. If not, proxies for term (π_t) and risk (x_t) premia may be relevant ($\rho_{Sx}, \rho_{S\pi} \neq 0$).

Imposing symmetry conditions on the parameters of the unrestricted 6-variable SVAR model reduces it to the restricted 3-variable model. The aggregate IS equation imposes a common real rate effect: $\alpha^N = \alpha^H = \alpha$. Likewise, the aggregate Phillips curve equation imposes a common sectoral output gap effect: $\gamma_{\pi x}^{NN} = \gamma_{\pi x}^{NH} = \gamma_{\pi x}^{HN} = \gamma_{\pi x}^{HH} = \gamma$. And the aggregate Taylor Rule imposes common sectoral effects in the output gap and inflation: $\theta_{Mx}^N = \theta_{Mx}^H = \theta_x$ and $\theta_{M\pi}^N = \theta_{M\pi}^H = \theta_\pi$. We test these restrictions sequentially using likelihood-ratio, Wald, and equivalence tests to identify which aggregate restrictions are inconsistent with the two-sector specification.

Suppressing the constant and lagged terms, the selected contemporaneous system after

⁶Note that (10) is not a statement of how the Fed actually, or should have, conducted monetary policy. Rather, it is an expanded rule that introduces real-world features, which the Fed may or may not have been taken into account in the setting of monetary policy. This specification enables testing of independent sectoral roles.

our analysis can be written in matrix form as

$$\begin{bmatrix} 1 & 0 & -\alpha_{x\pi}^N & 0 & \alpha_{xM}^N & 0 \\ 0 & 1 & 0 & -\alpha_{x\pi}^H & \alpha_{xM}^H & 0 \\ -\gamma^N & -\gamma^N & 1 & 0 & 0 & 0 \\ -\gamma^H & -\gamma^H & 0 & 1 & 0 & 0 \\ -\theta_{Mx}^N & -\theta_{Mx}^H & -\theta_{M\pi}^N & -\theta_{M\pi}^H & 1 & 0 \\ -\rho_{Sx}^N & 0 & -\rho_{S\pi}^N & 0 & -\rho_{SM} & 1 \end{bmatrix} \begin{bmatrix} x_t^N \\ x_t^H \\ \pi_t^N \\ \pi_t^H \\ M_t \\ S_t \end{bmatrix} = \begin{bmatrix} \varepsilon_t^{xN} \\ \varepsilon_t^{xH} \\ \varepsilon_t^{\pi N} \\ \varepsilon_t^{\pi H} \\ \varepsilon_t^M \\ \varepsilon_t^S \end{bmatrix}.$$

A just-identified six-variable system permits 15 such coefficients, so the selected specification imposes two overidentifying restrictions that can be tested against the data.

The aggregate IS relationship need not apply uniformly across sectors. Housing is particularly sensitive to financing conditions and interacts with borrowing and collateral constraints, while more generally sectors differ in their interest-rate sensitivity (Iacoviello, 2005; Kreamer, 2022). We therefore begin with the common real-rate restriction implied by the aggregate model but test whether its inflation and policy-rate coefficients can be imposed within and across the housing and non-housing sectors. This allows the data to distinguish rejection of a common real-rate relationship from rejection of cross-sector homogeneity.

The Phillips relationship may also differ across disaggregated markets. Multi-sector New Keynesian models allow differences in sectoral price adjustment to affect inflation dynamics (Aoki, 2001), while state-level evidence indicates substantial heterogeneity in Phillips-curve relationships below the national aggregate (Kumar and Orrenius, 2016; Hazell et al., 2022). We therefore allow housing and non-housing inflation to respond separately to the two output gaps before testing whether the activity coefficients can be aggregated or tied across sectors.

The policy equation follows the familiar Taylor-rule logic that the short-term policy rate responds to inflation and real economic activity (Clarida et al., 2000). We permit these responses to differ across housing and non-housing components and test whether the aggregate coefficients can be imposed. This equation is not intended as a literal description of the Federal Reserve’s operating rule, but as a parsimonious way to test whether sectoral information can be aggregated without loss. The mortgage-spread equation is motivated by the fact that mortgage borrowing costs are not a mechanical transformation of the short-term policy rate. Mortgage spreads reflect additional mortgage-market and risk components (Boyarchenko et al., 2019), while term and risk premia vary systematically with broader macroeconomic conditions (Bauer et al., 2013). We therefore initially consider activity, inflation, and the federal funds rate as potential determinants of the spread. The data leads us to select a non-housing specification due to fit.

4 Data and Diagnostics

This paper uses quarterly U.S. macroeconomic data from 1966Q1 to 2019Q4. All results are robust to a sample ending in 2007Q3 that omits the complexities of unconditional monetary policy. The split-sample comparison uses two non-overlapping windows: the original FS period, 1966Q1–1998Q2 (early sample), and the post-1998 period, 1998Q3–2019Q4 (late sample). The revised specification is estimated over the full 1966Q1–2019Q4 sample. All variables are constructed from standard U.S. macroeconomic sources, including U.S. Bureau of Economic Analysis (BEA), Bureau of Labor Statistics (BLS), Federal Reserve, Freddie Mac, Census, and Federal Deposit Insurance Corporation (FDIC) data. Appendix A has the complete data description, see Table A.1 for variable definitions, data sources, and transformations.

4.1 Variable Construction

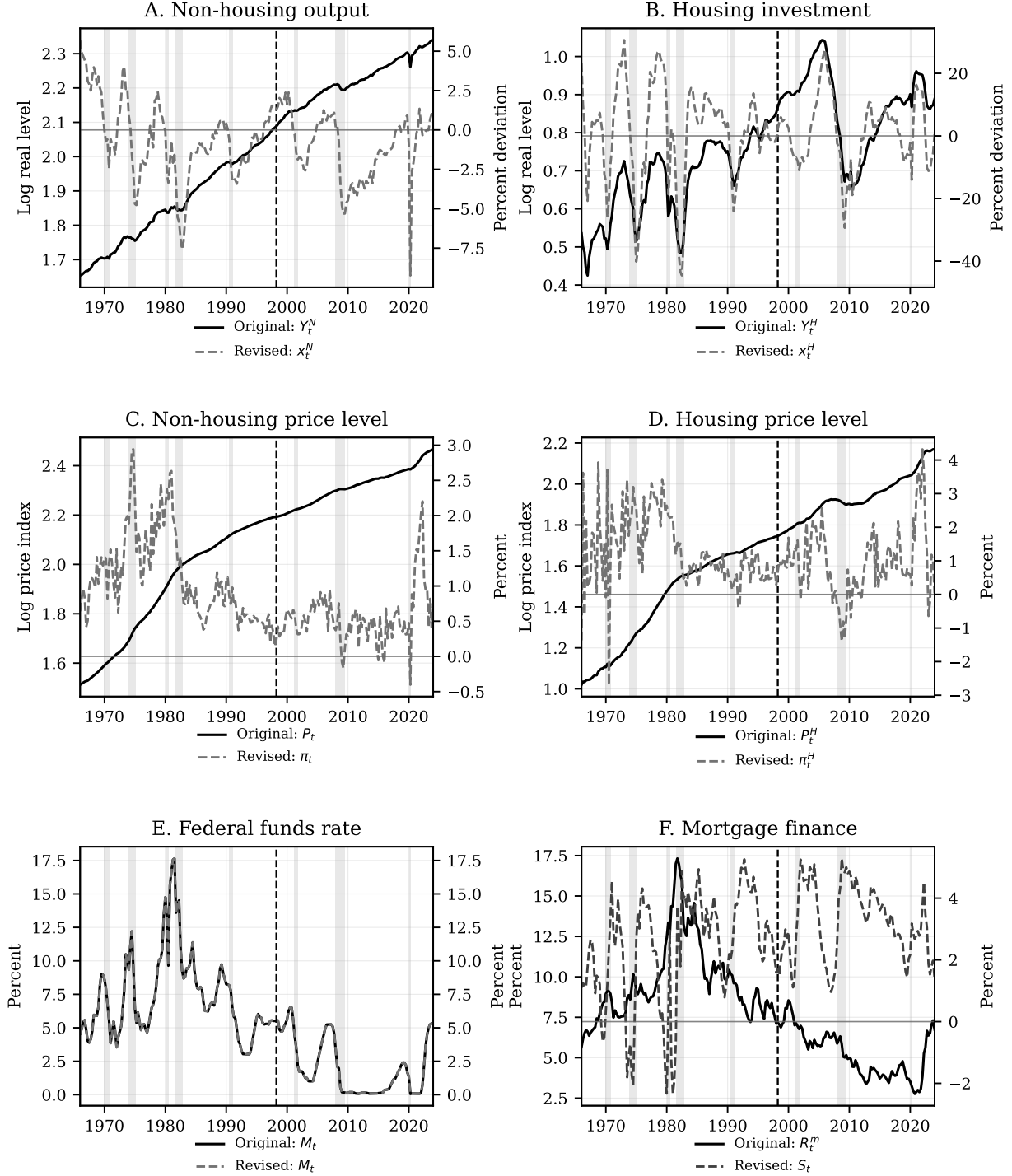
Figure 2 compares the variables entering the levels and rates specifications. The figure highlights the key measurement contrast between the two systems. The original specification uses persistent levels of output and prices, together with the federal funds rate and the mortgage rate. The revised specification preserves the same housing/non-housing architecture but measures the real, nominal, and financial blocks as stationary objects: sectoral output gaps, sectoral inflation rates, the federal funds rate, and the mortgage spread.

The revised variables are designed to better isolate short-run monetary transmission more directly. The non-housing and housing output gaps measure cyclical real activity in the two sectors. Non-housing and housing-investment inflation measure sectoral price pressure. The mortgage spread, defined as the mortgage rate less the federal funds rate, measures mortgage-finance conditions not summarized by the policy rate alone. Home ownership, rent inflation, and the loan-to-deposit ratio are introduced later as extensions that capture tenure, housing-services, and banking-sector balance-sheet margins outside the six-variable revised system.

4.2 Time-Series Properties and Model Diagnostics

Table A.2 summarizes the main time-series diagnostics. The FS level variables are highly persistent: Augmented Dickey-Fuller (ADF) tests generally fail to reject unit roots and Kwiatkowski–Phillips–Schmidt–Shin (KPSS) tests reject stationarity. Johansen tests indicate multiple long-run relationships, so the levels specification and post-1998 replication remain in levels to preserve comparability with Fratantoni and Schuh (2003); this is also

Figure 2: Levels and rates macro-housing variables (1966Q1–2024Q4)



Note: The dashed vertical line denotes 1998Q2, the end of the original sample used in Fratantoni and Schuh (2003). Shaded areas denote NBER recessions. Solid black lines plot the variables used in the original specification; dashed gray lines plot the corresponding variables used in the revised specification. The levels variables are output and price levels, the federal funds rate, and the mortgage rate. The rates variables are sectoral output gaps, sectoral inflation rates, the federal funds rate, and the mortgage spread.

consistent with inference in levels VARs with unit roots and cointegration (Sims et al., 1990).

The revised specification improves the properties most relevant for short-run analysis. Both output-gap variables reject a unit root (fail to reject stationarity), while inflation and financial variables remain persistent or yield mixed evidence. Thus, the revised system substantially reduces reliance on passive treatment of trending levels without requiring every variable to be strictly stationary.

Across specifications, two lags balance parsimony and dynamic flexibility. The estimated VARs are stable, and longer lag structures do not materially change the impulse responses. Residual autocorrelation and non-normality remain, particularly in the shorter post-1998 sample, so bootstrap confidence intervals are used for inference. Alternative recursive orderings such as reversing output and inflation, housing and non-housing activity, or the two financial variables change some impact responses but not the paper’s central conclusions.

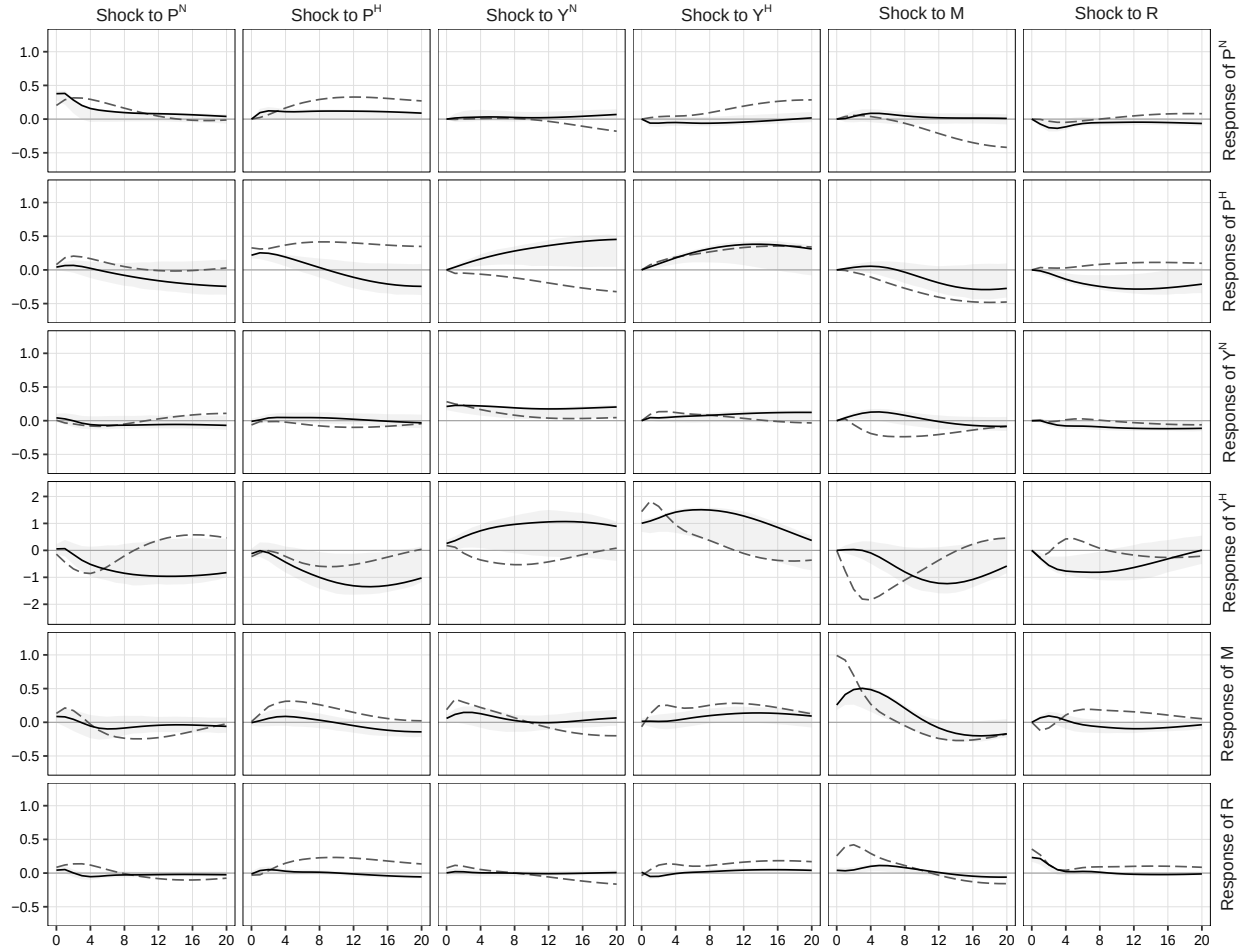
5 Early versus Late Sample

Figure 3 plots impulse response functions for the early and late samples. The split-sample comparison is designed to quantify the dynamic changes in housing and financial markets after 1998.⁷ It also provides a test of stability in the original VAR’s housing–monetary transmission mechanisms across markedly regimes and developments. Overall, the model dynamics are largely similar, with high correlations and few sign differences. However, there are some important differences that seem to reflect the new economic environment after 1998.

One important change is the effects of monetary policy on the system. Shocks to M_t generally have smaller, less persistent effects on output and prices in the later period. Most likely, this result reflects continued improvements in the conduct of monetary policy in the later sample. An important exception, however, is the response of Y_t^N , which declines slightly less and much later than in the early sample. This result may reflect a relatively slower, potentially suboptimal, response of monetary policy to the housing boom argued by Taylor (2012). Normalizing the policy shocks to have the same impact change in the federal funds rate produces the same qualitative contrast, so the difference is not driven only by shock size. Given the Great Moderation, the GFC, and the ZLB, the later federal funds rate innovation should be interpreted as evidence that the identified policy disturbance changed across regimes rather than as a literal expansionary effect of higher rates.

⁷All shocks reported within the paper are standardized to one standard deviation for comparability across specifications.

Figure 3: Impulse Responses: Early vs. Late Samples



Notes: The figure reports orthogonalized impulse responses from a VAR(2) in the log-level variables: non-housing prices P^N , housing prices P^H , non-housing output Y^N , housing investment/output Y^H , the federal funds rate M , and the mortgage rate R . The solid black line uses the late sample, 1998Q3–2019Q4, with shaded 90 percent residual-bootstrap confidence intervals based on 500 replications. The long-dashed gray line uses the early Fratantoni–Schuh sample, 1966Q1–1998Q2, without confidence intervals. Horizons are in quarters.

Another important change is related to the financial market. Shocks to R have a notably more negative effect on housing output and prices in the later period. The change is especially evident on Y_t^H , and to a somewhat lesser extent on P_t^H . Note that responses to R_t in the early period are modest and economically insignificant, suggesting the value of switching to the revised mortgage spread specification. Mortgage-rate innovations also carry more independent information after 1998, particularly for housing activity and prices. This weaker mapping from the federal funds rate to mortgage conditions motivates separating the policy rate from the mortgage spread in the rates specification. Despite the broader instability, the relative FS finding survives: housing remains more responsive than non-housing activity. Bootstrap intervals are wider in the shorter later sample, so the comparison is most informative about changes in timing, relative magnitude, and propagation.

Interestingly, the responses of M_t and R_t to shocks in output and prices of both sectors show little change between sample periods. Apparently, the influence of private-sector activity did not change its impact on policy and financial markets in a meaningful way. However, these private-sector shocks have larger, and generally more persistent, effects on Y_t^H and P_t^H . Perhaps not surprisingly, this result appears to reflect a greater interaction between housing and non-housing sectors in the late sample.

6 Levels versus Rates Specification

Figure 4 plots impulse responses to four shocks for the levels and rates model specifications.⁸ To facilitate the comparison, the levels responses are transformed to be equivalent to the stationary rates, and the mortgage rate is converted to a spread. The variable transformation comparison is designed to quantify dynamic changes over the full sample attributable to different treatments of non-stationarity. This comparison reveals more substantive difference in model dynamics across specifications of the long-run trends.⁹

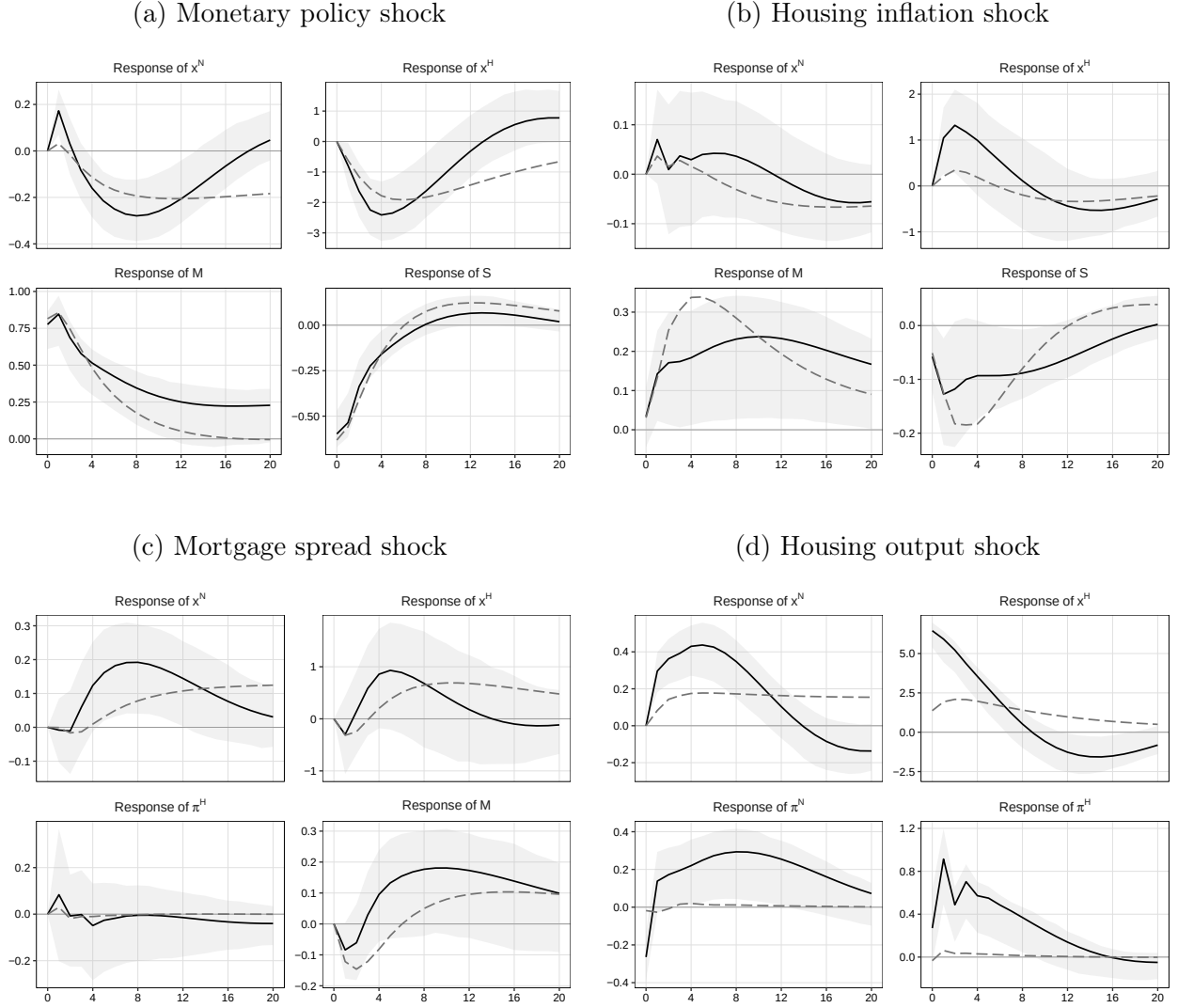
Figure 4a shows important differences in responses to a monetary policy shock. The output responses to a contractionary policy shock are similar, but responses in the rates model are faster and somewhat larger than the levels responses, suggesting the rates specification may capture short-run fluctuations better. The financial variable responses to a monetary policy shock are similar except the rates model M_t response is more persistent.

Responses to mortgage rate shocks in Figure 4c show larger differences. The mortgage spread captures a distinct financial margin rather than a conventional policy tightening.

⁸See Appendix Table A.1 for the full 6x6 set of impulse responses.

⁹Split-sample estimates of the rates specification are omitted to conserve space but do not alter the findings reported here significantly.

Figure 4: Impulse Responses: Levels vs. Rates



Notes: The solid line denotes the sectoral rates Cholesky specification, with shaded 90 percent residual-bootstrap confidence intervals based on 500 replications. The long-dashed gray line denotes the transformed full-period FS levels, 1966Q1–2019Q4, shown without confidence intervals. The transformed benchmark is ordered as Y^N , Y^H , ΔP^N , ΔP^H , M , and $S = R - M$. Horizons are in quarters.

Responses to shocks in the spread also are faster and larger in the rates specification, except for its effect on housing appreciation. In particular, the monetary policy response does not accommodate a rise in the spread nearly as much in the rates specification. Separating the mortgage rate from the policy rate via the spread is useful because mortgage-finance innovations do not simply reproduce the dynamics of a federal funds rate shock.

Figures 4b and 4d show that responses to housing shocks between the models have varied effects on the system. On one hand, housing appreciation shocks tend to have similar but more moderate impact on the rates model system, except for the response of non-housing. On the other hand, shocks to housing output produce larger and relatively faster responses in all variables. In particular, the responses of x_t^N and x_t^H are much larger and more transitory than the levels model. Likewise, housing output shocks have essentially no effect on sectoral inflation rates in the levels model, whereas they have very large positive effects on both inflation rates in the rates model. These results highlight the importance of interactions between variable transformations and sectoral heterogeneity.

6.1 Forecast Error Variance Decompositions (FEVD)

Table 2 reports the shares of forecast error variance attributable to each shock at 4-, 8-, and 16-quarter horizons. The benchmark decomposition is reported in Appendix Table A.4.

As usual, own shocks dominate real activity at short horizons, but the system becomes increasingly interconnected over time. The own-shock share of non-housing output falls from 86.0 percent at four quarters to 51.3 percent at sixteen quarters, while the corresponding share for housing output falls from 83.9 to 44.3 percent. By sixteen quarters, non-housing output shocks explain 24.1 percent of housing-output variance, and non-housing inflation shocks explain 18.7 percent. Housing activity is therefore highly cyclical but increasingly shaped by broader macroeconomic conditions beyond the first year.

The price block remains more persistent. Non-housing inflation shocks explain 65.4 percent of their own variance at sixteen quarters, while housing-inflation shocks explain 49.3 percent of housing-inflation variance. Housing inflation is nevertheless closely linked to the rest of the system: non-housing inflation shocks account for roughly one-quarter of its variance, and housing-output shocks account for 19.3 percent by sixteen quarters. This supports treating housing-investment inflation as a distinct price margin without isolating it from aggregate inflation and activity.

The financial block clarifies the direction of transmission. Federal funds rate shocks explain about one-third of mortgage-spread variance at eight and sixteen quarters, while spread shocks explain less than 3 percent of policy-rate variance. At the same time, housing-output

and non-housing-inflation shocks each explain about one-quarter of policy-rate variance by sixteen quarters. Thus, the spread contains a distinct mortgage-finance component, but the FEVD primarily shows policy and macroeconomic conditions feeding into mortgage financing rather than spread shocks driving monetary policy.

7 Recursive versus Structural Identification

This section reports the estimates of the SVAR impact matrix and compares the dynamics with the recursive identification in the VAR model.

7.1 Coefficient Estimates

Table 1 reports the final estimated coefficients and standard errors for the B_0 matrix with two over-identifying restrictions. All but one coefficient (ρ_{Sx}^N) is statistically significant and the model is not rejected by the likelihood ratio test (p-value 0.32). This final specification was obtained by following an econometric strategy that started with the least restricted specification of B_0 , and then subjectively imposed additional restrictions to obtain a data-consistent estimated model. Table A.3 reports the complete set of restriction tests and analysis.

Symmetry restrictions were mostly rejected in the IS and Phillips curve equations. All restrictions were rejected in the block of IS curve equations. The data reject a common real-rate specification: $\alpha_{x\pi}^N \neq -\alpha_{xM}^N$ and $\alpha_{x\pi}^H \neq -\alpha_{xM}^H$, instead suggesting important independent effects of π and M in each sector. Therefore, the data support retaining a sector-specific IS structure rather than the homogeneity restrictions implied by the aggregate benchmark. However, the Phillips curve block supports some symmetry conditions. A uniform coefficient γ across all sectors is rejected, but the coefficients on each sector's output gap is homogeneous within sectors: $\gamma_{\pi x}^{NN} = \gamma_{\pi x}^{NH} = \gamma^N$ and $\gamma_{\pi x}^{HN} = \gamma_{\pi x}^{HH} = \gamma^H$.

The financial variable equations also strongly rejected symmetric coefficient restrictions. In the monetary policy equation, the sector-specific output gaps and inflation rates have statistically and economically unique effects on M_t . However, the negative signs on θ_{Mx}^H and $\theta_{M\pi}^N$ are inconsistent with the standard theory of the Taylor Rule, which may reflect some mis-specification of the model (Bernanke et al., 2005; Orphanides, 2001; Clarida et al., 2000). The large positive coefficient on ρ_{SM} (0.764) suggests a deviation from the pure expectations theory of the term structure; the significant coefficient on $\rho_{S\pi}$ (-0.058) also supports that conclusion. More investigation of the financial economics roles of M_t and R_t in the model in future research appears warranted.

7.2 Model Dynamics

Figure 5 plots impulse responses for the recursive VAR and structural SVAR models to a monetary policy shock, which generates the most significant differences.¹⁰ This comparison highlights the role of long-run restrictions in the identification of structural shocks in the model. Within both identifications, the central qualitative result remains: housing is the more sensitive real-side margin following a monetary-policy innovation. This result shows that the principal housing–monetary transmission results do not depend mechanically on the recursive ordering.

In the SVAR model, monetary policy shocks exhibit three distinctly different effects. The responses of both sectors’ output gap is faster and, for housing, larger, although the gaps return to zero about the same. The responses of both sectors’ inflation is negative and economically significant instead of positive (non-housing) and roughly zero (housing). Finally, the responses of M_t and S_t are much smaller and mostly have the opposite sign.

In particular, a monetary policy shock to the recursive model raises the fed funds rate by approximately 0.78 percentage point on impact, whereas the corresponding structural innovation raises it by approximately 0.07 percentage point. Under the structural decomposition, more of the contemporaneous movement in the policy rate is attributed to systematic responses to activity and inflation, leaving a substantially smaller residual policy innovation.¹¹

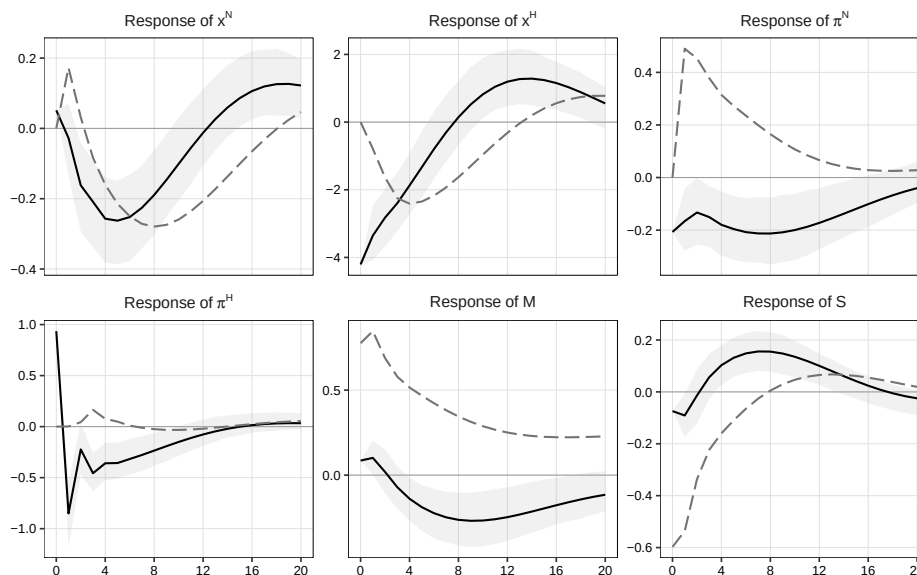
8 Six- versus Nine-Variable Models

This section introduces an extended macro VAR model with three variables absent from the original analysis: a financial variable (loan-to-deposit ratio) and two new housing variables (home ownership and rent inflation). All three variables exhibit substantial time-varying cross-section regional heterogeneity. The loan-to-deposit ratio is commonly used to proxy for bank lending conditions, complementing the mortgage spread by measuring the supply side of loans. Home ownership measures the margin between purchasing and renting, which is influenced R_t and by the relative price of houses and rental units. Minuci and Schuh (2025) documented a strong correlation between banking lending conditions and home ownership across states. Rent inflation captures housing-service costs, which may adjust differently from residential-investment prices (Dias and Duarte, 2019; Sommer et al., 2013).

¹⁰See Figure A.2 for the full 6x6 set of impulse response functions.

¹¹Recall that the shocks are one-standard deviation. A more common one-percentage-point (100 basis points) shock would require scaling the structural policy innovation by approximately 13.9 standard deviations, which is well outside the scale of the estimated structural shock. We therefore do not use such a normalization as the baseline comparison.

Figure 5: Monetary-Policy Responses: Recursive vs. Structural Identifications



Notes: The solid black line denotes the structural specification. The long-dashed gray line denotes the sectoral recursive Cholesky specification. Shaded regions are 90 percent conditional residual-bootstrap intervals for the structural model based on 500 replications; Cholesky responses are shown as point responses only. The structural model uses the spread variable $S = R - M$ and restricts the spread equation to depend contemporaneously on x^N , π^N , and M . Horizons are in quarters.

8.1 Extended Variables and State-Level Motivation

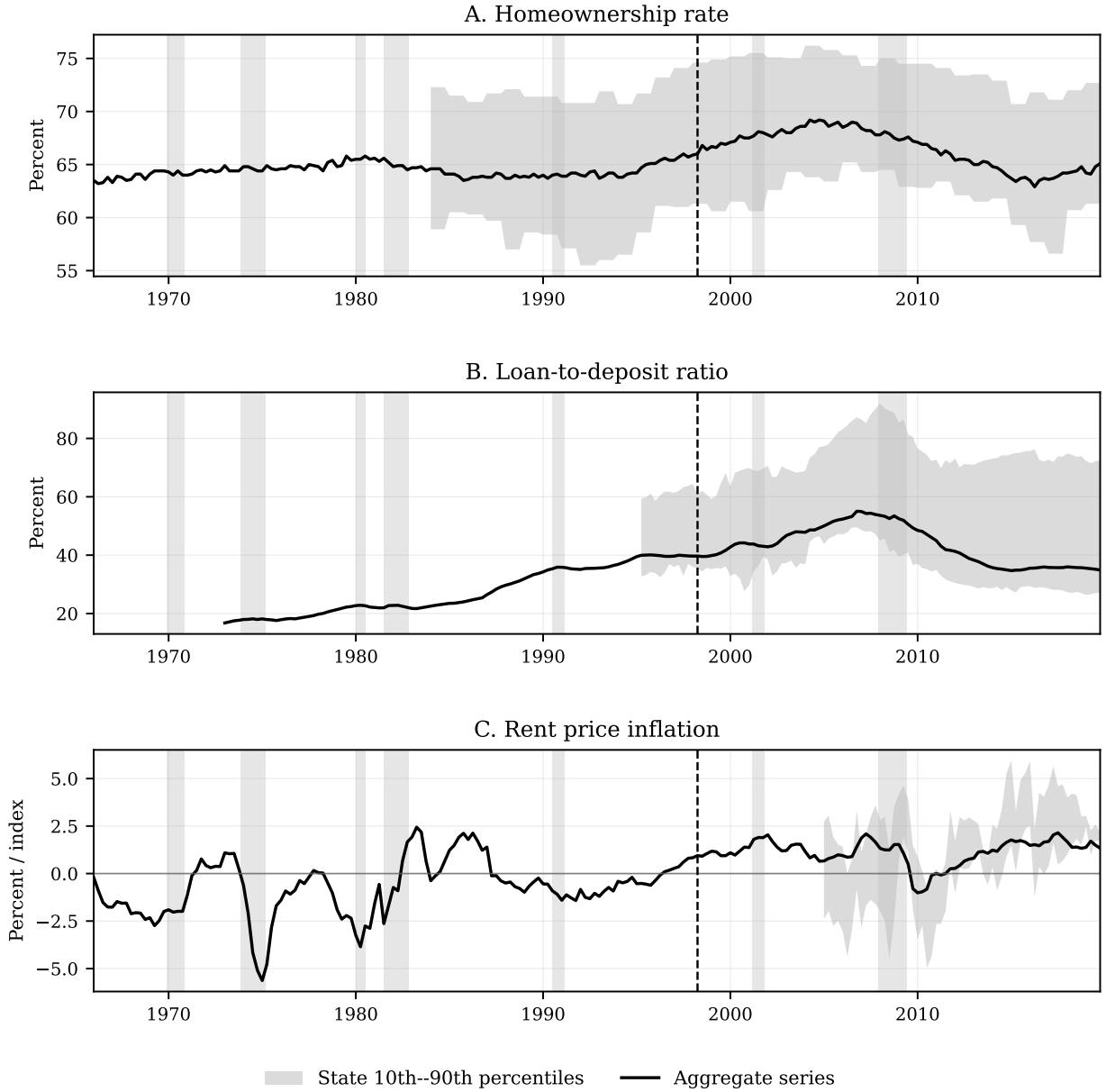
The new variables in the extended model are plotted in Figure 6. The solid black line is the national aggregate variable. The shaded gray area is the 90-10 percentile range across states that shows the high degree of cross-section heterogeneity. See Figures A.3–A.5 for the full cross-state box-plot distributions of the same concepts. The dispersion across states motivates future research that applies a full aggregation-consistent HAVAR model that includes these three additional variables.

Data for these variables are available to use in future state-level work. Home ownership maps directly from Census data, rent inflation is constructed from regional and Metropolitan Statistical Area (MSA) Consumer Price Index (CPI) rent data using population weights, and the FDIC loan-to-deposit measure is total real-estate loans relative to deposits. The rent series requires imputation and should be interpreted cautiously, while some extreme state loan-to-deposit observations reflect single-bank anomalies in small states.

8.2 Extended Model Results

We estimate the extended model to compare with the revised model specification. To facilitate comparison, we use the recursive identification approach for both the 6-variable and

Figure 6: Time series of extended model variables

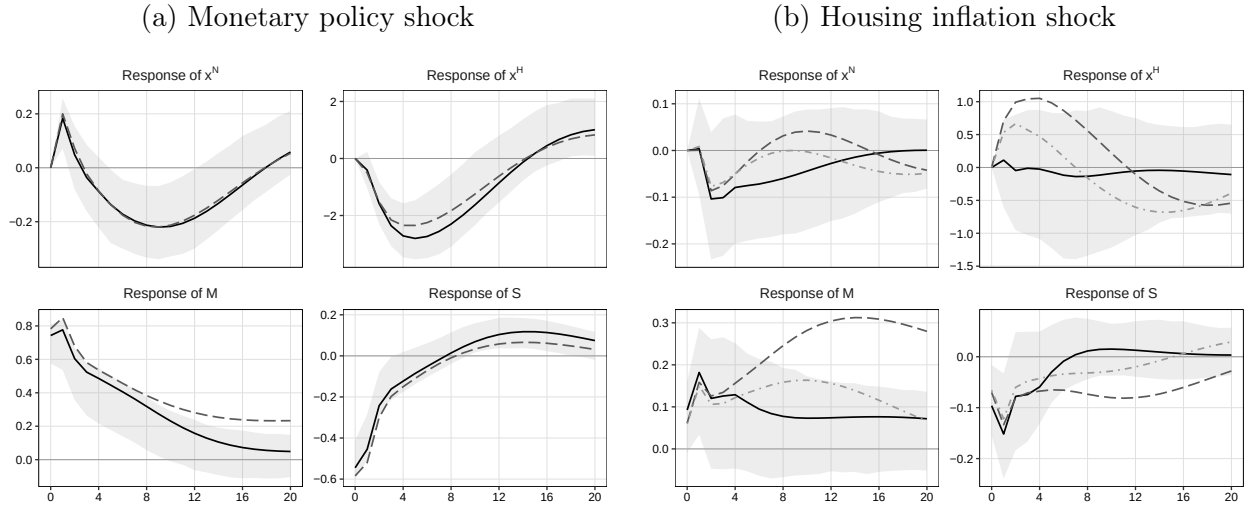


Note: The solid black line reports the national aggregate series used in the extended VAR. The light-gray band reports the cross-state 10th-90th percentile range in each period and summarizes state-level heterogeneity. The dashed vertical line denotes 1998Q2, the end of the early FS sample. State rent inflation is constructed from regional and MSA CPI rent data and should be interpreted as a mapped rent-price inflation measure. The rent series requires imputation and should be interpreted cautiously. Panel C includes a zero reference line for interpretability.

9-variable models. Home ownership is ordered first given its extreme persistence and the time involved in building, selling, and buying houses. The original six variables follow in the same order. Finally, rent inflation and the loan-to-deposit ratio are ordered last. Rent prices are presumed to move quickly, certainly more so than house prices. Banking financial market conditions are well known to experience sudden movements and crises.

Overall, the new variables in the extended model do not alter the dynamics of the original six variables significantly, so the full set of responses are not presented.¹² Instead, Figure 7 plots a selection of the least notable (monetary policy shocks) and most notable (housing appreciation shock) differences between the 6-variable and 9-variable model responses. Figure 7a shows the two models have essentially the same responses to a monetary policy shock, indicating the new variables do not alter the efficacy of monetary policy.

Figure 7: Impulse Responses: Six Variable vs. Nine Variable



Note: Solid black lines denote the full nine-variable extension with home ownership ordered first, relative rent next to last, and the loan-to-deposit ratio ordered last. Long-dashed dark-gray lines denote the core six-variable sectoral Cholesky model. Dot-dashed light-gray lines denote the loan-to-deposit extension, shown in panel (b). Shaded bands are 90 percent residual-bootstrap confidence intervals for the full nine-variable model based on 500 replications; the comparison models are shown as point responses only. The common sample is 1973Q1–2019Q4.

However, Figure 7b shows substantial differences between the responses to a housing appreciation shock. This panel contains a third response (chained line) representing a 7-variable model with only the loan-to-deposit ratio added to illustrate its marginal effects. The loan-to-deposit ratio has the largest and most significant influence on the macro VAR of the three new variables. Perhaps most interestingly, the response of the housing output gap

¹²The full set of impulse responses for the 9-variable model are available upon request.

is completely attenuated by the new variables instead of being large and positive, and the loan-to-deposit ratio accounts for about half of this change. The response of the non-housing output gap is about the same magnitude but more persistent, consistent with evidence that the systematic component of monetary policy responds endogenously to financial conditions (Caldara and Herbst, 2019). This interpretation is also consistent with models in which credit spreads or credit quantities enter the policy problem when financial frictions affect transmission (Cúrdia and Woodford, 2010). Most significantly, the response of monetary policy is much smaller and less persistent, suggesting that the Fed takes into account the endogenous response of financial conditions when setting rates (not surprisingly).

A few individual responses of the three new variables (not pictured) are worth noting briefly. The loan-to-deposit ratio responds positively to a shock to S_t and negatively to a shock to x_t^N . Both responses are sensible, marginally statistically significant, and economically meaningful. The response of home ownership to monetary policy is statistically insignificant and economically modest. This result is an example of an aggregate variable that doesn't contribute much to the macro VAR portion of the model but is expected to play an important role in the effects of regional heterogeneity on the time variation and state dependence of the aggregate responses. Curiously, rent exhibits a large and significant negative response to a shock in non-housing inflation.

9 Conclusions

This paper revisits the framework for modeling of the aggregate monetary-housing macro VAR block of the HAVAR model in Fratantoni and Schuh (2003) as a first step toward building an updated, revised, and expanded model in a future second step. The results in the paper suggest two main results.

First, the original (levels) and revised (rates) model specifications both capture well the primary developments in housing and monetary policy since 1998, but the rates specification appears to be an improvement to embrace in future research. The housing sector remains substantially more cyclically and interest sensitive than the non-housing sector, and the revised rates specification captures these developments better. An SVAR specification of the rates model is shown to be consistent with a basic New Keynesian model with two sectors, but also underscores the need for sectoral heterogeneity.

Second, the original FS macro VAR model is improved by adding additional variables to capture relevant financial and housing developments with substantial regional heterogeneity. Including the loan-to-deposit ratio captures fluctuations in mortgage lending conditions. Incorporating home ownership and rent inflation incorporate new dimensions of regional

housing markets in the macro VAR model. Thus, the evidence supports using the revised aggregate macro VAR as the national block for future housing–monetary HAVAR modeling. These new variables will add additional sources of time variation and state dependence in the aggregate responses to monetary policy and other shocks.

References

- Aastveit, K. A., Albuquerque, B., and Anundsen, A. K. (2023). Changing supply elasticities and regional housing booms. *Journal of Money, Credit and Banking*, 55(7):1749–1783.
- Adelino, M., Schoar, A., and Severino, F. (2018). The role of housing and mortgage markets in the financial crisis. *Annual Review of Financial Economics*, 10(1):25–41.
- Aoki, K. (2001). Optimal monetary policy responses to relative-price changes. *Journal of Monetary Economics*, 48(1):55–80.
- Bauer, M., Rudebusch, G. D., and Wu, J. C. (2013). Comment on ‘term premia and inflation uncertainty: Empirical evidence from an international panel dataset’. *American Economic Review, Forthcoming, Chicago Booth Research Paper*, (13-74).
- Beraja, M., Fuster, A., Hurst, E., and Vavra, J. (2019). Regional heterogeneity and the refinancing channel of monetary policy. *The Quarterly Journal of Economics*, 134(1):109–183.
- Bernanke, B. S., Boivin, J., and Elias, P. (2005). Measuring the Effects of Monetary Policy: A Factor-Augmented Vector Autoregressive (FAVAR) Approach. *The Quarterly Journal of Economics*, 120(1):387–422.
- Boyarchenko, N., Fuster, A., and Lucca, D. O. (2019). Understanding mortgage spreads. *The Review of Financial Studies*, 32(10):3799–3850.
- Caldara, D. and Herbst, E. (2019). Monetary Policy, Real Activity, and Credit Spreads: Evidence from Bayesian Proxy SVARs. *American Economic Journal: Macroeconomics*, 11(1):157–192.
- Calza, A., Monacelli, T., and Stracca, L. (2013). Housing finance and monetary policy. *Journal of the European Economic Association*, 11(S1):101–122.
- Canova, F. and Ferroni, F. (2011). Multiple filtering devices for the estimation of cyclical DSGE models. *Quantitative Economics*, 2(1):73–98.
- Canova, F. and Paustian, M. (2011). Business cycle measurement with some theory. *Journal of Monetary Economics*, 58(4):345–361.
- Chen, S.-S., Lin, T.-Y., and Wang, J.-K. (2024). Monetary Policy and Housing Market Cycles. *Macroeconomic Dynamics*, 28(8):1682–1714.

- Clarida, R., Galí, J., and Gertler, M. (2000). Monetary Policy Rules and Macroeconomic Stability: Evidence and Some Theory. *The Quarterly Journal of Economics*, 115(1):147–180.
- Cooper, D., Garga, V., and Luengo-Prado, M. J. (2025). The mortgage rate channel of monetary policy transmission: A tale of two countries. *Macroeconomic Dynamics*, 29:e163.
- Cooper, D., Luengo-Prado, M. J., and Olivei, G. P. (2022). Monetary Policy and Regional House-Price Appreciation. *International Journal of Central Banking*, 18(3):173–227.
- Cúrdia, V. and Woodford, M. (2010). Credit spreads and monetary policy. *Journal of Money, Credit and Banking*, 42(s1):3–35.
- Davis, M. A. and Heathcote, J. (2005). Housing and the business cycle. *International Economic Review*, 46(3):751–784.
- Del Negro, M. and Otrok, C. (2007). 99 luftballons: Monetary policy and the house price boom across US states. *Journal of Monetary Economics*, 54(7):1962–1985.
- Dias, D. A. and Duarte, J. B. (2019). Monetary policy, housing rents, and inflation dynamics. *Journal of Applied Econometrics*, 34(5):673–687.
- Drechsler, I., Savov, A., and Schnabl, P. (2017). The Deposits Channel of Monetary Policy. *The Quarterly Journal of Economics*, 132(4):1819–1876.
- Duncan, M. T. (2026). *Understanding Housing Market Adjustment: Evidence from Population Shocks, Regulation, and Monetary Policy*. PhD thesis, West Virginia University. Graduate Theses, Dissertations, and Problem Reports (ETD), 13263.
- Eickmeier, S. and Hofmann, B. (2013). Monetary policy, housing booms, and financial (im)balances. *Macroeconomic Dynamics*, 17(4):830–860.
- Fischer, M. M., Huber, F., Pfarrhofer, M., and Stauer-Steinnocher, P. (2021). The Dynamic Impact of Monetary Policy on Regional Housing Prices in the United States. *Real Estate Economics*, 49(4):1039–1068.
- Fratantoni, M. and Schuh, S. (2003). Monetary policy, housing, and heterogeneous regional markets. *Journal of Money, Credit and Banking*, pages 557–589.
- Furceri, D., Mazzola, F., and Pizzuto, P. (2019). Asymmetric effects of monetary policy shocks across US states. *Papers in Regional Science*, 98(5):1861–1892.
- Gertler, M. and Karadi, P. (2015). Monetary Policy Surprises, Credit Costs, and Economic Activity. *American Economic Journal: Macroeconomics*, 7(1):44–76.
- Greenwald, D. L. and Guren, A. (2025). Do credit conditions move house prices? *American Economic Review*, 115(10):3559–3596.
- Hazell, J., Herreno, J., Nakamura, E., and Steinsson, J. (2022). The slope of the Phillips curve: Evidence from US states. *The Quarterly Journal of Economics*, 137(3):1299–1344.

- Iacoviello, M. (2005). House prices, borrowing constraints, and monetary policy in the business cycle. *American Economic Review*, 95(3):739–764.
- Iacoviello, M. (2010). Housing in DSGE models: Findings and new directions. In *Housing markets in Europe: a macroeconomic perspective*, pages 3–16. Springer.
- Iacoviello, M. and Minetti, R. (2008). The credit channel of monetary policy: Evidence from the housing market. *Journal of Macroeconomics*, 30(1):69–96.
- Iacoviello, M. and Neri, S. (2010). Housing market spillovers: evidence from an estimated DSGE model. *American Economic Journal: Macroeconomics*, 2(2):125–164.
- Jarociński, M. and Karadi, P. (2020). Deconstructing Monetary Policy Surprises—The Role of Information Shocks. *American Economic Journal: Macroeconomics*, 12(2):1–43.
- Jarociński, M. and Smets, F. (2008). House prices and the stance of monetary policy. *Federal Reserve Bank of St. Louis Review*, 90(4):339–366.
- Justiniano, A., Primiceri, G. E., and Tambalotti, A. (2019). Credit supply and the housing boom. *Journal of Political Economy*, 127(3):1317–1350.
- Keys, B. J., Mukherjee, T., Seru, A., and Vig, V. (2010). Did Securitization Lead to Lax Screening? Evidence from Subprime Loans. *The Quarterly Journal of Economics*, 125(1):307–362.
- Kim, Y. and Lim, H. (2020). Transmission of monetary policy in times of high household debt. *Journal of Macroeconomics*, 63:103168.
- Kreamer, J. (2022). Sectoral heterogeneity and monetary policy. *American Economic Journal: Macroeconomics*, 14(2):123–159.
- Kumar, A. and Orrenius, P. M. (2016). A closer look at the phillips curve using state-level data. *Journal of Macroeconomics*, 47:84–102.
- Kydland, F. E., Rupert, P., and Šustek, R. (2016). Housing dynamics over the business cycle. *International Economic Review*, 57(4):1149–1177.
- Mavroeidis, S. (2021). Identification at the zero lower bound. *Econometrica*, 89(6):2855–2885.
- McConnell, M. M. and Pérez-Quirós, G. (2000). Output Fluctuations in the United States: What Has Changed Since the Early 1980s? *American Economic Review*, 90(5):1464–1476.
- Meeks, R., Nelson, B., and Alessandri, P. (2017). Shadow banks and macroeconomic instability. *Journal of Money, Credit and Banking*, 49(7):1483–1516.
- Mian, A. and Sufi, A. (2011). House prices, home equity-based borrowing, and the us household leverage crisis. *American Economic Review*, 101(5):2132–2156.

- Minuci, E. G. and Schuh, S. (2025). Are US states' banks unique? *Contemporary Economic Policy*.
- Orphanides, A. (2001). Monetary policy rules based on real-time data. *American Economic Review*, 91(4):964–985.
- Owyang, M. T. and Wall, H. J. (2009). Regional VARs and the channels of monetary policy. *Applied Economics Letters*, 16(12):1191–1194.
- Piazzesi, M. and Schneider, M. (2016). Housing and macroeconomics. NBER Working Paper 22354, National Bureau of Economic Research.
- Plagborg-Møller, M. and Wolf, C. K. (2021). Local Projections and VARs Estimate the Same Impulse Responses. *Econometrica*, 89(2):955–980.
- Sims, C. A., Stock, J. H., and Watson, M. W. (1990). Inference in Linear Time Series Models with Some Unit Roots. *Econometrica*, 58(1):113–144.
- Sommer, K., Sullivan, P., and Verbrugge, R. (2013). The Equilibrium Effect of Fundamentals on House Prices and Rents. *Journal of Monetary Economics*, 60(7):854–870.
- Stock, J. H. and Watson, M. W. (2018). Identification and Estimation of Dynamic Causal Effects in Macroeconomics Using External Instruments. *The Economic Journal*, 128(610):917–948.
- Taylor, J. B. (2012). Monetary policy rules work and discretion doesn't: A tale of two eras. *Journal of Money, Credit and Banking*, 44(6):1017–1032.
- Vargas-Silva, C. (2008). Monetary policy and the US housing market: A VAR analysis imposing sign restrictions. *Journal of Macroeconomics*, 30(3):977–990.
- Wu, J. C. and Xia, F. D. (2016). Measuring the Macroeconomic Impact of Monetary Policy at the Zero Lower Bound. *Journal of Money, Credit and Banking*, 48(2–3):253–291.

Tables

Table 1: Estimated B_0 Coefficients

Equation	x_t^N	x_t^H	π_t^N	π_t^H	M_t	S_t
x_t^N	—	—	0.150 (0.042)	—	-0.302 (0.054)	—
x_t^H	—	—	—	-10.550 (2.139)	156.153 (5.486)	—
π_t^N	-0.068 (0.010)	-0.068 (0.010)	—	—	—	—
π_t^H	0.190 (0.026)	0.190 (0.026)	—	—	—	—
M_t	0.726 (0.147)	-0.378 (0.017)	-1.753 (0.130)	0.536 (0.052)	—	—
S_t	0.022 (0.020)	—	-0.058 (0.016)	—	0.764 (0.022)	—

Notes: Entries report contemporaneous coefficients from $B_0 X_t = \varepsilon_t$ with standard errors in parentheses. Blank cells are zero restrictions. The sixth variable is the mortgage spread $S_t = R_t - M_t$. The selected spread specification restricts the spread equation to include x_t^N , π_t^N , and M_t contemporaneously.

Table 2: Forecast Error Variance Decomposition: Rates Identification

Panel A: Real activity and non-housing inflation responses									
Shock	x^N			x^H			π^N		
	4Q	8Q	16Q	4Q	8Q	16Q	4Q	8Q	16Q
Non-housing output (x^N)	86.0	66.5	51.5	5.0	18.2	24.5	2.1	2.0	2.3
Housing output (x^H)	12.0	23.5	21.2	83.7	57.3	44.2	4.6	7.9	13.4
Non-housing inflation (π^N)	0.3	1.9	13.4	2.5	10.5	18.9	74.8	71.1	66.2
Housing inflation (π^H)	0.2	0.2	0.2	2.8	2.3	2.0	1.8	3.6	5.4
Fed funds rate (M)	1.2	5.3	9.1	5.5	10.3	8.9	15.9	14.6	12.1
Mortgage spread (R)	0.1	2.3	4.3	0.2	1.2	1.1	0.5	0.5	0.4
Panel B: Housing inflation and financial responses									
Shock	π^H			M			R		
	4Q	8Q	16Q	4Q	8Q	16Q	4Q	8Q	16Q
Non-housing output (x^N)	1.6	2.6	6.5	12.9	11.7	7.5	6.5	5.4	2.7
Housing output (x^H)	13.5	18.6	19.4	8.5	16.4	26.1	8.1	13.2	20.2
Non-housing inflation (π^N)	24.4	25.7	24.4	10.1	20.8	25.1	6.5	15.9	26.3
Housing inflation (π^H)	60.0	52.7	49.3	2.5	4.0	6.3	0.9	2.7	5.4
Fed funds rate (M)	0.1	0.2	0.2	65.6	45.5	32.0	39.0	38.6	31.4
Mortgage spread (R)	<0.1	<0.1	<0.1	0.2	1.3	2.8	38.6	23.9	13.6

Notes: Entries report the percentage contribution of each orthogonalized shock to the forecast error variance at horizons of 4, 8, and 16 quarters. Rows denote shocks and column groups denote response variables. The VAR is ordered as x^N , x^H , π^N , π^H , M , and R , where R is the mortgage spread. The sample is 1966:Q1–2019:Q4 and the VAR includes two lags.

A Data Appendix

A.1 Variable Construction

This appendix summarizes the construction of the variables used in the six variable levels and rates and the nine variable specifications. The goal is to preserve the macro-housing structure in Fratantoni and Schuh (2003) while making the revised variables more closely aligned with short-run macroeconomic objects: sectoral output gaps, sectoral inflation rates, the policy rate, and mortgage-finance conditions.

The six variable levels specification approximates the aggregate macro VAR in Fratantoni and Schuh (2003). Non-housing output is constructed as real GDP excluding private residential fixed investment,

$$Y_t^N = \log \left(\frac{GDP_t - PRFI_t}{GDPDEF_t} \right), \quad (\text{A.12})$$

with the caveat that chain-weighted NIPA series are not strictly additive. Housing output, Y_t^H , is real private residential fixed investment. The price variables enter as levels: P_t is the aggregate price deflator and P_t^H is the residential investment price index. The financial variables are the federal funds rate, M_t , and the mortgage rate, R_t . The mortgage-rate series combines available Freddie Mac and FHA data to extend coverage over the full sample.

The revised specification keeps the same housing/non-housing division but changes the transformations. The real activity variables are output gaps, x_t^N and x_t^H , rather than log output levels. The nominal variables are inflation rates, π_t and π_t^H , rather than price levels. Non-housing inflation is constructed from the non-housing GDP deflator, while housing inflation is constructed from the residential investment deflator. The financial block uses the federal funds rate and the mortgage spread,

$$S_t = R_t - M_t, \quad (\text{A.13})$$

so that the final financial variable captures mortgage-finance conditions not summarized by the policy rate.

The extension variables add three margins that are not included in the six-variable revised specification. Homeownership captures tenure composition, rent inflation captures housing-service costs, and the loan-to-deposit ratio captures a quantity-side banking and credit margin. These variables are used to evaluate whether omitted housing and financial channels alter the core six-variable dynamics.

Table A.1 reports the variable definitions, data sources, and transformations used in the levels and rates specifications.

Table A.1: Levels, Rates, and Extension Variable Definitions and Data Sources

Panel A: Levels Specification (Fratantoni and Schuh, 2003)				
Variable	Notation	Source	Construction	Description
Aggregate Price Level	P_t	BEA NIPA (via FRED)	Level	Aggregate price deflator
Housing Price	P_t^H	BEA NIPA (via FRED)	Level	Residential investment price index
Non-Housing Output	Y_t^N	BEA NIPA (via FRED)	Derived	Real GDP excluding residential investment approximate decomposition
Housing Output	Y_t^H	BEA NIPA (via FRED)	Deflated	Real residential investment
Policy Rate	M_t	Federal Reserve (via FRED)	Level	Federal funds rate
Mortgage Rate	R_t	Freddie Mac + HUD (via FRED)	Level	30-year conventional mortgage rate
Panel B: Rates Specification				
Variable	Notation	Source	Construction	Description
Non-Housing Output Gap	x_t^N	BEA NIPA (via FRED)	Detrended	Non-housing output gap
Housing Output Gap	x_t^H	BEA NIPA (via FRED)	Detrended	Housing output gap
Non-Housing Inflation	π_t	BEA NIPA (via FRED)	Percent change	Non-housing GDP-deflator inflation
Housing Inflation	π_t^H	BEA NIPA (via FRED)	Percent change	Residential investment deflator inflation
Policy Rate	M_t	Federal Reserve (via FRED)	Level	Federal funds rate
Mortgage Spread	S_t	Freddie Mac + HUD (via FRED)	Difference	Mortgage rate minus federal funds rate
Panel C: Extension Variables				
Variable	Notation	Source	Construction	Description
Homeownership Rate	HO_t	Census Bureau	Level	Share of owner-occupied housing units
Rent Inflation	π_t^{rent}	BLS / regional CPI	Relative inflation	CPI rent inflation less non-housing GDP-deflator inflation
Loan-to-Deposit Ratio	LtD_t	Fed H.8 / FDIC	Ratio	Real-estate loans divided by deposits

Notes: This table summarizes the variables used in the six variable levels and rates and the nine variable VAR specifications. Output gaps are constructed using standard detrending methods. Non-housing and housing-investment inflation are constructed from corresponding GDP deflators. The rent extension is expressed relative to non-housing GDP-deflator inflation. Non-housing output is constructed as an approximate decomposition of real GDP using chain-weighted data. The national extension VAR uses the aggregate counterparts of the extension variables. State-level homeownership comes directly from Census data; state rent inflation is constructed from regional and MSA CPI rent data using population weights; and state loan-to-deposit ratios are constructed from FDIC data using real-estate loans relative to total deposits.

A.2 Diagnostics

Table A.2: Unit Root and Stationarity Tests

Variable	ADF Stat.	ADF p-val	KPSS Stat.	KPSS Null	Conclusion
<i>Panel A: Levels FS Specification</i>					
Y^N	-1.621	0.784	0.721	Rejected	I(1)
Y^H	-3.108	0.104	0.334	Rejected	I(1)
P	-0.134	0.993	1.030	Rejected	I(1)
P^H	-1.667	0.765	0.918	Rejected	I(1)
M	-1.844	0.359	2.460	Rejected	Persistent
R	-1.174	0.685	2.290	Rejected	I(1)
<i>Panel B: Rates Specification</i>					
x^N	-4.822	0.000	0.090	Not Rejected	I(0)
x^H	-4.080	0.001	0.087	Not Rejected	I(0)
π	-2.469	0.123	2.040	Rejected	Persistent
π^H	-3.818	0.003	1.210	Rejected	Mixed Evidence
M	-1.844	0.359	2.460	Rejected	Persistent
R	-3.778	0.003	0.918	Rejected	Mixed Evidence
<i>Panel C: Extension Variables</i>					
HO	-0.776	0.968	0.387	Rejected	I(1)
π^{rent}	-3.752	0.003	2.020	Rejected	Mixed Evidence
LtD	-1.594	0.487	2.740	Rejected	I(1)

Notes: ADF reports the Augmented Dickey–Fuller test statistic and MacKinnon p-value. KPSS reports the test statistic using the maximum lag selected by the Schwert criterion. Trend specifications are used for benchmark output, price level, and homeownership variables; all other variables are tested around a constant. The null hypothesis of the ADF test is a unit root, while the null hypothesis of the KPSS test is stationarity. Conclusions summarize the joint evidence from both tests.

B Structural Specification Details

This appendix reports the specification tests and numerical estimates underlying the restricted structural model discussed in Section 7. The estimation begins with a strongly restricted IS–Phillips–policy system augmented with a mortgage-rate equation and relaxes restrictions sequentially. The objective is not to select a structural specification according to its similarity to the recursive responses, but to identify which restrictions implied by a common aggregate macroeconomic structure are inconsistent with the housing and non-housing data.

Table A.3 reports the full sequence of likelihood-ratio, Wald, and fit comparisons. The tests point most strongly toward sector-specific IS and policy relationships. Common inflation and policy-rate coefficients across the two IS equations are strongly rejected, as are common sectoral responses in the policy equation. The evidence for distinct Phillips-curve slopes is weaker but remains statistically significant. With the financing variable measured

as the mortgage spread, the parsimonious spread equation is not rejected, and the final overidentified structural model is not rejected by the likelihood-ratio test against the unrestricted covariance representation.

Table A.3: Structural Specification Selection Evidence

Block	Restriction or comparison	Test	Stat. (df)	p -value	Implication
IS curves	Sector-specific versus tied IS coefficients, $\alpha_{x\pi}^N = \alpha_{x\pi}^H$ and $\alpha_{xM}^N = \alpha_{xM}^H$	LR	27.03 (2)	1.35×10^{-6}	Reject common IS coefficients.
IS curves	Joint equality of $\alpha_{x\pi}^N$ with $\alpha_{x\pi}^H$ and α_{xM}^N with α_{xM}^H	Wald	843.09 (2)	8.42×10^{-184}	Strongly reject joint equality across IS rows.
IS inflation	Free versus common/cross-sector inflation loadings in $\alpha_{x\pi}^N$ and $\alpha_{x\pi}^H$	LR	31.97 (3)	5.31×10^{-7}	Use own-sector inflation in each IS equation.
IS inflation	Equality of sectoral inflation terms in the IS block	Wald	284.59 (2)	1.59×10^{-62}	Reject tied inflation effects.
IS policy rate	Drop M from both IS equations, $\alpha_{xM}^N = \alpha_{xM}^H = 0$	LR	13.22 (1)	2.78×10^{-4}	Retain contemporaneous M .
IS policy rate	$\alpha_{xM} = 0$ in tied IS block	Wald	283.77 (1)	1.13×10^{-63}	Reject exclusion of M .
Rate choice	IS equations using M versus a long-rate alternative in α_{xM}^N and α_{xM}^H	IC	–	–	The federal funds rate fits slightly better in the IS block.
Policy rule	Sector-specific versus tied policy responses, $\theta_{Mx}^N = \theta_{Mx}^H$ and $\theta_{M\pi}^N = \theta_{M\pi}^H$	LR	14.23 (2)	8.12×10^{-4}	Allow sector-specific responses.
Policy rule	$\theta_{Mx}^N = \theta_{Mx}^H$ and $\theta_{M\pi}^N = \theta_{M\pi}^H$	Wald	147.19 (2)	1.09×10^{-32}	Reject joint equality.
Policy rule	Add contemporaneous spread to the policy rule	LR/Wald	0.00 / 0.38 (1)	0.99999 / 0.540	No evidence for adding S to the policy rule.
Phillips curves	Sector-specific versus tied Phillips block, $\gamma^N = \gamma^H$	LR	4.90 (1)	0.027	Retain sector-specific Phillips slopes.
Spread equation	Parsimonious spread row, $\rho_{Sx}^H = 0$ and $\rho_{S\pi}^H = 0$, versus row with x^H and π^H added	LR	1.79 (2)	0.409	Housing terms do not materially improve the spread equation within the maintained structural specification.
Real-rate restriction	Signed equality restrictions linking $\alpha_{x\pi}^j$ and α_{xM}^j within the IS block	Wald	25.41 (2)	3.04×10^{-6}	Estimate IS inflation and policy-rate coefficients freely.
Overall	Structural model versus recursive Cholesky	LR	2.28 (2)	0.320	Final overidentifying restrictions are not rejected.

Notes: Tests use the six-variable sectoral structural system described in the text. Parameter names follow the displayed B_0 matrix: $\alpha_{x\pi}^j$ and α_{xM}^j denote IS-curve inflation and policy-rate coefficients, γ^j denotes Phillips-curve slopes, θ_{Mx}^j and $\theta_{M\pi}^j$ denote policy-rule responses, and ρ_{Sx}^N , $\rho_{S\pi}^N$, and ρ_{SM} denote the contemporaneous spread-equation coefficients. LR tests are reported for nested comparisons where applicable. The selected spread model has objective value 8.8727, compared with 8.8621 for the unrestricted recursive covariance representation. The resulting overidentification statistic is 2.28 with two degrees of freedom ($p = 0.320$), so the final structural restrictions are not rejected. The 1.79 statistic is a nested test within the maintained structural specification: it asks whether adding x^H and π^H to the spread equation improves fit while holding the remaining structural restrictions fixed. The 2.28 statistic instead tests the complete selected structural model against the unrestricted covariance representation. Because the expanded spread model retains the other structural restrictions, the two LR statistics need not coincide.

innovation. A one-standard-deviation policy innovation moves M_t by approximately 0.078 percentage point on impact, compared with approximately 0.760 percentage point under the Cholesky decomposition. A common one-percentage-point impact normalization would therefore require scaling the structural innovation by approximately 12.8 standard deviations, so the main text reports model-specific one-standard-deviation innovations.

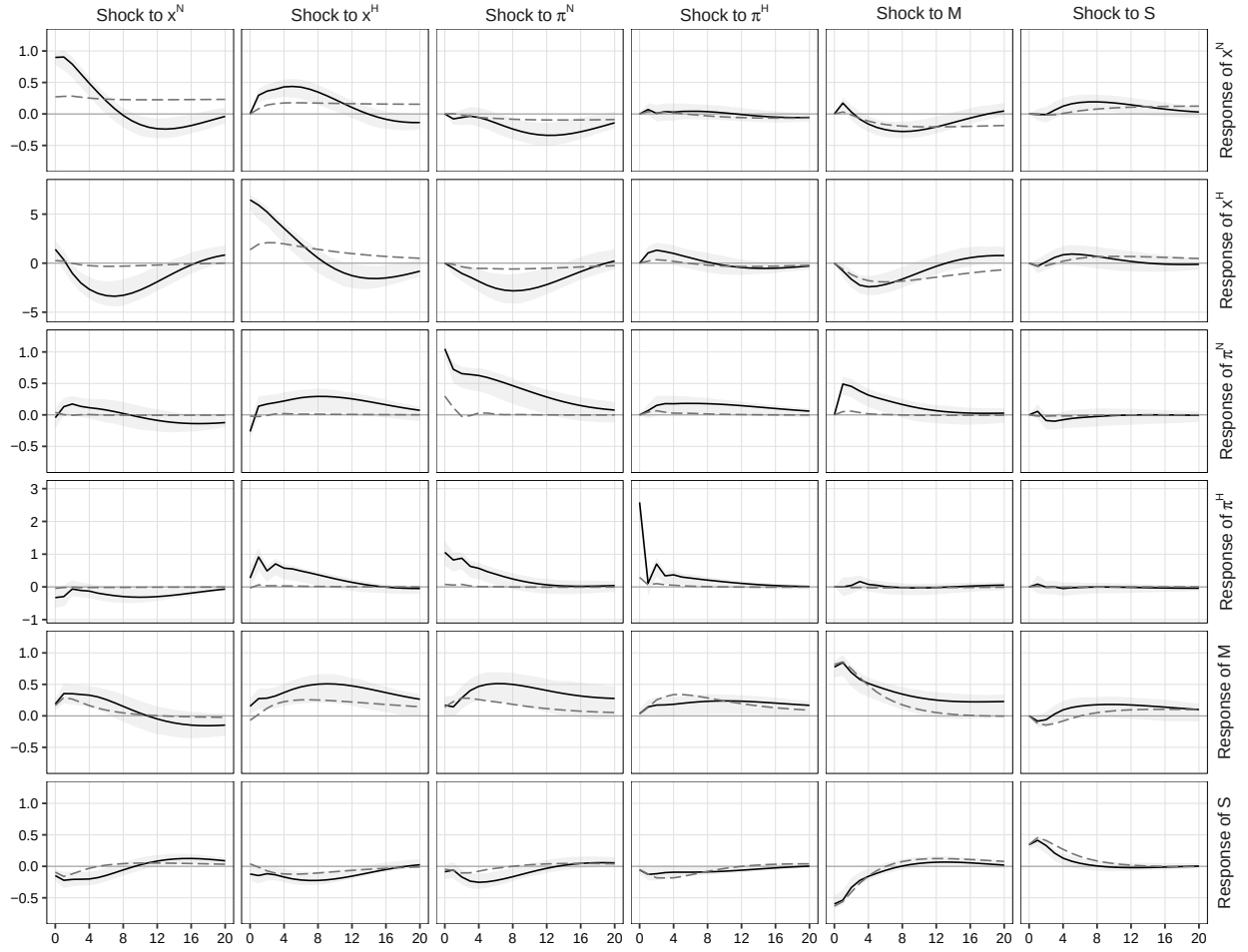
C Additional Impulse Responses

Table A.4: Forecast Error Variance Decomposition: Levels Full Period VAR

Response	P^N			P^H			Y^N			Y^H			M			R		
	4	8	16	4	8	16	4	8	16	4	8	16	4	8	16	4	8	16
p_n	92.4	81.5	66.7	2.9	8.6	20.0	0.0	0.0	0.1	0.0	0.6	4.5	2.9	4.7	3.6	1.7	4.6	5.0
p_h	10.7	8.2	4.3	80.0	72.6	60.5	0.0	0.0	0.1	9.0	17.9	28.3	0.1	1.2	6.3	0.2	0.1	0.6
y_n	0.3	1.1	1.3	1.5	0.7	0.8	80.1	56.7	37.2	13.6	18.3	15.1	3.1	22.2	45.1	1.4	1.1	0.6
y_h	0.8	1.1	1.0	0.2	0.9	4.7	0.5	0.5	0.8	76.5	59.6	48.6	20.9	36.4	42.4	1.2	1.5	2.6
m	5.5	5.2	4.4	4.2	9.8	14.5	5.8	4.9	4.2	3.3	10.3	18.5	78.8	67.3	55.6	2.4	2.5	2.9
r	11.3	12.0	9.2	2.8	12.2	25.5	2.2	1.4	1.6	1.6	4.9	10.9	45.2	47.4	37.8	37.0	22.2	15.0

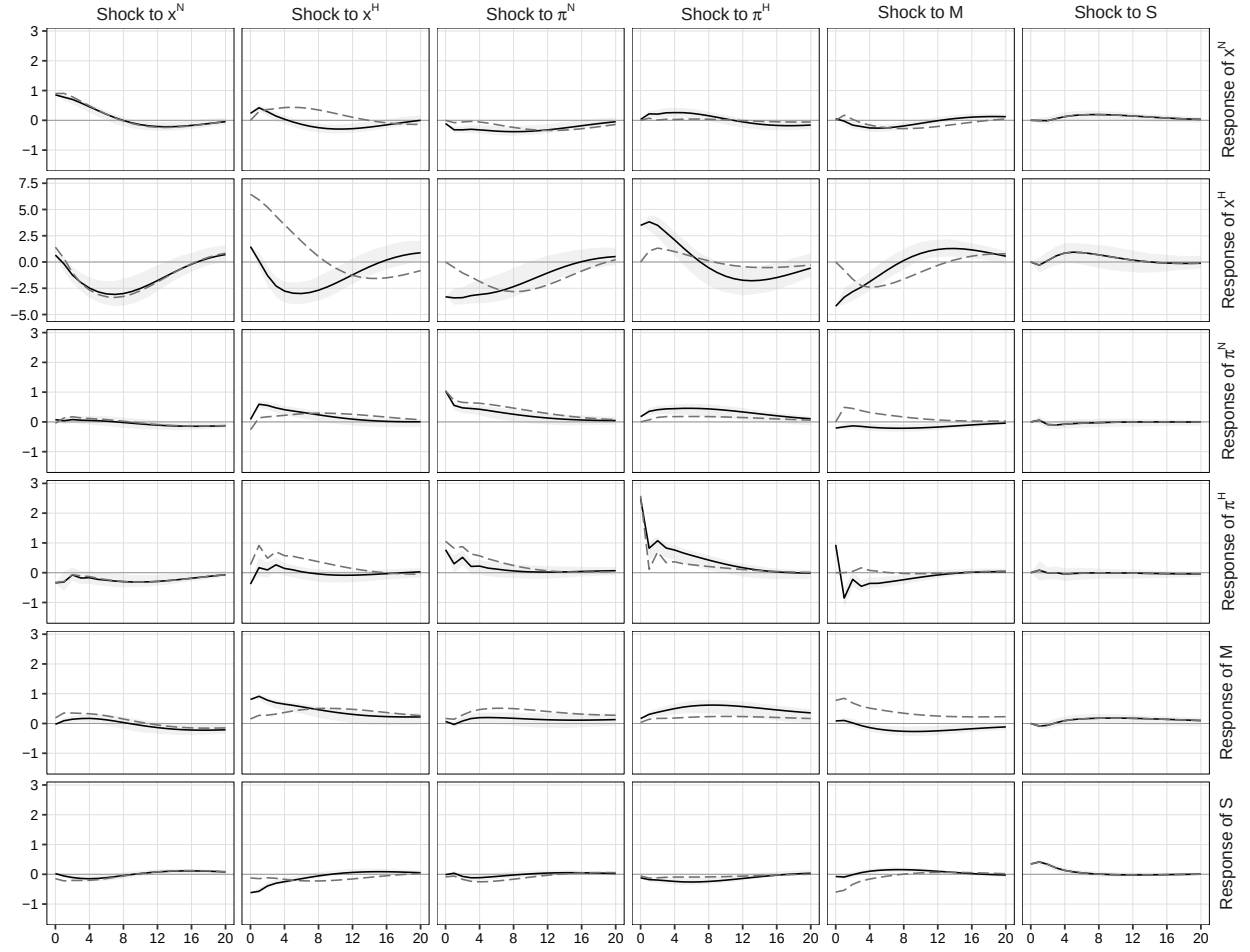
Notes: Entries report the percentage contribution of each orthogonalized shock to forecast error variance at horizons of 4, 8, and 16 quarters. Rows denote response variables and column groups denote shocks. The VAR is ordered as non-housing prices P^N , housing prices P^H , non-housing output Y^N , housing investment Y^H , the federal funds rate M , and the mortgage rate R . The sample is 1966:Q1–2019:Q4 and the VAR includes two lags.

Figure A.1: Impulse Responses: Levels vs. Rates



Notes: The solid black line denotes the updated six-variable sectoral rates specification ordered as x^N , x^H , π^N , π^H , M , and S , where $S = R - M$. Gray shaded regions are 90 percent residual-bootstrap confidence intervals for this specification based on 500 replications. The long-dashed gray line denotes the transformed full-period Fratantoni-Schuh levels specification, ordered as ΔP^N , ΔP^H , Y^N , Y^H , M , and $S = R - M$, and is shown as a point response only. The price-index variables in the transformed specification are first differenced to make them comparable to inflation rates in the rates specification. Horizons are in quarters. The updated sectoral model uses 1966Q1–2019Q4; the transformed benchmark begins in 1966Q2 because first differencing the price indexes removes the first observation.

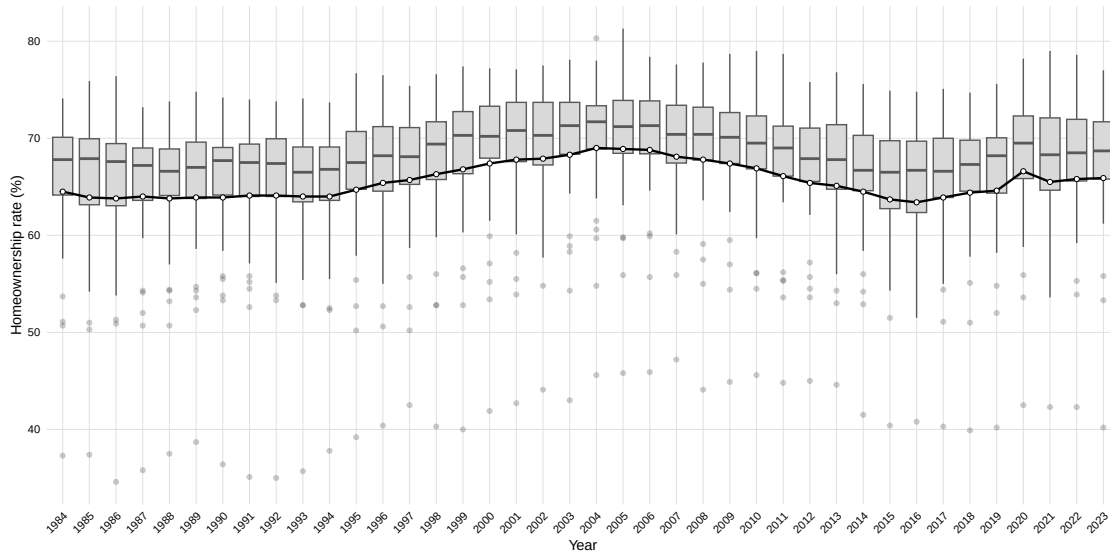
Figure A.2: Impulse Responses: Structural vs. Recursive



Notes: The figure compares the recursive Cholesky benchmark with the structural specification. The solid black line is the structural response. The long-dashed gray line is the recursive Cholesky response. The structural model imposes sector-specific IS curves, restricted Phillips curves, a sector-specific Taylor rule, and a parsimonious spread equation $S_t = \rho^{x^N} x_t^N + \rho^{\pi^N} \pi_t^N + \rho^M M_t + \varepsilon_t^S$. Shaded regions are 90 percent conditional residual-bootstrap intervals for the structural model based on 500 replications; the Cholesky response is shown without confidence bands for clarity. Horizons are in quarters. All response panels use a common vertical scale except the housing-output response, which is scaled separately.

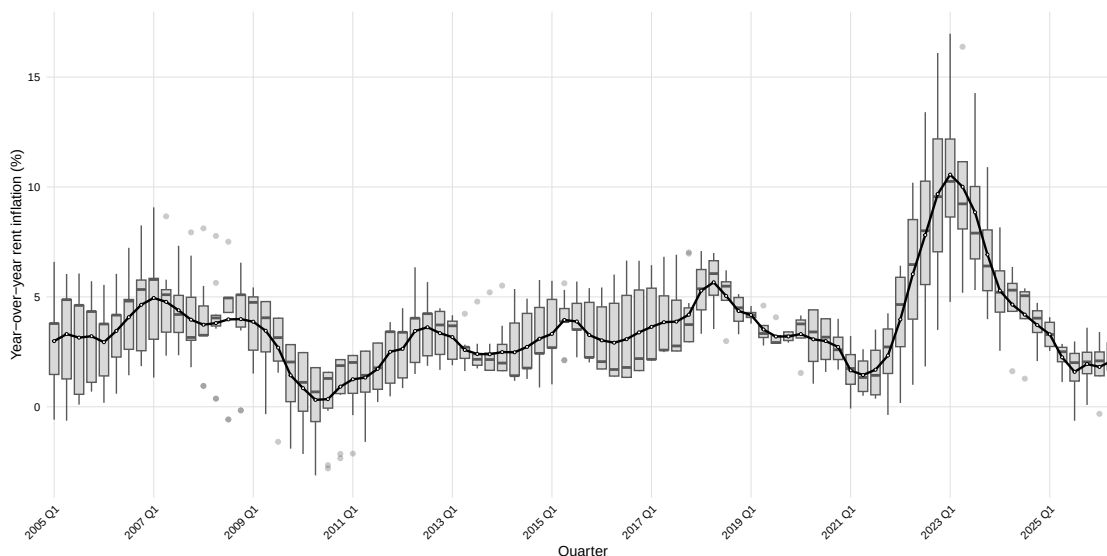
D Extensions

Figure A.3: State homeownership rates and national benchmark



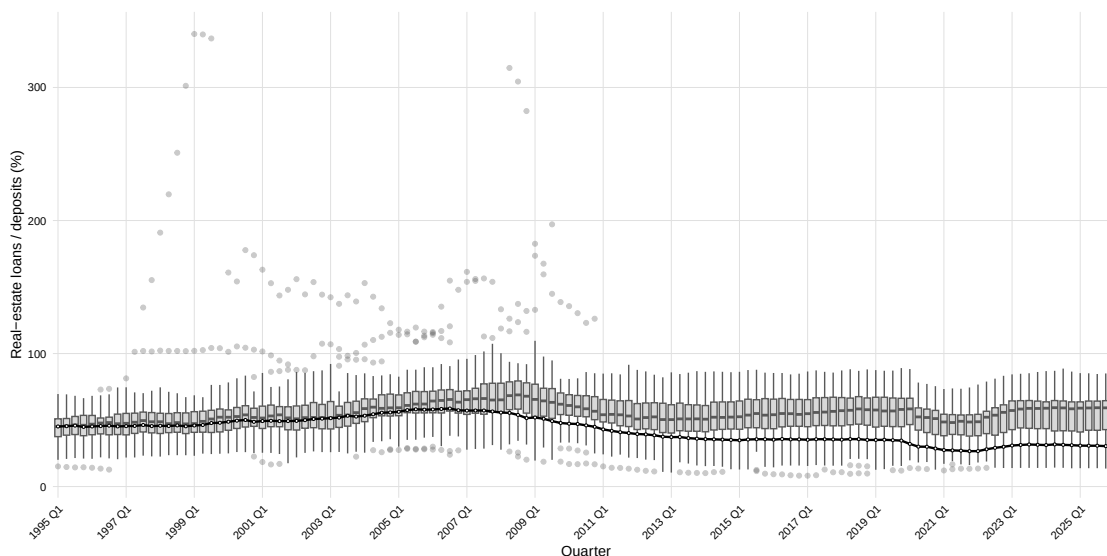
Note: Box plots summarize the cross-state distribution of homeownership rates by year. The solid black line with open-circle markers is the national homeownership rate used in the aggregate extension model. State homeownership is taken directly from Census data.

Figure A.4: State rent inflation and national benchmark



Note: Box plots summarize the cross-state distribution of the rent-based measure constructed from regional and MSA CPI rent indexes using population weights. The solid black line with open-circle markers is the average across covered state-level series. Because the state series requires imputation in a number of cases, it should be interpreted as suggestive rather than precise.

Figure A.5: State real-estate loan-to-deposit ratios and national benchmark



Note: Box plots summarize the cross-state distribution of FDIC real-estate loan-to-deposit ratios by quarter. Real-estate loans include residential, multifamily, construction, farmland, and nonfarm nonresidential loans. The solid black line with open-circle markers is the deposit-weighted national counterpart. A small number of extreme outliers are driven by single-bank anomalies in small states.