The Housing Channel of Monetary Policy*

Lu Han†

Arizona State University; University of Wisconsin-Madison

L. Rachel Ngai‡

London School of Economics

Kevin D. Sheedy§

London School of Economics

October 2026

Preliminary, please do not circulate

Abstract

This paper investigates the housing channel of monetary policy. We trace high-frequency monetary-policy shocks through short-term rates into mortgage borrowing costs and estimate how they propagate jointly across U.S. rental and ownership markets. Using new measures of buyer search and mortgage-backed market tightness, we show that higher mortgage rates reduce homeownership and loosen the ownership market: buyers purchase more quickly, sellers take longer to transact, and house prices fall. The rental market tightens instead, with faster leasing and higher rents. Active rental inventory initially falls, while new rental listings and buy-to-rent purchases rise with a lag, indicating a gradual reallocation of housing toward rental use. We rationalize these joint responses in a search model with endogenous tenure choice and investor entry. Search frictions are central to both the mechanism and its quantitative implications. Higher borrowing costs shift marginal households into rental search, tightening the rental market and raising rents through landlords' stronger bargaining position evidenced by shorter time-to-lease. Higher rents then attract buy-to-rent investors, but search delays the conversion of properties into rental use, generating the gradual supply response observed in the data. The model thus links the dynamics of market liquidity, rents, prices, and tenure reallocation through a common search mechanism.

*We thank Yi-Ting Wang and Zhengyang Gong for their excellent research assistance. We thank Jonathan Halket, Matias Vieyra and Tim McQuade for helpful discussions. We have benefited from the comments of Mark Gertler, Gianluca Benigno, Valerie Ramey and participants at AREUEA, UEA, Bank of Canada, Canadian Economics Association Annual Meeting, Conference in Honor of Nobu Kiyotaki at Princeton, De Nederlandsche Bank, SAET, T2M, and UIUC.

†Arizona State University. Email: luhan@asu.edu; University of Wisconsin-Madison. Email: lu.han@wisc.edu

‡London School of Economics, CEPR, and CfM. Email: L.Ngai@lse.ac.uk

§London School of Economics and CfM. Email: K.D.Sheedy@lse.ac.uk

1 Introduction

Housing is central to the transmission of monetary policy. It is the largest component of household expenditure, the dominant asset on household balance sheets, the main reason why households borrow, and a major component of measured inflation. The most widely studied channel of monetary policy transmission through housing emphasizes the effects on consumption due to the wealth effect, collateral effect, or the illiquid nature of housing.

The objective of this paper is to study how monetary policy affects housing markets themselves: the allocation of housing and households between owning and renting, housing costs in each market through house prices and rents, and market liquidity as households and properties are matched in the ownership and rental markets. The first two margins determine housing affordability and the distributional consequences of monetary policy. The third governs how quickly housing can be reallocated across households and tenure states, and hence the speed of housing-market adjustment. Together, they capture dimensions of monetary-policy transmission that cannot be inferred from house prices or rents alone.

The importance of these channels can be illustrated by considering a monetary tightening. Higher interest rates raise the cost of mortgages, pushing marginally constrained households from homeownership toward renting. The resulting increase in rental demand tightens the rental market and shortens the time taken to find a tenant, leading to higher rents because landlords are in a stronger bargaining position. Higher rental yields, in turn, attract new buy-to-rent investors who shift the housing stock from the ownership market to the rental market. This reallocation partly offsets the decline in owner-occupied demand, cushioning the negative effect of interest rates on house prices and market liquidity, while facilitating the movement of housing toward rental use. These responses highlight two broader implications. First, monetary tightening can place upward pressure on rents even as it lowers house prices, creating a novel housing-cost channel through which tighter policy can raise an important component of consumer-price inflation.[1] Second, the divergence between rents

[1]This housing-cost channel is different from the traditional cost channel where higher interest rate raises

and house prices has distributional consequences. Lower house prices benefit households able to purchase despite tighter credit conditions, while higher rents burden households that are in the rental market – often precisely those who struggle the most with housing affordability.

Empirically, we first establish the transmission from monetary policy to mortgage borrowing costs. Using high-frequency Bauer–Swanson monetary-policy surprises in a local-projection IV framework, we trace exogenous policy innovations through short-term interest rates into the 30-year fixed mortgage rate. We then use this induced variation in mortgage borrowing costs to estimate how monetary tightening propagates jointly across ownership and rental markets.

To trace adjustment across tenure markets, we combine granular data on mortgage credit inquiries, property transactions, MLS listing histories, investor purchase, and construction by intended tenure. This allows us to go beyond conventional measures of price and transaction volumes. We introduce two liquidity measures that, to our knowledge, have not been available in the existing literature: time-to-buy, constructed by linking a household's first mortgage inquiry - a natural marker of serious entry into the purchase process - to its eventual home purchase, and mortgage-backed market tightness, measured as a ratio of buyer search duration to seller search duration. We complement these with rich measures of tenure-specific listing flows and stocks – new and active rental listings and new and active for-sale listings – as well as measures of buy-to-rent investor entry and built-for-rent versus built-for-sale construction. Together with repeated-transaction quality-adjusted measures of rents, house prices, time-to-lease, and time-to-sell, these data allow us to distinguish demand from supply adjustment, stocks from flows, and the reallocation of existing properties across tenures from the creation of new housing supply.

The resulting impulse responses reveal a systematic reallocation of demand and liquidity across tenure markets. Following a rise in mortgage rates, homeownership falls and mortgage-backed ownership-market tightness declines; mortgage-financed buyers face less competition

the credit cost of borrowing constrained firms, whom then pass this higher cost to consumers by raising prices (Barth and Ramey, 2001).

and find homes more quickly while sellers take longer to transact. The rental market moves in the opposite direction. Units lease more quickly and rents rise even as house prices fall. This divergence indicates that tighter policy shifts housing demand from ownership toward renting rather than simply reducing demand for housing services overall.

The listing and investor responses reveal how housing supply adjusts to this shift in demand. Active rental inventory initially falls, while new rental listings rise only with a lag, indicating that rental demand tightens first and supply responds gradually. Buy-to-rent purchases increase as well, consistent with existing properties being reallocated toward rental use. Taken together, these responses show that monetary tightening does not simply contract housing demand. It changes who is searching, where they search, and how housing stock is reallocated across tenure markets.

We formalize this housing channel of monetary policy in a search-and-matching model with both rental and ownership markets with endogenous tenure choice and entry of buy-to-rent investors. Households differ in their effective cost of mortgage finance and periodically choose whether to rent or own. Home-buyers and investors both search in the ownership market to purchase properties. Properties purchased by investors are subsequently listed in the rental market awaiting match with renters. Households are subject to moving shocks, generating flows into the two markets. Investors are subject to liquidity shocks where they will exit the market by selling properties in the ownership market. House price and rents are determined by Nash Bargaining from the two sides of each market. We assume monetary policy has a direct effect on real mortgage rate, abstracting from the standard nominal rigidities mechanism.

When mortgage rates rise, marginal households shift toward the rental market, increasing rental-market tightness and reducing time-to-lease. This improves the bargaining position of landlords because they can find tenants more quickly. Because rents are determined through bilateral bargaining, the resulting change in outside options raises equilibrium rents. Higher rents, in turn, induce buy-to-rent investor entry. As investors enter, they absorb part of the

decline in household ownership demand, cushion the fall in house prices, and bring additional properties as new rental listings.

We discipline the model by calibrating the steady state of the model using evidence on homeownership, flows across and within tenure states, price-to-rent ratios, transaction times, investor participation, mortgage leverage, transaction costs, and matching elasticities. The persistence of the interest-rate shock and the duration of household liabilities are tied to their empirical counterparts, while investor-entry dynamics govern the speed of cross-tenure reallocation. The calibrated model reproduces the central findings in the data: homeownership and mortgage-financed market tightness fall; time-to-lease falls; rents rise; time-to-sell initially rises; investor participation and new rental listings increase; and house prices decline only modestly.

To evaluate the quantitative importance of search frictions in generating the rise in rent, we introduce a short run adjustment cost parameter to govern the speed for investor entry which is essential for accounting the observed response of investor entry. Shutting down this channel implies that search frictions alone can explain a substantial fraction the response in housing costs and flows within and across housing markets.

The plan of the paper is as follow. Related literature is discussed below. Section 2 present the data for empirical analysis in Section 3. Section 4 presents the model and its quantitative results are presented in Section 5. Section 6 concludes.

Related literature There is a large literature on the transmission of monetary policy through the housing market, which has traditionally focused on house prices, residential investment, and collateral constraints since early work of Aoki et al. (2004) and Iacoviello (2005). While the majority of this literature focuses on aggregate effects, there is a strand that studies the distributional impact of monetary policy via the housing market due to households' exposure to mortgage, across those with and without a mortgage (Doepke and Schneider, 2006; Cloyne et al., 2020) and across fixed-rate and adjustable-rate mortages

(Garriga et al., 2017; Auclert, 2019). This literature generally considers on the effects on consumption of housing as wealth and collateral. The focus of this paper is the decision to rent versus own. Our reallocation mechanism from own to rent and higher rents due to the tightening of monetary policy is an important for policy discussions of housing affordability and inequality since many renters are already facing rising expenditure on rent in recent decades (Ioannides and Ngai, 2025).

There is a recent empirical literature highlighting the effects of monetary policy on the rental market, rents and the homeownership rate (Gete and Reher, 2018; Dias and Duarte, 2019; Cloyne et al., 2020; Dias and Duarte, 2022; De la Roca et al., 2024; Groiss and Syrichas, 2025; Abramson et al., 2025). Building on these advances in measurement and identification, we provide a unified empirical analysis that jointly examines prices, rents, market liquidity, and buy-to-rent investor activity, allowing us to characterize the full adjustment of the housing market. These additional margins reveal a reallocation process that is not visible from rents, prices, or the homeownership rate alone.

Recent work incorporates imperfect adjustment of rental supply into New Keynesian frameworks to understand and quantify the effects of monetary policy on the allocation of the housing stock across the ownership and rental markets. Dias and Duarte (2022) and Castellanos et al. (2024) use heterogeneous-agent frameworks, while De Llanos (2026) develops a multi-agent-type DSGE model with borrowers, savers, and landlords/entrepreneurs. To explain the effects on rents, these papers build on the idea from Greenwald and Guren (2025) that the two markets are not perfectly integrated with some degree of segmentation: there is some adjustment cost to convert housing between rental and ownership market. In a nutshell, this segmentation approach generates effects on rents through there being an upward-sloping rental supply curve.[2] Our approach is complementary but provides a more

[2]This slow adjustment also features in the intuition provided by De la Roca et al. (2024) in explaining their empirical findings on rent. They suggest that mortgage lock-in, arising from the limited portability of long-duration U.S. mortgages, may spill over to rental markets. Reduced mobility in the ownership market can keep would-be buyers in the rental sector, placing upward pressure on rents when the housing stock adjusts only gradually.

directly measurable foundation for this sluggish reallocation. Search frictions themselves slow adjustment across tenure markets. When higher borrowing costs shift households toward renting, rental-market tightness rises and time-to-lease falls; in a search environment with bilateral bargaining, this strengthens landlords' bargaining position and raises rents. At the same time, investors cannot instantaneously expand rental supply: they must search for suitable properties, deploy capital, underwrite and complete transactions, and then bring those properties to the rental market. These search frictions therefore generate gradual investor entry and rental-supply adjustment even without an additional reduced-form conversion cost. Importantly, the relevant frictions can be disciplined directly by observed transaction durations. Our data measure time-to-buy, time-to-sell, and time-to-lease, allowing us to quantify matching frictions on both sides of the ownership market and in the rental market. In particular, time-to-buy provides an empirical counterpart to the time required for buyers—including investors—to locate and acquire suitable properties, while time-to-sell and time-to-lease discipline the corresponding matching processes on the seller and rental sides. This provides a measurable foundation for the adjustment friction, rather than inferring it solely from relative price and quantity responses. We nevertheless allow for an additional residual adjustment cost in the quantitative model, enabling us to assess how much of the observed dynamics in rents, investor entry, and rental-supply expansion can be accounted for by measured search frictions and how much requires other sources of sluggish reallocation.

The use of search-and-matching models to study frictions in the housing market is long established, going back to Wheaton (1990). But there are only a handful of papers that consider both rental and ownership markets jointly (Halket and Pignatti, 2015; Ioannides and Zabel, 2019; Bo, 2026), and even fewer that are disciplined by data on search frictions in the two markets. This paper builds on the model developed in Han et al. (2026) in the context of analysing transaction taxes. Here, the model is used to study housing reallocation due to monetary policy shocks that have a large impact on market tightness, which is a key margin in search models in generating effects on liquidity and prices. The quantitative

predictions of the model are compared to data on market liquidity.

2 Data

Our analysis combines multiple data sources to construct a high-frequency panel of housing-market outcomes, mortgage inquiries, investor activity, and tenure-specific construction, along with monetary-policy shocks.

Interest Rates and Credit Conditions

To characterize monetary policy and mortgage credit conditions, we combine interest-rate series from Federal Reserve Economic Data (FRED) with high-frequency monetary policy surprises. Our primary borrowing-cost measure is the 30-year fixed mortgage rate. To isolate exogenous variation in monetary policy, we use the monetary policy surprises from Bauer and Swanson (2023), which are constructed from high-frequency financial-market movements around Federal Open Market Committee (FOMC) announcements and orthogonalized with respect to pre-announcement macroeconomic and financial information. These shocks capture the unexpected component of policy changes and provide an exogenous variation for movements in mortgage rates.

Ownership Market Data

We use Cotality, formerly CoreLogic, to construct measures of owner-occupied housing-market activity, liquidity, investor participation, and market tightness. Cotality combines Multiple Listing Service (MLS) records, property transaction records, and historical property characteristics. The MLS records provide detailed for-sale listing histories, including listing price, listing date, closing date, sale price, and a unique property identifier. The transaction records report sale dates, buyer mailing addresses, and corporate identifiers. The historical property files provide time-varying property characteristics, including tax year, year built,

number of rooms, bathrooms, square footage, and other housing attributes.

We use the for-sale MLS records to measure owner-occupied market liquidity. Time-to-sell is defined as the number of days between the listing date and the completed sale date. We use property identifiers and historical property characteristics to construct repeated-property and hedonic quality-adjusted measures of time on market, so that changes in liquidity are not driven by shifts in the composition of listed homes.

Finally, following Abramson et al. (2025), we classify a buyer as a buy-to-rent investor when the buyer's mailing address differs from the purchased property's address; owner-occupiers are identified when the two addresses coincide. This investor measure includes both individual investors and corporate buyers. We also separately identify corporate buyers using Cotality deeds records, providing a narrower measure of investor activity.

Rental Market Data

We measure rental-market conditions using two complementary sources. The first is rental listing data from Altos Research, which compiles a national database of rental listings from online platforms and Multiple Listing Services. The data are observed at weekly frequency and contain listed rents, property characteristics such as bedrooms, bathrooms, square footage, and year built, as well as geographic identifiers. We use the high-frequency, ZIP-code-level repeated-rent index constructed from the Altos data by Abramson et al. (2025). The index compares rents for the same unit over time and therefore controls for time-invariant unit quality. Relative to traditional survey-based measures such as CPI rent, listing-based repeated-rent indices capture rents faced by new tenants and respond more quickly to changes in market conditions.

The second source is the rental MLS data from Cotality, formerly CoreLogic, which we use to measure rental-market liquidity and listing flows. The MLS records provide detailed listing histories, including listing date, closing or off-market date, listing price, property identifiers, and property characteristics. We define time-to-lease as the number of days

between the rental listing date and the date on which the property is leased. This provides a disciplined transaction-based measure of marketing time for completed leases, because MLS listings are typically managed by real estate professionals and closed as part of the leasing workflow. By contrast, many online rental listing data, including Altos, measure listing duration as the time between the first and last date on which a listing is observed. That measure is less well suited for time-to-lease because online listings may remain posted after the unit has effectively been rented, especially when individual landlords fail to update or remove listings promptly. Similarly, we construct quality-adjusted time-to-lease measures using repeated observations of the same property from the Cotality historical property data.

We also use the Cotality MLS records to measure rental listing flows. Active rental listings are defined as the stock of listings available in a ZIP code-month. New rental listings measure the flow of properties beginning a new marketing spell. We classify a listing as new if it has not appeared before the current listing began. This measure captures units newly offered for rent, including both newly built rental units and existing owner-occupied properties converted to rental use. Importantly, new rental listings include all newly listed units, regardless of whether they are eventually leased.

Credit Bureau Data (Experian)

We use consumer credit bureau data from Experian to observe mortgage-related credit inquiries at the individual level. The records allow us to identify the timing of mortgage inquiries and to follow consumers through the mortgage-shopping process. We link these inquiry histories to completed property transactions in Cotality, which allows us to measure buyer-side search and transaction duration—an object that is generally unobserved in housing-market data. We use the linked data to construct time-to-buy and, together with seller time-on-market from the MLS, mortgage-backed housing-market tightness at the county-quarter level.

For mortgage-financed households that can be matched to a completed home purchase,

we define *time-to-buy* as the number of days between the household's first mortgage-related credit inquiry and the subsequent property transaction recorded in Cotality. We interpret the first inquiry as a proxy for the beginning of serious home search. In the U.S., mortgage qualification and housing search are closely linked: buyers commonly obtain prequalification or preapproval as they begin searching seriously for a home.[3] Although the first inquiry need not coincide exactly with the first property viewed, it provides a consistently observed marker of entry into the mortgage-financed purchase process. Time-to-buy therefore captures the broader duration of home purchase, including housing search, financing, and contracting.

We construct the corresponding seller-side measure, *time-to-sell*, from the Cotality MLS data as the duration between a property's initial listing date and its subsequent transaction date. We similarly aggregate this measure to the county-quarter level using the median listing duration. Together, these two duration measures allow us to characterize market tightness without directly observing the complete stocks of potential buyers and sellers.

Following the search-and-matching framework of Genesove and Han (2012), we define mortgage-backed owner-market tightness as

$$\theta_{ct} = \frac{\widetilde{T}_{ct}^{B}}{\widetilde{T}_{ct}^{S}},$$

where $\widetilde{T}_{ct}^{,B}$ is median time-to-buy and $\widetilde{T}_{ct}^{,S}$ is median time-to-sell in county c and quarter t. In a stationary matching market, search durations are inversely related to transaction hazards. Because buyers and sellers exit the market in matched pairs, the relative duration of buyer and seller search reveals the relative stocks of buyers and sellers. Thus, a larger θ_{ct} corresponds to a tighter market: buyers spend more time searching relative to the time required for sellers to find a buyer, consistent with greater buyer demand per seller.

Our measure differs from a standard duration-based buyer–seller ratio (e.g., Genesove

[3]The National Association of REALTORS (2025) reports that 88 percent of home buyers purchase through a real estate agent or broker. The Consumer Financial Protection Bureau notes that many households are asked by their agents to obtain mortgage preapproval when they are ready to begin shopping seriously for a home and that preapproval signals to sellers that the household is a serious buyer with likely access to financing.

and Han (2012)) in two respects. First, the buyer side is identified through mortgage-related credit inquiries and therefore excludes buyers who do not require mortgage financing, most notably cash buyers. We accordingly refer to θ_{ct} as *mortgage-backed market tightness*. Persistent differences in the prevalence of cash purchases across locations and common changes over time are absorbed by location and time fixed effects in our empirical specifications. Second, our time-to-buy measure begins with the first mortgage inquiry and therefore encompasses not only housing search but also financing and contracting. We view this broader duration as economically relevant for mortgage-financed buyers, while recognizing that it need not correspond exactly to pure physical search time.

New Construction

We measure new construction using the U.S. Census Bureau's *New Privately Owned Housing Units Started and Completed by Purpose and Design* data, available at the quarterly regional level for the Northeast, Midwest, South, and West. The dataset reports the number of newly started housing units by construction purpose, including built-for-sale single-family units, contractor-built single-family units, owner-built single-family units, and built-for-rent multifamily units.[4] We use these series as proxies for the flow supply of new housing entering local markets and merge them with our region-quarter panel.

[4]Definitions follow the U.S. Census Bureau's *Survey of Construction Definitions*. https://www.census.gov/construction/soc/definitions.html *Built-for-rent* units are houses constructed on a builder's land with the intention of renting the unit, including lease-purchase and continuing-care arrangements. *Built-for-sale* units are houses constructed on a builder's land with the intention of selling both the structure and land in a fee-simple transaction; this category also includes condominiums, cooperative projects, and time-sharing arrangements. These definitions allow us to distinguish between different channels of housing supply adjustment, including speculative construction, rental-oriented development, and owner-directed construction activity.

3 Empirical Analysis

3.1 Pass-Through from Monetary Policy to Mortgage Rates

We begin by establishing the pass-through from monetary policy to mortgage borrowing costs. A large literature shows that contractionary monetary policy shocks, once purged of central-bank information effects, raise Treasury yields across maturities and tighten financial conditions (Nakamura and Steinsson, 2018; Jarociński and Karadi, 2020; Miranda-Agrippino and Ricco, 2021). Building on this literature, we trace monetary transmission to mortgage rates in three steps: from the policy rate to the 1-year Treasury rate, from the 1-year Treasury rate to the 30-year fixed mortgage rate, and directly from the policy rate to the mortgage rate.

For each horizon h, we estimate impulse responses using the local projection instrumental-variables (LP-IV) approach of Jordà (2005):

$$\Delta^{(h)}\text{Treasury}_{t+h} = \beta_1^{(h)}\Delta\text{EFFR}_t + \Gamma_1^{(h)}X_{t-1} + u_{1,t+h}, \tag{1}$$

$$\Delta^{(h)}\text{MortgageRate}_{t+h} = \beta_2^{(h)}\Delta\text{Treasury}_t + \Gamma_2^{(h)}X_{t-1} + u_{2,t+h}, \tag{2}$$

$$\Delta^{(h)}\text{MortgageRate}_{t+h} = \beta_3^{(h)}\Delta\text{EFFR}_t + \Gamma_3^{(h)}X_{t-1} + u_{3,t+h}. \tag{3}$$

Here, $\Delta^{(h)}Z_{t+h} \equiv Z_{t+h} - Z_{t-1}$ denotes the cumulative change in Z through horizon h, while ΔEFFR_t and $\Delta\text{Treasury}_t$ denote contemporaneous changes in the policy rate and the 1-year Treasury rate, respectively. The control vector X_{t-1} includes four lags of the monthly change in the policy rate, one lag of the change in the national unemployment rate, one lag of year-over-year core PCE inflation, one lag of the relevant policy variable, and twelve lags of the change in the dependent variable. Estimation is conducted monthly over the pre-COVID sample.

Because the effective federal funds rate is constrained by the zero lower bound for a substantial part of the sample, we use the Wu and Xia (2016) shadow federal funds rate as our measure of the monetary-policy stance. Shadow-rate measures provide a continuous

policy-rate series when the observed federal funds rate is near zero and are widely used in such settings (Kim and Singleton, 2012; Bauer and Rudebusch, 2016; Bullard, 2012; Krippner, 2013). To isolate exogenous monetary-policy variation, we instrument changes in the shadow federal funds rate in equations (1) and (3), and changes in the 1-year Treasury rate in equation (2), using the high-frequency monetary-policy shocks of Bauer and Swanson (2023). Throughout, impulse responses are scaled to a 25-basis-point increase in the corresponding right-hand-side variable.

Figure 1 shows substantial pass-through to mortgage borrowing costs. Panel (a) indicates that a 25-basis-point increase in the Wu–Xia shadow rate raises the 1-year Treasury rate by about 60 basis points on impact. Panel (c) shows that a 25-basis-point increase in the 1-year Treasury rate raises the 30-year fixed mortgage rate by about 20 basis points. Combining the two estimates implies that a 25-basis-point increase in the shadow rate raises the mortgage rate by approximately $20 \times \frac{60}{25} = 48$ basis points, closely matching the direct estimate in Panel (d).

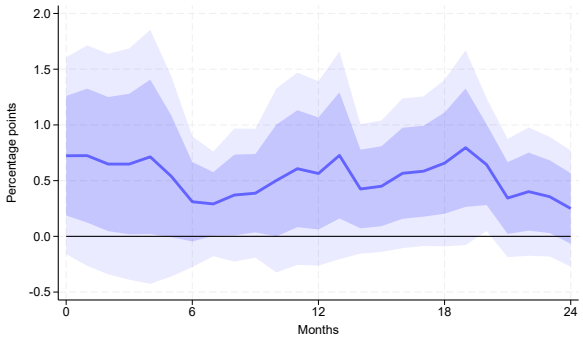
These results establish the first link in the housing transmission mechanism: contractionary monetary policy raises mortgage borrowing costs, providing the source of credit tightening whose effects on ownership and rental markets we examine next.

3.2 Pass-Through to Housing Markets

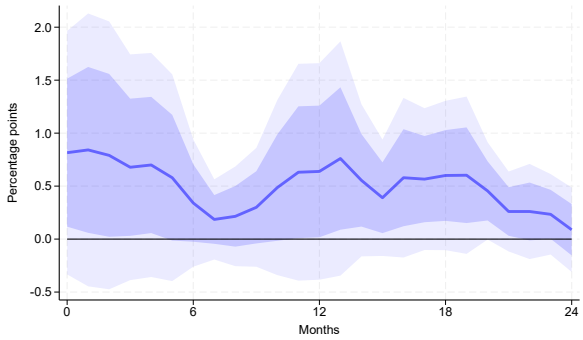
Having established that contractionary monetary policy raises mortgage borrowing costs, we now examine how this shock propagates across ownership and rental markets. We focus on the pre-pandemic period, avoiding both the exceptional housing-market conditions of 2020 and the break in the availability of the orthogonalized Bauer–Swanson shock during that year. For each outcome and horizon h, we estimate a local-projection instrumental-variables specification of the form

$$\Delta^{(h)} Y_{i,t+h} = \beta^{(h)} \Delta m_t + \Gamma^{(h)} X_{i,t-1} + \lambda_{i \times s(t-1)} + u_{i,t+h}, \tag{4}$$

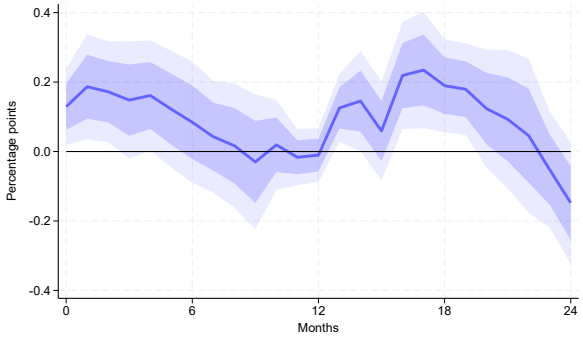
Figure 1: *Impulse Responses of Interest Rates to a Monetary Policy Shock*



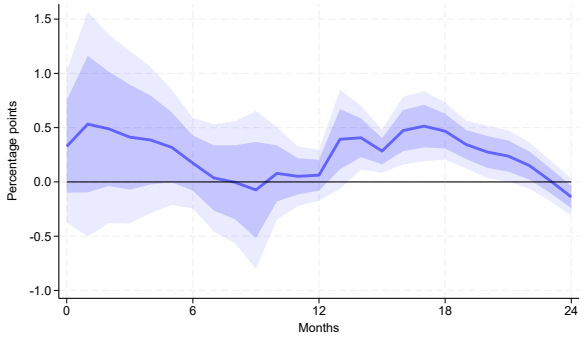
(a) *1-Year Treasury Rate*



(b) *2-Year Treasury Rate*



(c) *30-Year Mortgage Rate on 1-Year Treasury Rate*



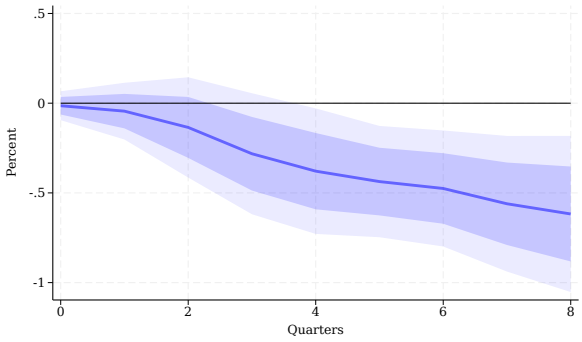
(d) *30-Year Mortgage Rate*

Notes: Panels (a)–(b) report the local projection IV impulse responses of the 1-year and 2-year Treasury rates (`DGS1` and `DGS2`) to an instrumented 25-basis-point increase in the Wu–Xia shadow federal funds rate. The 1-year Treasury rate (`DGS1`), 2-year Treasury rate (`DGS2`), and 30-year fixed mortgage rate (`MORTGAGE30US`) are obtained from the Federal Reserve Economic Data (FRED), Federal Reserve Bank of St. Louis. The shadow rate follows Wu and Xia (2016) and is instrumented using the Bauer–Swanson monetary policy surprise shock. Panel (c) reports the local projection IV impulse response of the 30-year fixed mortgage rate to an instrumented 25-basis-point increase in the 1-year Treasury rate. Panel (d) reports the local projection IV impulse response of the 30-year fixed mortgage rate to an instrumented 25-basis-point increase in the Wu–Xia shadow federal funds rate.

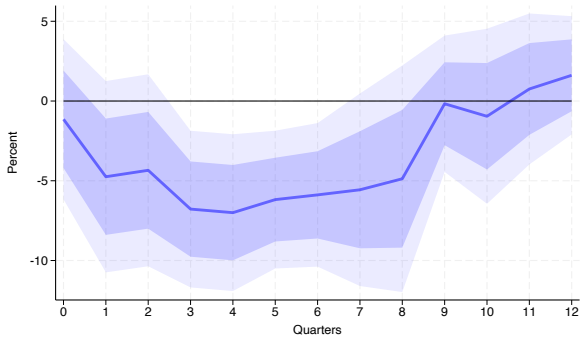
where $\Delta^{(h)} Y_{i,t+h} \equiv Y_{i,t+h} - Y_{i,t-1}$ denotes the cumulative change in outcome Y through horizon h, and Δm_t is the change in the 30-year fixed mortgage rate, instrumented by the high-frequency monetary-policy surprise of Bauer and Swanson (2023). $\lambda_{i\times \mathrm{soy}(t-1)}$ denotes a geography-by-lagged-season fixed effect, absorbing both time-invariant differences across ZIP codes and ZIP-specific seasonal patterns.

For house prices, rents, and rental and for-sale listing stocks and flows, we estimate

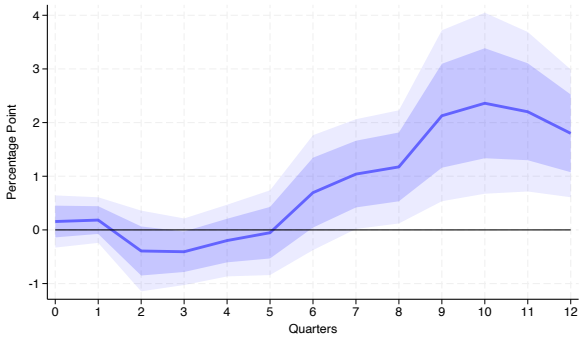
Figure 2: *Tenure Reallocation*



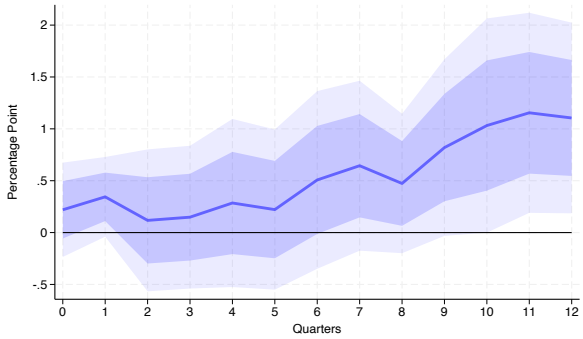
(a) *Homeownership*



(b) *Mortgage-Backed Market Tightness*



(c) *Buy-to-Rent Investor Share*



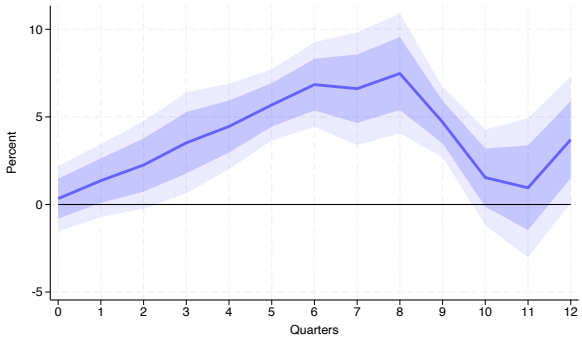
(d) *Corporate Investor Share*

Notes: This figure reports impulse responses to a 25-basis-point increase in the 30-year fixed mortgage rate. Panel (a) reports the homeownership rate; Panel (b) reports mortgage-backed ownership-market tightness, measured as mortgage inquiries relative to active for-sale listings; Panel (c) reports the share of purchases by buy-to-rent investors; and Panel (d) reports the share of purchases by corporate buyers. Dark and light shaded regions denote 68% and 90% confidence intervals, respectively, based on Newey–West standard errors.

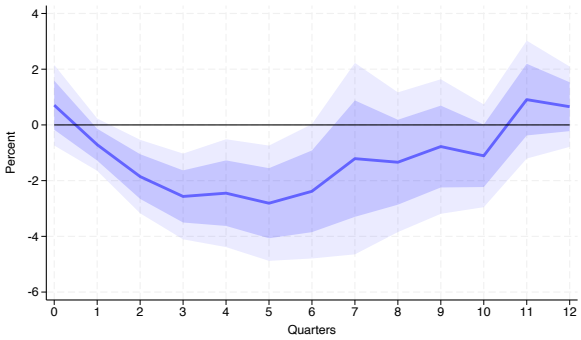
equation (4) at the ZIP-code–month level. These outcomes enter in logs. The control vector includes twelve lags of the outcome's monthly growth, one lag of year-over-year core PCE inflation, one lag of the year-over-year change in unemployment, one lag of the monetary-policy shock, and four lags of the change in the mortgage rate. ZIP-code-by-lagged-calendar-month fixed effects absorb persistent differences across ZIP codes and ZIP-specific seasonality. Standard errors are two-way clustered by ZIP code and month, and the regressions are weighted by lagged listing counts, using rental listings for rental-market outcomes and for-sale listings for ownership-market outcomes.

Homeownership, mortgage-backed market tightness, investor shares, time-to-buy, time-

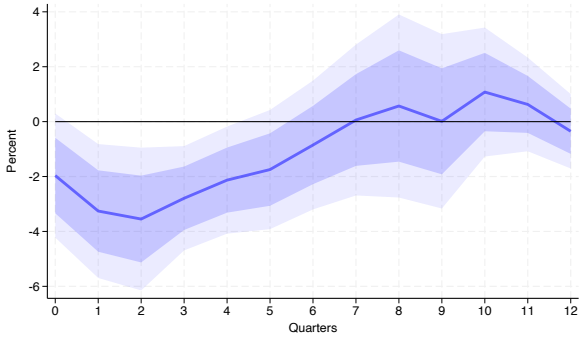
Figure 3: *Housing Cost and Market Liquidity Across Tenure*



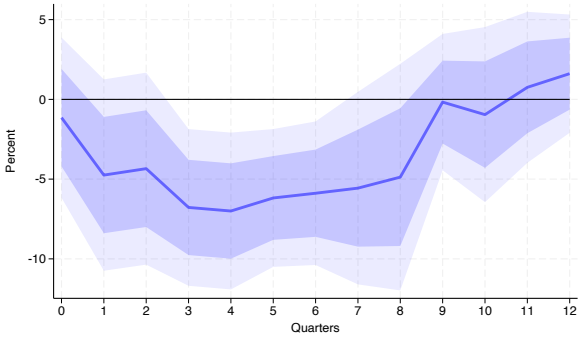
(a) *Time to Sell (MLS, repeated sale)*



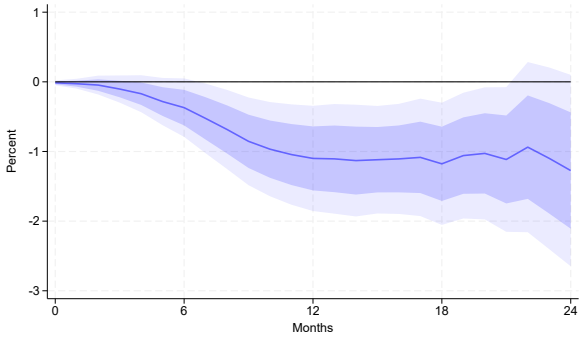
(b) *Time to Lease (MLS, repeated lease)*



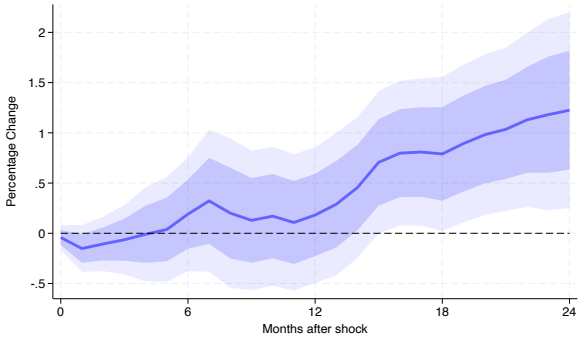
(c) *Time to Buy (Experian + MLS)*



(d) *Market Tightness (Experian + MLS)*



(e) *House Prices (ZHVI, repeated sales)*

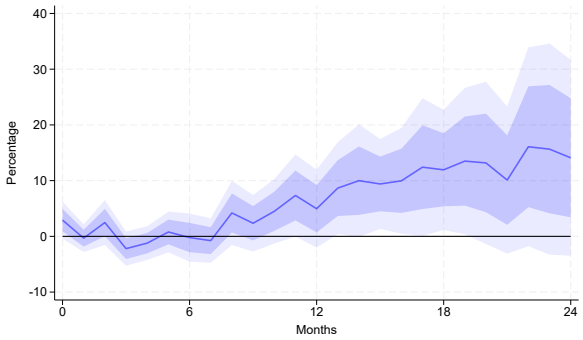


(f) *Rents (ADH-RRI, repeated lease)*

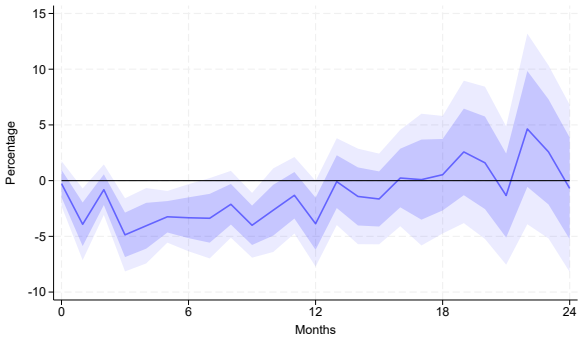
Note: This figure displays the impulse response function of time-to-sell (Panel (a)), time-to-lease (Panel (b)), house price (Panel (c)) and rents (Panel (d)) to a 25bps increase in the 30-year fixed rate mortgage. Dark (light) shaded areas represent 68% (90%) confidence intervals based on Newey and West (1987) standard errors.

to-sell, and time-to-lease are estimated at the county–quarter level. We aggregate the monthly monetary-policy surprise and other monthly variables to the quarterly frequency and estimate the corresponding LP-IV over horizons of up to twelve quarters. The quarterly

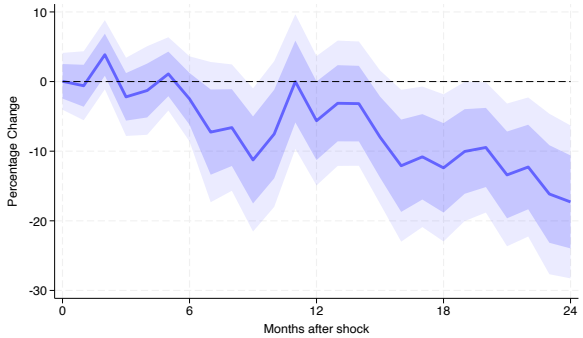
Figure 4: *Listing Flows Across Tenure*



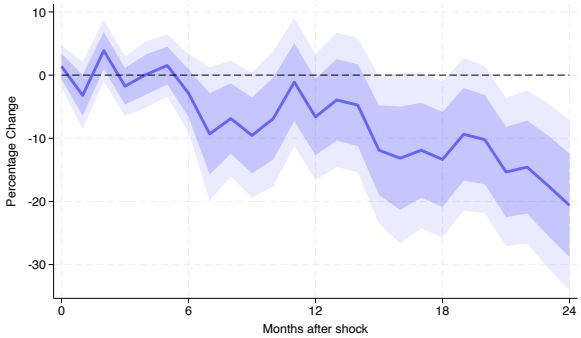
(a) *Number of New Rental Listings*



(b) *Number of Active Rental Listings*



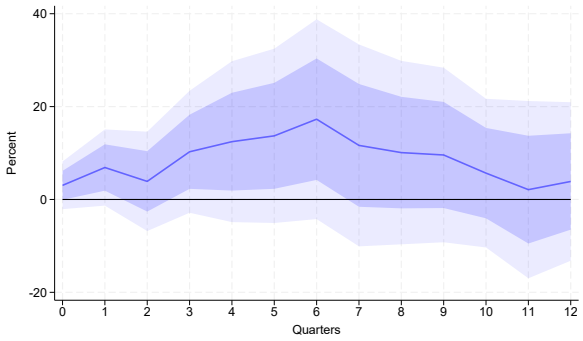
(c) *Number of New Sale Listings*



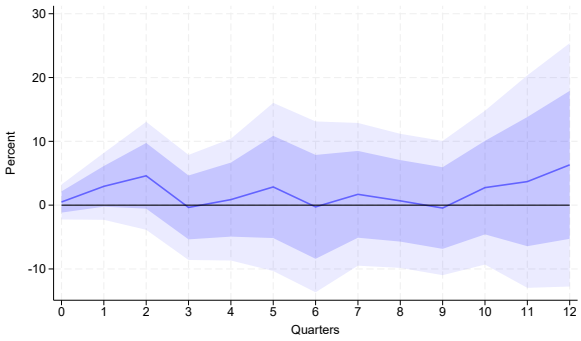
(d) *Number of Active Sale Listings*

Note: This figure displays the impulse response function of new rental listings, active rental listings, new sales listings, active sales listings to a 25bps increase in the 30-year fixed rate mortgage. Dark (light) shaded areas represent 68% (90%) confidence intervals based on Newey and West (1987) standard errors.

Figure 5: *New Construction Across Tenure*



(a) *Built for Rent*



(b) *Built for Sale*

Note: This figure displays the impulse response function of built-for-rent starts and built-for-sale starts to a 25bps increase in the 30-year fixed rate mortgage. Dark (light) shaded areas represent 68% (90%) confidence intervals based on Newey and West (1987) standard errors.

control vector includes four lags of the outcome's own growth, one lag of year-over-year core PCE inflation, one lag of the year-over-year change in unemployment, one lag of the quarterly change in the mortgage rate, and the economic and financial news controls of Bauer and Swanson (2023). County-by-lagged-quarter-of-year fixed effects absorb both persistent county differences and county-specific seasonal patterns, and standard errors are two-way clustered by county and quarter. For transaction-based outcomes, we restrict the estimation sample to counties with sufficiently large transaction volume to limit measurement error in county-quarter aggregates.

Finally, built-for-rent and built-for-sale housing starts are observed at the Census-region–quarter level for the Northeast, Midwest, South, and West. We therefore estimate an analogous quarterly LP-IV specification at the regional level, preserving the same identification strategy while allowing the geographic aggregation to follow the underlying construction data. All impulse responses throughout the analysis are scaled to a 25-basis-point increase in the 30-year fixed mortgage rate.

This common framework allows us to estimate the response of each housing-market margin at the finest frequency and geographic level supported by the underlying data, while maintaining a common source of identifying variation. Three benchmark responses—rents, homeownership, and investor participation—were previously documented in **?**. We reproduce them here and combine them with new evidence on buyer- and seller-side liquidity, mortgage-backed market tightness, listing stocks and flows, and tenure-specific construction. Together, these outcomes allow us to trace not only how housing costs respond to monetary tightening, but also the adjustment process linking the ownership and rental markets and the dynamics linking flows and stocks in each market.

Tenure reallocation. We begin with the extensive-margin response at the center of the mechanism. Figure 2a shows that higher mortgage rates reduce homeownership. As mortgage financing becomes more expensive, households near the rent–own margin become less

likely to enter the ownership sector and instead shift toward renting.

This contraction in household ownership demand is also visible within the for-sale market. Figure 2b shows that mortgage-backed market tightness falls sharply following the shock before gradually recovering. We measure tightness from the relative search durations of mortgage-financed buyers and home sellers: when buyer search becomes shorter relative to seller time on market, the market has become less tight from the buyer's perspective. The decline therefore indicates that fewer mortgage-financed households are competing for each home offered for sale. In the next section, we show that this decline in tightness is reflected on both sides of the market: successful buyers purchase more quickly, while sellers take longer to transact.

At the same time, the decline in household ownership demand is partly offset by investors. Figures 2c–2d show that a 25-basis-point increase in the mortgage rate raises the buy-to-rent investor share by roughly 2 percentage points, with most of the increase driven by corporate investors, who are less dependent on mortgage credit. Monetary tightening therefore changes not only the level but also the composition of housing demand: mortgage-financed household demand contracts, while investor demand for properties intended for rental use expands.

Taken together, these responses reveal a reallocation rather than a uniform contraction in housing demand. Higher mortgage rates shift marginal households away from ownership and toward renting, loosening the mortgage-financed ownership market. At the same time, the stronger relative value of rental housing attracts buy-to-rent investors, who replace part of the lost household demand in the ownership market while beginning to reallocate properties toward rental use. The next section traces how this reallocation appears in transaction liquidity and housing costs across the two tenure markets.

Market liquidity and housing costs across tenure. Having established that higher mortgage rates shift marginal households away from ownership and toward renting, we next examine how this reallocation changes transaction conditions and housing costs in the two

tenure markets. Figure 5 shows a striking divergence in liquidity. Following a 25-basis-point increase in the mortgage rate, time-to-buy among successful mortgage-financed buyers falls by roughly 3–4 percent, while time-to-sell rises by about 6–7 percent. Thus, the households that remain in the ownership market purchase more quickly even as sellers wait longer to transact.

These opposing duration responses are naturally summarized by our mortgage-backed market-tightness measure, shown in Panel 5d. Tightness falls by roughly 7 percent at its trough before gradually recovering. Intuitively, higher financing costs reduce the number of mortgage-financed households competing for homes. With fewer such buyers relative to properties available for sale, the buyers who remain face less competition and complete purchases more quickly, while sellers take longer to find a buyer. The decline in time-to-buy therefore should not be interpreted as stronger ownership demand; it reflects more favorable transaction conditions for the selected set of mortgage-financed households that continue to search and ultimately purchase.

The rental market moves in the opposite direction. Panel 5b shows that time-to-lease falls by roughly 3 percent over the first several quarters following the shock. Rental units are therefore absorbed more quickly precisely when liquidity weakens on the ownership side. Combined with the decline in homeownership documented above, this pattern points to a reallocation of housing demand across tenure: mortgage-financed buyer pressure falls, while renter pressure rises.

Housing costs adjust in the same direction as these liquidity changes. Panels 5e and 5f show that house prices decline gradually, by a little over 1 percent after two years, while rents rise by roughly 1.2–1.3 percent. The joint response is informative. If monetary tightening simply reduced housing demand uniformly, one would expect weaker transaction conditions and downward pressure on housing costs in both sectors. Instead, the ownership market becomes less tight and house prices fall, while rental units turn over more quickly and rents rise. The evidence therefore points to a shift in demand from owning toward renting rather

than a common contraction in the demand for housing services.

The divergence in rents and house prices also helps explain why the price response is modest relative to a benchmark in which house prices alone absorb the increase in financing costs. Consider the standard user-cost relation,

$$\frac{R_t}{P_t} = r_t + m_t - g_t \,,$$

where r_t is the real mortgage rate, m_t captures operating, maintenance, and depreciation costs, and g_t is expected real appreciation. Starting from a rent–price ratio of 8 percent, a 25-basis-point increase in the real financing cost would, holding rents and the other components fixed, require house prices to fall by roughly 3 percent. In the data, however, part of the adjustment occurs through higher rents: after two years, rents are about 1.2–1.3 percent higher while house prices are a little over 1 percent lower. Both margins therefore contribute to the increase in the rent–price ratio. This joint adjustment is consistent with the broader reallocation documented above: higher mortgage rates reduce the relative demand for owner-occupied housing while increasing demand for rental housing.

Listing stocks and flows across tenure. Taken together, the higher rents and faster rental absorption documented in Figure 3 indicate that the mortgage-rate shock increases rental-market tightness, with more households searching for rental housing relative to the stock of units available for lease.

This tightening could, in principle, reflect either a shift in demand from ownership toward renting or a contraction in rental availability. The listing data allow us to trace how the supply side of existing housing stock responds to this shift in demand. Active listings are stocks, while new listings are flows into those stocks. In the rental market, $\text{Active Listings}_{t+1} = \text{Active Listings}_t + \text{New Listings}_{t+1} - \text{Leases}_{t+1} - \text{Other Exits}_{t+1}$, with an analogous accounting identity for the ownership market.

Figure 4a shows that new rental listings stay flat for the first 6 months and then rise

by about 15 percent over the first two years. Thus, the increase in rents and the decline in time-to-lease cannot be attributed to a contraction in rental supply. Rental supply is responding endogenously in the opposite direction: additional properties are being offered for rent.

Yet active rental inventory initially declines. The combination of falling active inventory and shorter time-to-lease indicates that existing rental units are being absorbed more rapidly, while the delayed increase in new listings shows that supply responds only gradually. Once new rental entry begins to expand, those units continue to be absorbed sufficiently quickly that they do not immediately accumulate as active inventory. The timing therefore points to rental demand rising first and faster, followed by an endogenous supply response.

The ownership-side listing flows complete the picture. New for-sale listings decline after the mortgage-rate shock, and active for-sale inventory also falls despite the increase in time-to-sell. Together with the decline in mortgage-backed market tightness and the shorter time-to-buy among successful buyers, these responses indicate that both sides of the ownership market contract, but mortgage-financed buyer demand falls more sharply than the flow of homes offered for sale.

Taken together, the opposing listing flows across tenure are consistent with a gradual reallocation of the existing housing stock. New for-sale listings contract while new rental listings eventually expand. Buy-to-rent investors provide a natural link between the two markets: by purchasing properties in the ownership market and placing them into rental use, investors simultaneously add demand to the ownership market and expand rental supply. The rise in investor purchases together with the later increase in new rental listings is therefore consistent with existing properties being reallocated toward rental use as the relative value of renting rises.

New construction across tenure. Finally, we ask whether the supply response extends beyond the reallocation of the existing housing stock to new construction. Figure 5 reports

LP-IV responses separately for built-for-rent and built-for-sale housing, both measured by the number of starts.

The two sectors respond differently. Built-for-rent construction increases following the mortgage-rate shock, with the response building gradually and peaking around six quarters after the shock. By contrast, built-for-sale construction shows little systematic response and is generally indistinguishable from zero. Thus, monetary tightening not only reallocates existing properties toward rental use; over a longer horizon, it also shifts the composition of new housing supply toward the rental sector.

The timing is informative. Rents rise and rental units are absorbed more quickly well before the increase in built-for-rent construction materializes. New construction therefore cannot account for the initial tightening of the rental market. In the short run, adjustment occurs primarily through the shift of households toward rental demand and the reallocation of existing properties toward rental use. Over longer horizons, the increase in rents and the stronger value of rental use induce an additional supply response through new built-for-rent construction. This gradual expansion of rental supply ultimately works to alleviate, rather than generate, the initial increase in rental-market tightness.

Putting all these together. The joint responses reveal a sequence of adjustment that is difficult to see from rents or house prices alone. Higher mortgage rates first reduce the attractiveness of homeownership: homeownership and mortgage-backed buyer pressure fall. Households displaced from the ownership margin enter rental search, where units lease faster and rents rise. Higher rents increase the relative value of rental use and attract buy-to-rent investors, leading additional properties to enter the rental market. Because these units are initially absorbed faster than they arrive, active rental inventory remains scarce even as new rental listings increase. Over longer horizons, built-for-rent construction provides an additional supply response.

This sequence also explains the muted response of house prices. Monetary tightening

reduces mortgage-financed homebuyer demand, but the rise in rents increases the value of rental property and draws investors into the ownership market. Investor demand therefore partially absorbs the properties released by the contraction in household ownership demand and cushions the decline in house prices.

The evidence points to a housing-market reallocation mechanism rather than a uniform contraction in housing demand. Monetary policy changes the allocation of households and properties across tenure sectors, while search frictions govern the speed at which the two markets adjust. The next section formalizes these forces in a model with endogenous tenure choice, search and matching in both housing markets, and buy-to-rent investor entry, and quantifies their contribution to the estimated responses here.

4 A search model of the rental and ownership markets

This section presents a simple search model that highlights our mechanism of the housing cost channel, where both the housing tenure decision of households and the entry of buy-to-rent investors respond to monetary policy through its effect on interest rates. The model abstracts from various features of the economy not essential to its main mechanisms.

4.1 Search frictions

There is a market for renting or leasing properties (the 'rental market') and a market for buying or selling properties (the 'ownership market'). Both markets are subject to search frictions.

Search frictions are captured by matching functions in each market that determine the flow of new matches m_{jt} at time t, where $j \in \{l, o\}$ indexes the two markets (l for the rental market, o for the ownership market). Time t is continuous. New matches depend on the stock of properties u_{jt} available for lease or for sale and those looking to rent or to buy,

denoted b_{jt}. The matching function has the following Cobb-Douglas functional form:

$$m_{jt} = \mu_j u_{jt}^{\eta_j} b_{jt}^{1-\eta_j}, \quad \text{for } j \in \{l, o\}, \tag{5}$$

where η_j is the elasticity of the flow of new matches with respect to properties available for lease or for sale in market j, and μ_j is a parameter representing matching efficiency.

The matching function (5) has constant returns to scale, which implies that the speed of transactions on both sides of the market can be written in terms of market tightness θ_{jt}, the ratio of buyers to sellers in the market:

$$\frac{m_{jt}}{b_{jt}} = \nu_{jt} = \mu_j \theta_{jt}^{-\eta_j}, \quad \text{and} \quad \frac{m_{jt}}{u_{jt}} = \theta_{jt}\nu_{jt}, \quad \text{where} \quad \theta_{jt} \equiv \frac{b_{jt}}{u_{jt}}. \tag{6}$$

The transaction rate v_{jt} for buyers/renters decreases in tightness and the transaction rate $\theta_{jt}\nu_{jt}$ for sellers/landlords increases in tightness.

4.2 The rental market

Rents and rental transactions result are determined by households looking to rent and the properties available for rent. These properties are owned by buy-to-rent investors ('landlords'), and their decision to enter the rental market is analysed later. Similarly, which households become renters or owners is studied later.

Rents A key component of the housing cost channel is that search frictions lead to a bilateral monopoly rent arising from a match between a landlord and a tenant. This is the total surplus from a successful match in the rental market, and the housing rent paid by the tenant to the landlord divides this total surplus. Bargaining over the division of the surplus implies that housing rents are higher when the market is tighter. Later it is seen how interest rates affect housing tenure choices and entry decisions of investors, which have implications for market tightness.

The value function of a household successfully matched with a property owned by a

landlord is V_t, which depends on the rent R_t paid at time t. The landlord's value function is L_t, which depends on the rent received. Housing rents at each instant of time t are set through Nash bargaining without any commitment to long-term contracts, so the bargaining problem is the same at the beginning of a match as subsequently. Each party is free to walk away, abandoning the match and receiving their outside options. For a household, this is the value $B_{l,t}$ of searching for a new property in the rental market. For a landlord, this is the value $U_{l,t}$ of searching for a new tenant. The tenant's surplus is $V_t - B_{l,t}$ and the landlord's surplus is $L_t - U_{l,t}$, so the total surplus Σ_{lt} from a rental match is

$$\Sigma_{lt} = V_t + L_t - B_{lt} - U_{lt}\,, \tag{7}$$

The Nash bargaining problem sets R_t to maximize the Nash product $(L_t - U_{lt})^{\omega_l}(V_t - B_{lt})^{1-\omega_l}$, where ω_l is the bargaining power of the landlord. Since the rent R_t acts to transfer surplus between the parties, $\partial V_t/\partial R_t = -\partial L_t/\partial R_t$, which implies the following division of the surplus:

$$L_t - U_{lt} = \omega_l \Sigma_{lt}\,, \quad \text{and} \;\; W_t - B_{lt} = (1-\omega_l)\Sigma_{lt}\,. \tag{8}$$

Solving for rent R_t that implements this split requires characterizing the value functions V_t, L_t, B_{lt}, and U_{lt}.

Value functions All agents in the model discount future payoffs at rate ρ_t. The analysis focuses on the effects of a one-off aggregate shock. Following such a shock, the future paths of aggregate variables can be anticipated and expectations are not explicitly indicated in what follows.

Moving shocks While matched to a rental property, households receive a utility flow normalized to 1 and pay housing rent R_t. Households face occasional shocks that cause them to become mismatched. With arrival rate α_l, a moving shock reduces the utility flow from occupying the property to zero, causing the household to search for a new rental

property. With arrival rate λ, landlords face liquidity shocks that force them to sell their property and end the current tenancy. In either of these cases, the household searches for a new rental property, which has value B_{lt}.

In addition, with arrival rate β, households receive a tenure choice shock. This causes them to become mismatched and move out, but also gives them an opportunity to choose whether to buy a property. The value of choosing whether to own or to rent is N_t. Unless the tenure choice shock is received, tenants must remain in the rental market. Since rents can be continually renegotiated, households who do not become mismatched otherwise want to remain in the property they currently occupy.

Bellman equations The Bellman equation for the value of a tenant currently matched to a rental property is

$$\rho_t V_t = 1 - R_t + (\alpha_l + \lambda)(B_{lt} - V_t) + \beta(N_t - V_t) + \dot{V}_t \,. \tag{9}$$

The first term is the net flow value of being a tenant. The following terms show the effects of changes in status owing to the arrival of shocks. The final term $\dot{V}_t$, denoting the derivative of V_t with respect to time t, captures changes over time in the value of being a tenant.

For households searching for a property to rent, the Bellman equation is

$$\rho_t B_{lt} = \nu_{lt}(V_t - B_{lt}) + \beta(N_t - B_{lt}) + \dot{B}_{lt} \,. \tag{10}$$

Given search frictions, households find a successful match with a rental property at rate ν_{lt} from (6), and once this occurs, a rent is negotiated so that the landlord agrees the household can move in and receive value V_t. While searching, households can also receive tenure choice shocks at rate β, which might lead them to switch to searching in the ownership market.

There are also two Bellman equations for landlords currently matched with a tenant (value L_t) and those searching for a new tenant (value U_{lt}). The first of these is

$$\rho_t L_t = R_t + (\alpha_l + \beta)(U_{lt} - L_t) + \lambda(U_{ot} - L_t) + \dot{L}_t \,. \tag{11}$$

Landlords receive a flow of rent R_t until either tenants move out (rate $\alpha_l + \beta$) or they themselves are forced to exit the market owing to a liquidity shock (arrival rate λ). In the latter case, landlords put up their property for sale in the ownership market described below and receive value U_{ot}. The second Bellman equation for the value of having a property available to lease is

$$\rho_t U_{lt} = \theta_{lt}\nu_{lt}(L_t - U_{lt}) + \lambda(U_{ot} - U_{lt}) + \dot{U}_{lt}\,, \tag{12}$$

where a new tenant is found at rate $\theta_{lt}\nu_{lt}$. Liquidity shocks can also arrive while a property is not currently matched to a tenant.

The total surplus and its division Combining the Bellman equations (9)–(12) and the Nash bargaining solution (8) shows that the total surplus from a match in the rental market (Σ_{lt} in 7) satisfies the differential equation:

$$(\rho_t + \alpha_l + \beta + \lambda + (1-\omega_l)\nu_{lt} + \omega_l\theta_{lt}\nu_{lt})\,\Sigma_{lt} = 1 + \dot{\Sigma}_{lt}\,. \tag{13}$$

This equation is derived in Appendix A.1. It shows that the total surplus is given by the net utility flow gain 1 from a rental match discounted not only by ρ_t, but also by the combined rate at which matches dissolve $\alpha_l + \beta + \lambda$, and the rates ν_{lt} and $\theta_{lt}\nu_{lt}$ at which tenants and landlords could find an alternative match, weighted by their respective bargaining powers $1-\omega_l$ and ω_l. Given time paths of these terms, the explicit solution for the surplus Σ_{lt} is

$$\Sigma_{lt} = \int_{s=t}^{\infty} e^{-\int_{\tau=t}^{s}(\rho_\tau+\alpha_l+\beta+\lambda+(1-\omega_l)\nu_{l\tau}+\omega_l\theta_{l\tau}\nu_{l\tau})\mathrm{d}\tau}\mathrm{d}s\,. \tag{14}$$

The housing rent R_t that implements the division of the surplus from (8) is derived in Appendix A.1:

$$R_t = \omega_l\left(1 + (1-\omega_l)(\theta_{lt}-1)\nu_{lt}\Sigma_{lt}\right)\,. \tag{15}$$

Taking the total surplus Σ_{lt} as given, which depends on the path of the discount rate and market tightness in the future, the current rent R_t depends only on bargaining power ω_l and current rental-market tightness θ_{lt}, which determines ν_{lt} according to (6). The term $(\theta_{lt}-1)\nu_{lt} = \theta_{lt}\nu_{lt} - \nu_{lt}$ is the difference between the rate at which the landlord could find an alternative tenant and the rate at which the tenant could find an alternative property. Using (6), this difference is increasing in market tightness θ_{lt}, so higher θ_{lt} raises rents R_t.

4.3 Interest rates

Shock to interest rates The short-term risk-free real interest rate r_t is exogenous in this model. A full general-equilibrium model with nominal rigidities could be used to explain how monetary policy and other factors influence r_t. Here, r_t is taken as given, and the focus is on a one-off shock to r_t. After the shock, the subsequent dynamics of r_t are given by

$$\dot{r}_t = -\psi(r_t - r)\,, \tag{16}$$

where r is the long-run steady state for r_t and ψ is the rate of mean reversion following a shock. If at time $t=0$ a shock raises the interest rate to $r_t = r + \zeta$, where ζ is the size of the shock, the anticipated path of r_t for $t \geq 0$ is $r_t = r + \zeta e^{-\psi t}$, so $e^{-\psi t}$ is the fraction of the original shock that remains after time t has elapsed.

Long-term interest rates In the subsequent analysis of the link between interest rates and the housing market, it is important to distinguish long-term interest rates from the instantaneous short-term rate r_t. For example, consider a long-term bond making a series of coupon payments $e^{-\delta\tau}$ at each point in time $t+\tau$. The parameter δ captures the rate at which the future payments decline, which is linked to the duration of the bond. The price Q_t of this bond at time t satisfies the no-arbitrage condition $r_t Q_t = 1 - \delta Q_t + \dot{Q}_t$. The yield-to-maturity y_t, or interest rate, on this bond is defined by $Q_t = \int_{\tau=0}^{\infty} e^{-y_t\tau} e^{-\delta\tau} \mathrm{d}\tau = 1/(\pi + y_t)$. The duration of the bond is $J_t = \frac{1}{Q_t}\int_{\tau=0}^{\infty} \tau e^{-y_t\tau} e^{-\delta\tau} \mathrm{d}\tau = 1/(\delta + y_t)$.

Since $\dot{Q}_t = -\dot{y}_t/(\delta + y_t)^2$, the long-term bond yield satisfies the differential equation

$$(\delta + y_t)(r_t - y_t) = -\dot{y}_t \,, \tag{17}$$

which implies that y_t is a weighted average of current and anticipated future short-term interest rates.

Discount rates The model does not include a full analysis of households' consumption and saving decisions over time. In place of this, the discount rate ρ_t reflects the current short-term interest rate r_t:

$$\rho_t = r_t \,. \tag{18}$$

This stands in for the consumption Euler equation that links the marginal rate of substitution between current and future consumption for unconstrained households to the risk-free interest rate r_t.

Credit frictions Households face credit frictions when they take out finance to purchase properties. The following simple reduced form is used to build these frictions into the model.

Households who become home-buyers must first take out a mortgage of size D, where D is a parameter. This is assumed to be an interest-only mortgage, where the debt is paid off only if a household ceases to be a homeowner. The utility flow cost of servicing the constant mortgage debt D is $(1+x)r_tD$, where $x \geq 0$ indexes a household's type. The risk-free interest rate r_t is a common component faced by all borrowers and x is an idiosyncratic component that varies across different households and measures the severity of credit frictions. Having higher x can be interpreted as being a more borrowing-constrained household with a higher marginal utility of immediate consumption than less constrained households, or households facing an interest-rate spread that scales the risk-free interest rate r_t.

The type x of an individual household persists over time unless a tenure-choice shock is received, in which case the household redraws an x from a probability distribution indepen-

dent of the previous x.

Note that the flow cost of servicing the mortgage is linked to the short-term interest rate r_t. Nonetheless, because mortgages are taken out over long periods of time on average, the present value of these payments can be represented in terms of an equivalent long-term interest rate.

4.4 The ownership market

Existing homeowners Consider first a household that has successfully matched with and purchased a property. The value of a household in this position is $H_t(x)$, indexed by x because this affects the cost of servicing the mortgage debt. Homeowners receive a utility flow value of $1 + \gamma$, where γ represents a 'warm glow' from ownership (tenants receive a utility flow of only 1).

With arrival rate α_h (which can differ from α_l for tenants), homeowners become mismatched with their properties and sell them, but retain the same x and do not change their tenure status, re-entering the market to buy another property. The value of selling a property is U_{ot}, and the value of being a buyer searching for a new property is $B_{ht}(x)$, noting that this depends on the household's credit friction x. With arrival rate β, households also become mismatched and sell, but make a new housing tenure choice after redrawing their type x. Prior to learning the new x, but after repaying the existing mortgage D (because the household may become a renter), the value of making the tenure chouce decision is N_t, which does not depend on the current x.

With these assumptions, the Bellman equation for $H_t(x)$ is

$$\rho_t H_t(x) = 1+\gamma-(1+x)r_t D+\alpha_h(B_{ht}(x)+U_{ot}-H_t(x))+\beta(N_t-D+U_{ot}-H_t(x))+\dot{H}_t(x)\,. \quad (19)$$

Sellers There are two types of buyer b_{ot} in the ownership market, home-buyers b_{ht} and buy-to-rent investors b_{it}. Sellers successfully match with buyers at rate $\theta_{ot}\nu_{ot}$, with a fraction ξ_t of these matches being with investors and $1-\xi_t$ being with home-buyers, reflecting the fraction

of these groups among all buyers. Sellers observe the type of buyers and thus bargained prices depend on this. If P_{ht} is the price at which sales are made to home-buyers and P_{it} the price for sales to investors, the Bellman equation for the value U_{ot} of being a seller is

$$\rho_t U_{ot} = \theta_{ot}\nu_{ot}\left(\xi_t P_{it} + (1-\xi_t)P_{ht} - U_{ot}\right) + \dot{U}_{ot}\,, \quad \text{where } \xi_t = \frac{b_{it}}{b_{ht}+b_{it}}\,. \tag{20}$$

There is effectively only one type of seller, irrespective of whether the seller is a former homeowner or a former investor.

Home-buyers Home-buyers have taken out a mortgage and already received funds D to finance buying a property. They successfully match with sellers at rate ν_{ot} and receive value $H_t(x)$ after paying price P_{ht} and a transaction cost C. The Bellman equation for a home-buyer is

$$\rho_t B_{ht}(x) = -(1+x)r_t D + \nu_{ot}(H_t(x) - P_{ht} - C - B_{ht}(x)) + \beta(N_t - D - B_{ht}(x)) + \dot{B}_{ht}(x)\,, \tag{21}$$

where $(1+x)r_tD$ is the cost of servicing the mortgage. Tenure-choice shocks can arrive at rate β while searching to buy, in which case the household makes a new tenure status decision with a new x that has ex-ante value N_t after repaying the mortgage D taken out with the current credit friction x.

The assumption on the timing of mortgage finance implies $(1+x)r_tD$ drops out from $H_t(x) - B_{ht}(x)$. By subtracting (21) from (19), $(\rho_t + \alpha_h + \beta + \nu_{ot})\left(H_t(x) - B_{ht}(x)\right) = 1 + \gamma + (\alpha_h + \beta)U_{ot} + \nu_{ot}(P_{ht} + C) + (\dot{H}_t(x) - \dot{B}_{ht}(x))$, so $H_t(x) - B_{ht}(x)$ is independent of x. This implies the total surplus Σ_{ht} from a successful match between a seller and a home-buyer is also independent of x:

$$\Sigma_{ht} = H_t(x) - B_{ht}(x) - U_{ot} - C\,. \tag{22}$$

Investors Buy-to-rent investors successfully match with sellers at rate ν_{ot}. After purchasing a property at price P_{it} and paying transaction cost C, an investor lists it as available in

the rental market, pay a flow search cost F and receives value U_{lt}. The Bellman equation for the value I_t of an investor who is searching for a property is

$$\rho_t I_t = -F + \nu_{ot}(U_{lt} - P_{it} - C - I_t) + \dot{I}_t \,. \tag{23}$$

Note that investors are not subject to the credit frictions faced by households who become home-buyers. Investor payoffs are discounted at rate ρ_t, which is equal to the interest rate r_t (see 18). The total surplus Σ_{it} from a successful match between a seller and a buy-to-rent investor is

$$\Sigma_{it} = U_{lt} - I_t - U_{ot} - C \,. \tag{24}$$

House prices House prices are determined by Nash bargaining between buyers and sellers, where sellers have bargaining power ω_o. Similar to (8), the total surpluses Σ_{ht} and Σ_{it} from matches of sellers with home-buyers and investors respectively are divided as follows:

$$\begin{aligned} P_{ht} - U_{ot} = \omega_o \Sigma_{ht} \,, \quad H_t(x) - B_{ht}(x) - P_{ht} - C = (1-\omega_o)\Sigma_{ht} \,, \\ P_{it} - U_{ot} = \omega_o \Sigma_{it} \,, \quad \text{and} \;\; U_{lt} - P_{it} - I_t - C = (1-\omega_o)\Sigma_{it} \,. \end{aligned} \tag{25}$$

This confirms that the price P_{ht} is independent of x, as was supposed earlier in (20) and (21). Expressions for the total surpluses Σ_{ht} and Σ_{it} and the prices P_{ht} and P_{it} can be derived along similar lines to (14) and (15). These are presented in Appendix A.1.

4.5 Housing tenure choices

Owning versus renting Suppose a household has received a tenure-choice shock and drawn a new value of the credit friction x. Any existing mortgage debt has been repaid at this point. The household then chooses whether to enter the rental market or the ownership market to search for a property. The value of entering the rental market is B_{lt}, which is independent of x (as was implicitly supposed in 10) because tenants do not take out

mortgages and any subsequent tenure-choice shocks would lead to a new draw of x. Entering the ownership market requires taking out a mortgage of size D, where the cost of servicing and ultimately repaying this mortgage is accounted for in the value $B_{ht}(x)$ of being a home-buyer. Adding the D mortgage capital that has not yet been spent on buying a property, the payoff from entering the ownership market is $B_{ht}(x) + D$, which is compared to B_{lt}.

Equations (18), (21), and (25) imply that $(r_t + \beta)B_{ht}(x) = -(1 + x)r_t D - \beta D + \beta N_t + (1 - \omega_o)\nu_{ot}\Sigma_{ht} - (1 - \omega_l)\nu_{lt}\Sigma_{lt} + \dot{B}_{ht}(x)$ for all x. Differentiating with respect to x yields $(r_t + \beta)B'_{ht}(x) = -r_t D + \dot{B}'_{ht}(x)$, and hence $B'_{ht}(x) < 0$ since $r_t > 0$. As $B_{ht}(x)$ is decreasing in x, there is threshold z_t below which household choose to enter the ownership market. At the threshold, households are indifferent between the two markets:

$$B_{ht}(z_t) + D = B_{lt}\,. \tag{26}$$

Households become home-buyers if $x \leq z_t$. Intuitively, home-buyers are those households who face better credit conditions.

The equation for $B'_{ht}(x)$ also shows this derivative is independent of x, so $B_{ht}(x)$ is linear in x and can be written as $B_{ht} = B_{ht}(0) + B'_{ht}(0)x$. Using (10) together with the earlier equation for $B_{ht}(x)$ implies $(r_t + \beta)(B_{ht}(0) + D - B_{lt}) = (1 - \omega_o)\nu_{ot}\Sigma_{ht} - (1 - \omega_l)\nu_{lt}\Sigma_{lt} + (\dot{B}_{ht}(0) - \dot{B}_{lt})$. Together with the linearity of $B_{ht}(x)$, this implies the threshold z_t defined by (26) can be written as follows:

$$\begin{aligned} G_t = z_t Y_t\,, \quad \text{where } (r_t + \beta)Y_t = Dr_t + \dot{Y}_t \quad \text{and} \\ (\rho_t + \beta)G_t = (1 - \omega_o)\nu_{ot}\Sigma_{ht} - (1 - \omega_l)\nu_{lt}\Sigma_{lt} + \dot{G}_t\,. \end{aligned} \tag{27}$$

The term G_t represents the net benefits of homeownership relative to renting, excluding the additional financing cost arising from the credit friction. The differential equation for G_t implies it is a discounted sum of the current and anticipated future difference between the surpluses $(1 - \omega_o)\Sigma_{ht}$ and $(1 - \omega_l)\Sigma_{lt}$ received by home-buyers and renters, multiplied by the speeds ν_{ot} and ν_{lt} at which matches in those markets can be found. The comparison of the

surpluses depends on factors such as the 'warm glow' γ from homeownership versus renters' avoidance of paying transaction costs C on every move. The relative speed at which matches can be found depends on the relative tightness of the two markets.

While higher G_t increases the threshold z_t in (27) and leads more households to become homeowners, higher Y_t increases it and leads to fewer becoming homeowners. The term Y_t represents changes in the severity of credit frictions driven by the interest rate r_t. The differential equation for Y_t shows that it depends on current and anticipated future interest rates, similar to the long-term bond yield y_t in equation (17). Hence, equation (27) captures the key trade-off between the benefits of homeownership versus the cost of servicing mortgages.

Tenure-choice shocks Since all households can receive tenure-choice shocks at rate β, the model allows for two-way transitions of tenure status across the ownership and rental markets. Following a shock, the value of x is redrawn independently of a household's current x. This capture idiosyncratic changes in the credit conditions faced by households over time. It can also capture life-cycle patterns where households in the ownership market exit the market through death and are replaced by new households in the rental market.

Assume new draws of x independently come from a Normal distribution with mean χ and standard deviation σ. Among households who receive a tenure-choice shock, the fraction with $x \leq z_t$ who become home-buyers is

$$n_t = \Phi\left(\frac{z_t - \chi}{\sigma}\right), \tag{28}$$

where $\Phi(\cdot)$ is the standard Normal distribution function. While drawing negative x is possible with the Normal distribution, in practice, the mean and standard deviation that are chosen imply only a negligible probability that this occurs. Prior to knowing what x is drawn, the expected value of making a tenure-choice decision is

$$N_t = \int_x \max\left\{B_{ht}(x) + D, B_{lt}\right\} \frac{1}{\sigma}\phi\left(\frac{x - \chi}{\sigma}\right) \mathrm{d}x\,, \tag{29}$$

where $\phi(\cdot)$ is the standard Normal density function.

4.6 Entry of investors

Buy-to-rent investors first enter the ownership market to purchase properties and then rent them out. The value of entering the ownership market to invest is I_t. In the absence of any other frictions, investors would enter up to the point where $I_t = 0$. Here, this is generalized so that investor entry is not perfectly sensitive to any deviation of I_t from zero.

If b_{it} denotes the measure of investors currently trying to purchase property, the investor entry condition is specified as follows:

$$\dot{b}_{it} = \kappa I_t \,, \tag{30}$$

which links the change in b_{it} over time to the incentive to enter I_t with sensitivity parameter κ. This implicitly represents a form of convex adjustment cost for property investors where the cost depends on the rate of entry $\dot{b}_{it}$.

The special case of free entry is represented by $\kappa \to \infty$. A finite value of κ is not essential for the qualitative results of the model, but it helps to make the speed of investor entry more realistic and to match some of the empirical findings.

4.7 Allocation of households and properties across the markets

The allocation of households and properties across the rental and ownership markets depends on households' tenure decisions and the entry of investors. A crucial feature of the model is that the two markets are linked by the presence of buy-to-rent investors, who buy properties in the ownership market to let out in the rental market.

In what follows, q_{lt} denotes the stock of surviving rental-market matches between tenants and landlords and q_{ht} the stock of surviving matches between homeowners and their properties. Unmatched properties that are for lease or for sale are u_{lt} and u_{ot} respectively. The measure of households searching for a property to rent is b_{lt}, and the measure of home-buyers

searching in the ownership market is b_{ht}. Total buyers in the ownership market comprise home-buyers b_{ht} and buy-to-rent investors b_{it}, that is, $b_{ot} = b_{ht} + b_{it}$. As defined earlier, the fraction of investors among all buyers is $\xi_t = b_{it}/b_{ot}$.

Population and housing stock There is a fixed population of measure one and a fixed stock of properties, also of measure one. Hence, the measures of households over all statuses q_{lt}, b_{lt}, q_{ht}, and b_{ht} must sum to one. Similarly, the measures of properties over all statuses q_{lt}, u_{lt}, q_{ht}, and u_{ot} must also sum to one:

$$q_{lt} + b_{lt} + q_{ht} + q_{ht} = 1\,, \quad \text{and} \quad q_{lt} + u_{lt} + q_{ht} + u_{ot} = 1\,. \tag{31}$$

Stocks and flows The evolution over time of the stocks of successful matches q_{lt} and q_{ht} is described by

$$\begin{aligned} \dot{q}_{lt} &= \nu_{lt} b_{lt} - (\alpha_l + \beta + \lambda) q_{lt}\,, \quad \text{and} \\ \dot{q}_{ht} &= \nu_{ot} b_{ht} - (\alpha_h + \beta) q_{ht}\,. \end{aligned} \tag{32}$$

Inflows to these stocks consist of new matches formed by the households b_{lt} and b_{ht} searching in the respective markets with transaction rates ν_{lt} and ν_{ot}. Outflows consist of matches dissolved due to moving shocks (with tenure-specific arrival rates α_j) or tenure-choice shocks (arrival rate β) affecting households in either market, or liquidity shocks (arrival rate λ) hitting landlords in the rental market.

The stocks of households b_{lt} and b_{ht} searching in the two markets evolve according to

$$\begin{aligned} \dot{b}_{lt} &= (\alpha_l + \lambda) q_{lt} + \beta(1 - n_t) - (\nu_{lt} + \beta) b_{lt} \quad \text{and} \\ \dot{b}_{ht} &= \alpha_h q_{ht} + \beta n_t - (\nu_{ot} + \beta) b_{ht}\,, \end{aligned} \tag{33}$$

where n_t from (28) is the fraction of those receiving a tenure-choice shock who choose to search in the ownership market. Inflows come from those receiving moving or tenure-choice shocks, and outflows occur due to successful matches (or changes in tenure status while

searching).

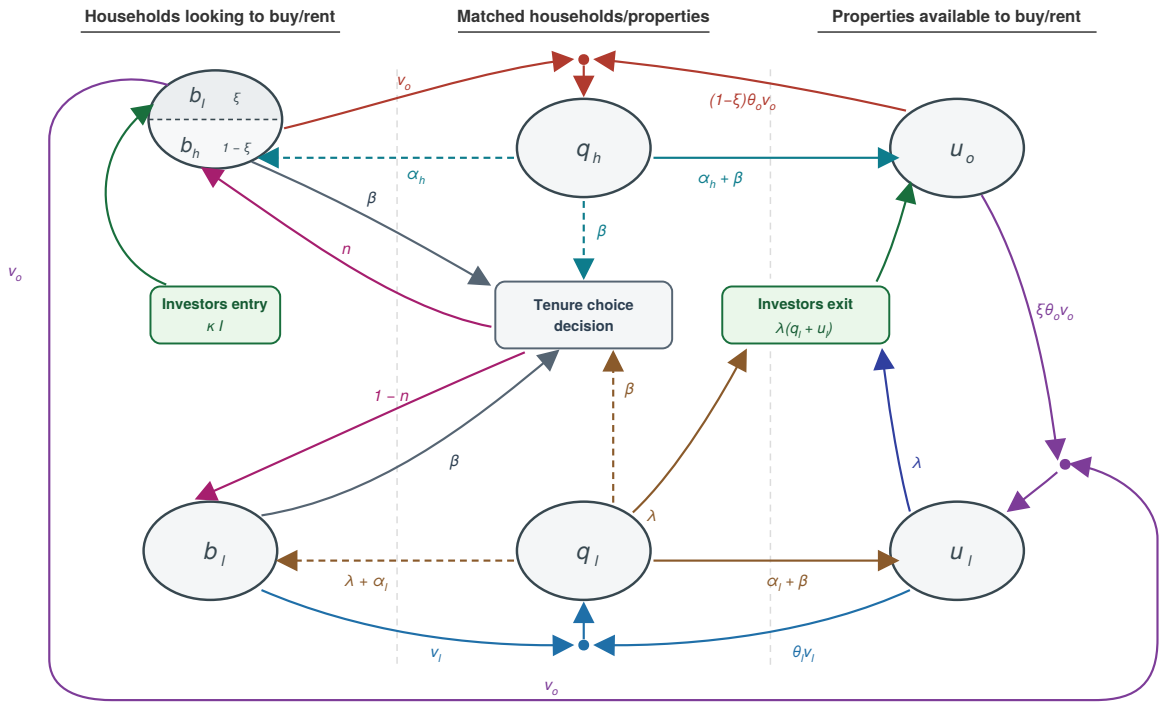
The dynamics of the stocks of properties u_{jt} available in the two markets $j \in \{l, o\}$ are given by

$$\begin{aligned} \dot{u}_{lt} &= (\alpha_l + \beta) q_{lt} + \nu_{ot} b_{it} - (\theta_{lt} \nu_{lt} + \lambda) u_{lt} \,, \quad \text{and} \\ \dot{u}_{ot} &= (\alpha_h + \beta) q_{ht} + \lambda (q_{lt} + u_{lt}) - \theta_{ot} \nu_{ot} u_{ot} \,. \end{aligned} \tag{34}$$

Inflows come from matches that dissolve, either because of moving shocks or tenure-choice shocks. Additionally, there are inflows to the stock of properties listed in the rental market from successful purchases $\nu_{ot} b_{it}$ in the ownership market by buy-to-rent investors, and inflows to the ownership market from landlords selling up after receiving liquidity shocks. Outflows occur because of successful matches at rate $\theta_{jt} \nu_{jt}$ in market j (or because of liquidity shocks to landlords with vacant rental properties).

All the flows described in equations (32)–(34) are depicted in Figure 6.

Figure 6: *The flows of households and properties in the model*



The homeownership rate The homeownership rate h_t is the sum of the measures of homeowners q_{ht} and home-buyers b_{ht}. Adding together the equations for $\dot{q}_{ht}$ and $\dot{b}_{ht}$ in (32) and (33) implies that

$$\dot{h}_t = \beta(n_t - h_t)\,, \quad \text{where} \;\; h_t = q_{ht} + b_{ht}\,. \tag{35}$$

This shows that the homeownership rate converges at rate β towards the fraction n_t of those choosing to be home-buyers after receiving a tenure-choice shock.

Flows between tenure statuses The model makes predictions for the various flows between different tenure statuses of households. Let $f_{l2h,t}$ and $f_{h2l,t}$ denote respectively the flows of households who switch from renting to owning and owning to renting. At time t, a fraction of households $1 - h_t$ are renters and h_t are in the ownership market. Of those receiving a tenure-choice shock, $1 - n_t$ choose to be renters and n_t choose to buy. With tenure-choice shocks arriving at rate β, these flows are

$$f_{l2h,t} = \beta n_t(1 - h_t) \quad \text{and} \;\; f_{h2l,t} = \beta(1 - n_t)h_t\,. \tag{36}$$

Moving rates As well as flows across tenure statuses, there is also moving within the same housing tenure. Let $f_{l2l,t}$ and $f_{h2h,t}$ denote respectively rent-to-rent flows and own-to-own flows. These are given by

$$f_{l2l,t} = (\alpha_l + \lambda)q_{lt} + \beta(1 - n_t)(1 - h_t), \quad \text{and} \;\; f_{h2h,t} = \alpha_h q_{ht} + \beta n_t h_t\,. \tag{37}$$

Time on the market In the rental market, properties owned by investors are able to find tenants at rate $\theta_{lt}\nu_{lt}$, and tenants are able to find matches at rate ν_{lt}. In the ownership market, the rates at which successful matches are found for sellers and buyers are respectively $\theta_{ot}\nu_{ot}$ and ν_{ot}. These rates imply the following times on the market for sellers and buyers in

the two markets:

$$T_{sl,t} = \frac{1}{\theta_{lt}\nu_{lt}}, \quad T_{bl,t} = \frac{1}{\nu_{lt}}, \quad T_{so,t} = \frac{1}{\theta_{ot}\nu_{ot}}, \quad \text{and} \quad T_{bo,t} = \frac{1}{\nu_{ot}}. \tag{38}$$

Two other variables of interest are the flow of new rental listings $l_t = (\alpha_l + \beta)q_{lt} + \nu_{ot}b_{it}$ and ownership market tightness $\theta_{ht} = b_{ht}/u_{ot}$ for mortgage-dependent home-buyers only.

5 Quantifying the housing channel

5.1 Calibration

The parameters of the model are calibrated largely by matching the model's steady-state predictions to empirical targets. In what follows, steady-state values of variables are indicated by omitting the time subscript t. The targets used in this calibration exercise are listed in Table 1. The unit of time is assumed to be one year.

The arrival rate β of tenure-choice shocks is disciplined by the evidence on rent-to-own and own-to-rent flows from Bachmann and Cooper (2014) together with the average homeownership rate. The arrival rate α_h of the moving shock with no redrawing of credit frictions and no change in tenure status is obtained from evidence on own-to-own flows also provided by Bachmann and Cooper (2014), together with the average time on the market T_{bo} for buyers.

The arrival rate λ of liquidity shocks is calibrated using the fraction ξ of investors among all buyers in the ownership market and the ratio of buyer to seller time on the market. Evidence on ξ is taken from Han et al. (2026) and T_{bo}/T_{so} comes from Genesove and Han (2012).

The arrival rate α_l of moving shocks with no tenure-choice decision is calibrated using evidence on rent-to-rent flows from Bachmann and Cooper (2014) together with landlords' average time on the market T_{sl}.

The elasticities η_l and η_o of the matching functions in the two markets are important

Table 1: *Calibration targets*

Target	Notation	Value	Source
Homeownership rate	h	66%	Census
Rent-to-own plus own-to-rent flows	$f_{l2h} + f_{h2l}$	4.2%	Bachmann and Cooper (2014)
Rent-to-rent flows	f_{l2l}	7.2%	Bachmann and Cooper (2014)
Own-to-own flows	f_{h2h}	4.1%	Bachmann and Cooper (2014)
Price-to-rent ratio	P_h/R	14.9	Altos and Cotality
Matching elasticity w.r.t. sellers	η_o	0.16	Genesove and Han (2012)
Matching elasticity w.r.t. landlords	η_l	0.16	Same for both markets
Landlord time on the market	T_{sl}	$\frac{77/365}{1-0.34}$	Altos and Cotality
Seller time on the market	T_{so}	$\frac{101/365}{1-0.34}$	Altos and Cotality
Relative buyer-seller time-on-market	T_{bo}/T_{so}	1.3	Genesove and Han (2012)
Share of purchases by investors	ξ	5%	Han et al. (2026)
Transaction costs relative to price	C/P_h	10%	Ngai and Sheedy (2020)
Loan-to-value ratio for mortgages	D/P_h	80%	Standard
Marginal home-buyer interest spread	$\hat{s}$	1.7%	30yr mortgage – 10yr Treasury
Average home-buyer interest spread	$\bar{s}$	2.3%	HMDA
Duration of long-term bond	J	5	Doepke and Schneider (2006)
% of shock remaining after two years	$e^{-2\psi}$	1/3	Impulse responses
Bargaining power of sellers	ω_o	0.5	Imposed
Sensitivity of investor entry	κ	0.025	Imposed

parameters because these affect the link between market tightness and transaction speed, and hence the rents and prices that result from bargaining. There is a small literature on estimating matching functions in the ownership market. See Ngai et al. (2026) for a recent estimate of the elasticity and a discussion of the existing literature. For the rental market, we are aware of only one paper that estimates the elasticity (Badarinza et al., 2024). Here, we use the most well known paper in the literature, Genesove and Han (2012), and set $\eta_o = 0.16$. For simplicity, we use the same elasticity for the rental market ($\eta_l = \eta_o$).

Market tightness θ_o tied down by the target for T_{bo}/T_{so}, and the fractions u_o and u_l of properties available for sale or for lease are determined by the shock arrival rates identified above and evidence on average transaction speeds in the two markets. With θ_o, u_o, u_l, and the target for ξ, market tightness θ_l in the rental market is tied down by an accounting identity. With data on transaction speeds, the average tightness of each market, and the

elasticities η_l and η_o, the matching efficiency parameters μ_l and μ_o are determined.

The average discount rate ρ and interest rate r are calibrated using the average price-to-rent ratio. The model makes predictions for the price-to-rent ratio in terms of ρ, shock arrival rates, and average transaction speeds.

The parameter δ that defines the duration of borrowing for the long-term interest rate is set to match a 5-year effective duration of household debt liabilities from Doepke and Schneider (2006).

The rate of mean reversion ψ of the interest-rate shock is set to imply 1/3 of the shock remains after two years, as guided by the estimated interest-rate impulse responses.

The bargaining power ω_o of sellers is set directly to the conventional value of 1/2. Using the model predictions for rents R and the target for the price-to-rent ratio, this ties down house prices P_h. The parameters D and C then directly follow from the targets for the loan-to-value ratio D/P_h and transaction costs relative to house prices C/P_h.

The credit friction for the marginal home-buyer is equivalent to an interest-rate spread of $\hat{s} = zr$. The average spread faced by all home-buyers is $\bar{s} = \mathbb{E}[x \,|\, x \leq z]r$. Targets for $\hat{s}$ and $\bar{s}$ together with the homeownership rate h determine the mean χ and standard deviation σ of the distribution of x.

With targets for the price-to-rent ratio and transaction speeds in the two markets, and the credit friction faced by the marginal home-buyer, the indifference condition for the threshold z determines the bargaining power of landlords ω_l given the imposed value of the bargaining power of sellers ω_o.

Given the price-to-rent ratio, transaction speeds, and bargaining powers, the steady-state investor entry condition ties down the 'warm glow' parameter γ given that the indifference condition for the marginal home-buyer was already used to set ω_o.

Finally, this leaves the parameter κ for the sensitivity of investor entry. A value of $\kappa = 0.025$ is imposed to obtain a realistic speed of response of investors to shocks observed in the data.

Table 2: *Model parameters*

Parameter	Notation	Value
Matching efficiency in the rental market	μ_l	5.8
Matching efficiency in the ownership market	μ_o	2.9
Meeting function elasticity w.r.t. landlords	η_l	0.16
Meeting function elasticity w.r.t. sellers	η_o	0.16
Arrival rate of tenure-choice shock	β	9.4%
Unconditional mean of credit friction x	χ	0.46
Standard deviation of credit friction x	σ	0.11
'Warm glow' from homeownership	γ	0.34
Size of mortgage	D	8.8
Arrival rate of liquidity shocks	λ	0.92%
Sensitivity of investor entry	κ	0.025
Arrival rate of moving shock for tenants	α_l	18%
Arrival rate of moving shock for homeowners	α_h	0.037%
Transaction cost faced by buyers	C	1.1
Bargaining power of landlords	ω_l	0.78
Bargaining power of sellers	ω_o	0.50
Long-term bond parameter	δ	0.14
Discount rate and interest rate	ρ	5.7%
Rate of mean reversion of shock	ψ	55%

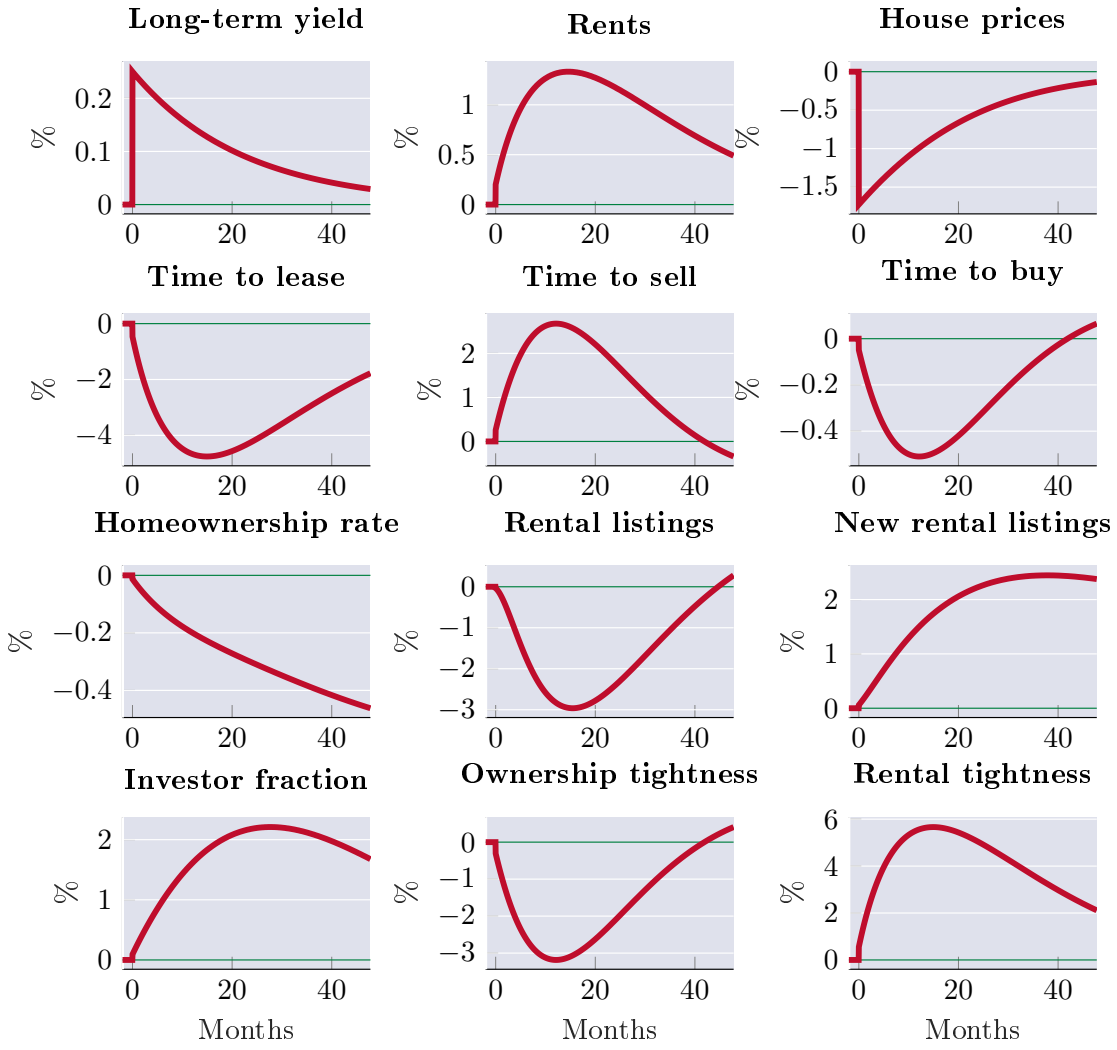
The details of how to derive the unique model parameters exactly matching these calibration targets are described in Appendix A.3. The resulting parameters are given in Table 2.

5.2 Quantitative results

The model is now solved to show the effects of a one-off shock to the interest rate r_t. The solution is approximated using a first-order perturbation method around the model's non-stochastic steady state, with continuous time discretized to a daily frequency. Further details are provided in Appendix A.4. The size ζ of the shock to r_t is chosen to give a 25-basis-point increase in the long-term interest rate y_t on impact. This makes the impulse responses comparable to the earlier local projection results with shocks to the mortgage interest rate.

The impulse response functions for key variables are reported in Figure 7 over the following 48 months. The interest rate, the homeownership rate, and the fraction of investors are

Figure 7: *Model predictions following an interest-rate shock*



reported as percentage point deviation from steady state. All other variables are reported as percentage deviations from their steady-state values. While the model is simulated at a daily frequency, variables are averaged within months in the impulse response functions.

While the long-term interest rate rises by 0.25% percentage points initially, after two years, it is less than 0.1% from its steady state. This is a feature of the calibration designed to match the persistence of interest rates seen in the empirical impulse response functions.

The rise in interest rates leads to a tightening of credit conditions for home-buyers. Fewer of those who receive a tenure-choice shock during the period after the shock become home-buyers. Households are displaced to the rental market, which increases market tightness

there (the number of households looking to rent a property relative to the number of properties available to lease). The increase in market tightness makes it easier for landlords to find tenants, and thus the average time taken to lease is shorter. From the perspective of households, the time taken to find a suitable rental property rises as the number of available rental listings shrinks.

Lower time to lease and the longer time for households to find rental properties strengthens the bargaining position of landlords because their outside option has improved, while the outside option of potential tenants has worsened. Rent negotiations therefore lead to higher rents. Search frictions explain the rising rents from the sudden imbalance between the number of households searching for rental properties and the number of properties available on the market. Quantitatively, the size of the effects on rents and the time taken to lease are close to the empirical findings.

Higher interest rates increase the number of households exiting the ownership market and decrease the number of entrants. Consequently, the homeownership rate declines, albeit slowly because not all households immediately make a new tenure choice decision. This reduction in demand for properties leads to lower house prices. Together with rising rents, the price-to-rent ratio declines.

The fall in the price-to-rent ratio (or equivalently, the rise in the rental yield), makes it more attractive for buy-to-rent investors to enter the ownership market. The model assumes this entry does not take place instaneously owing to some implicit adjustment costs for landlords, so in the short term, the tightness of ownership market declines and the average time taken to sell increases. After a delay, entry of investors leads to a tightening of the ownership market (though market tightness including only buyers dependent on mortgages remains low). The rise in tightness reverses the earlier fall in time taken to sell and mitigates the drop in house prices. Overall, with entry of investors, the increase in rents means that house prices do not have to fall by as much.

Once buy-to-rent investors have purchased properties, the supply of new rental listings

increases, which reduces tightness in the rental market and dampens the increase in rents. However, some increase in rents persists as this is necessary to attract the additional investors.

Overall, the results of the calibrated model are broadly in line with the empirical findings after a shock to interest rates.

5.3 The role of search frictions

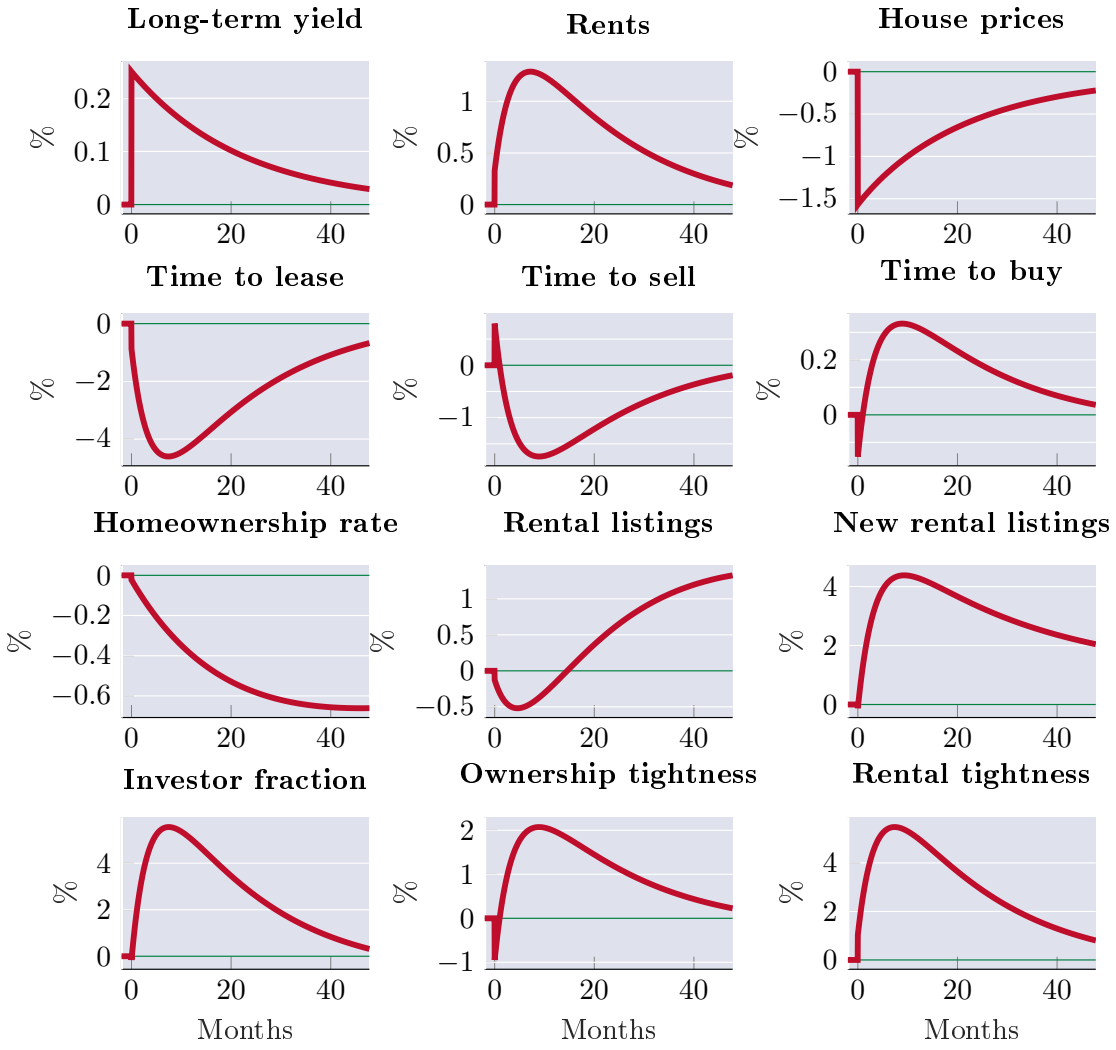
The special case where a free-entry condition for investors holds at every instant of time ($I_t = 0$) helps understand the role played by search frictions in the analysis. This is the limiting case where the parameter κ tends to infinity and thus making investor entry perfectly elastic. The effects of the interest-rate shock in this case are shown in Figure 8. All other parameters from Table 2 remain the same as used in Figure 7 (and continue to match the calibration targets in Table 1).

While investor entry is faster with $\kappa \to \infty$, search frictions in the ownership and rental markets imply that the supply of rental properties does not adjust by enough to offset the increase in the number of households entering the rental market. It takes time for investors to find a suitable property to purchase and then more time for them to find a tenant with a good match to the property. Consequently, rents still rise because the time taken to lease a property is lower than before.

6 Conclusions

Our findings show that housing reallocation across rental and ownership markets subject to search frictions has important implications for understanding the transmission of monetary policy and its effects on inequality. First, they highlight a *housing cost channel* through which monetary tightening can exert upward pressure on measured inflation via higher rents. Second, they imply that monetary policy can have unintended consequences for housing

Figure 8: *An interest-rate shock with investor free entry*



affordability, particularly for renters, while lower house prices benefit those buyers who do not need a mortgage. In this sense, monetary policy may inadvertently redistribute housing costs towards more constrained households, amplifying inequality, even though it aims to stabilize the aggregate economy. More broadly, the results highlight the importance of incorporating housing-market search frictions and tenure choice into models of monetary policy transmission.

References

Abramson, B., Han, L., and De Llanos, P. (2025). Monetary policy and rents. *Available at SSRN 5353365*.

Aoki, K., Proudman, J., and Vlieghe (2004). House prices, consumption, and monetary policy: a financial accelerator approach. *Journal of Financial Intermediation*, 13:414 – 435.

Auclert, A. (2019). Monetary policy and the redistribution channel. *American Economic Review*, 109(6):2333–2367.

Bachmann, R. and Cooper, D. (2014). The ins and arounds in the U.S. housing market. working paper 14–3, Federal Reserve Bank of Boston.

Badarinza, C., Balasubramaniam, V., and Ramadorai, T. (2024). In search of the matching function in the housing market. Working paper, ECB.

Barth, M. and Ramey, V. (2001). The cost channel of monetary transmission. *NBER Macroeconomics Annual*, 10:199 – 255.

Bauer, M. D. and Rudebusch, G. D. (2016). Monetary policy expectations at the zero lower bound. *Journal of Money, Credit and Banking*, 48(7):1439–1465. Working paper version circulated in 2013.

Bauer, M. D. and Swanson, E. T. (2023). A reassessment of monetary policy surprises and high-frequency identification. *NBER Macroeconomics Annual*, 37(1):87–155.

Bo, E. (2026). Buy to let: the role of rental investors in housing boom. *International Economics Review*, 67(2):657–696.

Bullard, J. (2012). Shadow interest rates and the stance of u.s. monetary policy. *Federal Reserve Bank of St. Louis Review*, 94(2):87–101.

Castellanos, J., Hannon, A., and Paz-Pardo, G. (2024). The aggregate and distributional implications of credit shocks on housing and rental markets.

Cloyne, J., Ferreira, C., and Surico, P. (2020). Monetary policy when households have debt: new evidence on the transmission mechanism. *The Review of Economic Studies*, 87(1):102–129.

De la Roca, J., Giacoletti, M., and Liu, L. (2024). Mortgage rates and rents: Evidence from

local mortgage lock-in effects. *Working paper*.

De Llanos, P. (2026). Housing market segmentation and monetary policy. Working paper, Columbia University, 2026.

Dias, D. A. and Duarte, J. B. (2019). Monetary policy, housing rents, and inflation dynamics. *Journal of Applied Econometrics*, 34(5):673–687.

Dias, D. A. and Duarte, J. B. (2022). Monetary policy and homeownership: Empirical evidence, theory, and policy implications. *International Finance Discussion Paper*, (1344).

Doepke, M. and Schneider, M. (2006). Inflation and the redistribution of nominal wealth. *Journal of Political Economy*, 114(6):1069–1097.

Garriga, C., Kydland, F. E., and Šustek, R. (2017). Mortgages and monetary policy. *The Review of Financial Studies*, 30(10):3337–3375.

Genesove, D. and Han, L. (2012). Search and matching in the housing market. *Journal of Urban Economics*, 72:31–45.

Gete, P. and Reher, M. (2018). Mortgage supply and housing rents. *Review of Financial Studies*, 31(12):4884–4911.

Greenwald, D. L. and Guren, A. (2025). Do credit conditions move house prices? *American Economic Review*, 115(10):3559–3596.

Groiss, M. and Syrichas, N. (2025). Monetary policy, property prices and rents: Evidence from local housing markets. *Property Prices and Rents: Evidence from Local Housing Markets*.

Halket, J. and Pignatti, M. (2015). Homeownership and the scarcity of rentals. *Journal of Monetary Economics*, 76:107–123.

Han, L., Ngai, L. R., and Sheedy, K. D. (2026). To own or to rent? the effects of transaction taxes on housing markets. *Review of Economic Studies*, 93:2605–2645.

Iacoviello, M. (2005). House prices, borrowing constraints, and monetary policy in the business cycle. *American economic review*, 95(3):739–764.

Ioannides, Y. and Ngai, L. R. (2025). Housing and inequality. *Journal of Economic Literature*, 63:916 – 963.

Ioannides, Y. M. and Zabel, J. E. (2019). Housing and labor market vacancies and Beveridge curves: Theoretical framework and illustrative statistics. In Ioannides, Y. M., editor,

Recent Developments in the Economics of Housing, volume II. Edward Elgar.

Jarociński, M. and Karadi, P. (2020). Deconstructing monetary policy surprises—the role of information shocks. *American Economic Journal: Macroeconomics*, 12(2):1–43.

Jordà, Ò. (2005). Estimation and inference of impulse responses by local projections. *American economic review*, 95(1):161–182.

Kim, D. H. and Singleton, K. J. (2012). Term structure models and the zero bound: An empirical investigation of japanese yields. *Journal of Econometrics*, 170(1):32–49.

Krippner, L. (2013). Measuring the stance of monetary policy in zero lower bound environments. *Economics Letters*, 118(1):135–138.

Miranda-Agrippino, S. and Ricco, G. (2021). The transmission of monetary policy shocks. *American Economic Journal: Macroeconomics*, 13(3):74–107.

Nakamura, E. and Steinsson, J. (2018). High-frequency identification of monetary non-neutrality: The information effect. *Quarterly Journal of Economics*, 133(3):1283–1330.

Newey, W. K. and West, K. D. (1987). A simple, positive semi-definite, heteroskedasticity and autocorrelation consistent covariance matrix. *Econometrica*, 55(3):703–708.

Ngai, L. R., Iglhaut, F., Sheedy, K. D., Wu, F., and Zhang, S. (2026). Matching people to properties: A matching function for the housing market. Discussion paper 21392, CEPR.

Ngai, L. R. and Sheedy, K. D. (2020). The decision to move house and aggregate housing-market dynamics. *Journal of the European Economic Association*, 18(5):2487–2531.

Wheaton, W. C. (1990). Vacancy, search, and prices in a housing market matching model. *Journal of Political Economy*, 98(6):1270–1292.

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.

A Appendices

A.1 Equilibrium rents and prices

Rental market Multiplying the rental-market surplus Σ_{lt} in (7) by ρ_t and substituting from the Bellman equations (9)–(12) and the Nash bargaining solution (8):

$$\rho_t \Sigma_{lt} = 1 - (\alpha_l + \lambda + \beta + \nu_{lt})(1-\omega_l)\Sigma_{lt} - (\alpha_l + \beta + \lambda + \theta_{lt}\nu_{lt})\omega_l \Sigma_{lt} + \dot{\Sigma}_{lt}\,,$$

where the terms in R_t, N_t, and U_{ot} cancel out, and (7) implies $\dot{\Sigma}_{lt} = \dot{V}_t + \dot{L}_t - \dot{B}_{lt} - \dot{U}_{lt}$. Collecting terms in Σ_{lt} on the left-hand side confirms (13). The solution (14) can be verified by differentiating with respect to time t and substituting into (13).

The Nash bargaining solution (8) implies $\rho_t L_t - \rho_t U_{lt} = \omega_l \rho_t \Sigma_{lt}$. Hence, by subtracting (12) from (11), housing rents R_t satisfy:

$$R_t - (\alpha_l + \beta + \lambda)\omega_l \Sigma_{lt} - \theta_{lt}\nu_{lt}\omega_l \Sigma_{lt} + \omega_l \dot{\Sigma}_{lt} = \omega_l \rho_t \Sigma_{lt}\,,$$

where terms in U_{ot} cancel out and the Nash bargaining solution (8) is used again, noting that it also implies $\dot{L}_t - \dot{U}_{lt} = \omega_l \dot{\Sigma}_{lt}$. It follows that $R_t = \omega_l \left((\rho_t + \alpha_l + \beta + \lambda + \theta_{lt}\nu_{lt})\Sigma_{lt} - \dot{\Sigma}_{lt} \right)$. Since (13) implies $\dot{\Sigma}_{lt} = (\rho_t + \alpha_l + \beta + \lambda + (1-\omega_l)\nu_{lt} + \omega_l \theta_{lt}\nu_{lt})\,\Sigma_{lt} - 1$, substituting for $\dot{\Sigma}_{lt}$ in the equation for rents confirms (15). Since $\Sigma_{lt} > 0$, the result from (6) that $\theta_{lt}\nu_{lt} - \nu_{lt} = \mu_l \left(\theta_{lt}^{1-\eta_l} - \theta_{lt}^{-\eta_l} \right)$ is increasing in θ_{lt} demonstrates that R_t rises with rental-market tightness θ_{lt}.

Ownership market Multiplying the home-buyer surplus Σ_{ht} from (22) by ρ_t gives $\rho_t \Sigma_{ht} = \rho_t H_t(x) - \rho_t B_{ht}(x) - \rho_t U_{ot} - \rho_t C$, conjecturing that Σ_{ht} is independent of x. By substituting the Bellman equations (19)–(21) and the Nash bargaining solution (25):

$$\begin{aligned}\rho_t \Sigma_{ht} = 1 + \gamma - (\alpha_h + \beta)\Sigma_{ht} - (\alpha_h + \beta)C - \nu_{ot}(1-\omega_o)\Sigma_{ht} \\ - \theta_{ot}\nu_{ot}(1-\xi_t)\omega_o \Sigma_{ht} - \theta_{ot}\nu_{ot}\xi_t \omega_o \Sigma_{it} - \rho_t C + \dot{\Sigma}_{ht}\,.\end{aligned}$$

where the terms in $(1+x)r_t D$ and $\beta(N_t - D)$ cancel out, Σ_{it} is the investor surplus from (24), and $\dot{\Sigma}_{ht} = \dot{H}_t(x) - \dot{B}_{ht}(x) - \dot{U}_{ot}$. Collecting terms in the levels of the surpluses Σ_{ht} and Σ_{it} on the left-hand side:

$$\begin{aligned}(\rho_t + \alpha_h + \beta + (1-\omega_o)\nu_{ot} + \omega_o(1-\xi_t)\theta_{ot}\nu_{ot})\,\Sigma_{ht} + \omega_o \xi_t \theta_{ot}\nu_{ot}\Sigma_{it} \\ = 1 + \gamma - (\rho_t + \alpha_h + \beta)C + \dot{\Sigma}_{ht}\,. \quad \text{(A.1)}\end{aligned}$$

Following a similar method, multiplying (24) by ρ_t and substituting from the Bellman equations (12), (20), and (23), and the Nash bargaining solutions (8) and (25):

$$\begin{aligned}\rho_t \Sigma_{it} = \theta_{lt}\nu_{lt}\omega_l \Sigma_{lt} - \lambda(\Sigma_{it} + I_t + C) - \nu_{ot}(1-\omega_o)\Sigma_{it} \\ - \theta_{ot}\nu_{ot}\xi_t \omega_o \Sigma_{it} - \theta_{ot}\nu_{ot}(1-\xi_t)\omega_o \Sigma_{ht} - \rho_t C - \dot{\Sigma}_{it}\,,\end{aligned}$$

using $\dot{\Sigma}_{it} = \dot{U}_{lt} - \dot{I}_t - \dot{U}_{ot}$ implied by (24). Collecting terms in Σ_{it} and Σ_{ht} on the left-hand side:

$$\begin{aligned}(\rho_t + \lambda + (1-\omega_o)\nu_{ot} + \omega_o \xi_t \theta_{ot}\nu_{ot})\,\Sigma_{it} + \omega_o(1-\xi_t)\theta_{ot}\nu_{ot}\Sigma_{ht} \\ = \omega_l \theta_{lt}\nu_{lt}\Sigma_{lt} - (\rho_t + \lambda)C - \lambda I_t + \dot{\Sigma}_{it}\,. \quad \text{(A.2)}\end{aligned}$$

For house prices, the P_{ht} paid by home-buyers satisfies $\rho_t P_{ht} = \rho_t U_{ot} + \omega_o \rho_t \Sigma_{ht}$ and $\dot{P}_{ht} = \dot{U}_{ot} + \omega_o \dot{\Sigma}_{ht}$ using the Nash bargaining solution (25). Hence, $\rho_t P_{ht} - \dot{P}_{ht} = (\rho_t U_{ot} - \dot{U}_{ot}) + \omega_o \rho_t \Sigma_{ht} - \omega_o \dot{\Sigma}_{ht}$. Substituting the Bellman equation (20) and bargaining solution (25), and using (A.1) to substitute

for $-\dot{\Sigma}_{ht}$, it follows that:

$$\rho_t P_{ht} - \dot{P}_{ht} = \theta_{ot}\nu_{ot}\xi_t\omega_o\Sigma_{it} + \theta_{ot}\nu_{ot}(1-\xi_t)\omega_o\Sigma_{ht} + \omega_o\rho_t\Sigma_{ht} + \omega_o\left(1+\gamma-(\rho_t+\alpha_h+\beta)C\right) \\ - \omega_o(\rho_t+\alpha_h+\beta+(1-\omega_o)\nu_{ot}+\omega_o(1-\xi_t)\theta_{ot}\nu_{ot})\Sigma_{ht} - \omega_o^2\xi_t\theta_{ot}\nu_{ot}\Sigma_{it}\,.$$

This differential equation for the home-buyer price P_{ht} can be simplified to:

$$\rho_t P_{ht} = \omega_o\big(1+\gamma-(\rho_t+\alpha_h+\beta)C-(\alpha_h+\beta)\Sigma_{ht} \\ + (1-\omega_o)\left(\theta_{ot}\nu_{ot}\left(\xi_t\Sigma_{it}+(1-\xi_t)\Sigma_{ht}\right)-\nu_{ot}\Sigma_{ht}\right)\big) + \dot{P}_{ht}\,. \quad \text{(A.3)}$$

A similar method can be used to find a differential equation for the price P_{it} paid by investors. Starting from $P_{it} = U_{ot} + \omega_o\Sigma_{it}$ implies $\rho_t P_{it} - \dot{P}_{it} = (\rho_t U_{ot} - \dot{U}_{ot}) + \omega_o\rho_t\Sigma_{it} - \omega_o\dot{\Sigma}_{it}$. Substituting from (20), (25), and (A.2):

$$\rho_t P_{it} - \dot{P}_{it} = \theta_{ot}\nu_{ot}\xi_t\omega_o\Sigma_{it} + \theta_{ot}\nu_{ot}(1-\xi_t)\omega_o\Sigma_{ht} + \omega_o\rho_t\Sigma_{it} + \omega_o\big(\omega_l\theta_{lt}\nu_{lt}\Sigma_{lt} - (\rho_t+\lambda)C - \lambda I_t \\ - (\rho_t+\lambda+(1-\omega_o)\nu_{ot}+\omega_o\xi_t\theta_{ot}+\nu_{ot})\,\Sigma_{it} + \omega_o(1-\xi_t)\theta_{ot}\nu_{ot}\Sigma_{ht}\big)\,,$$

which after simplification becomes:

$$\rho_t P_{it} = \omega_o\big(\omega_l\theta_{lt}\nu_{lt}\Sigma_{lt} - (\rho_t+\lambda)C - \lambda(I_t+\Sigma_{it}) \\ + (1-\omega_o)\left(\theta_{ot}\nu_{ot}\left(\xi_t\Sigma_{it}+(1-\xi_t)\Sigma_{ht}\right)-\nu_{ot}\Sigma_{it}\right)\big) + \dot{P}_{it}\,. \quad \text{(A.4)}$$

A.2 Steady state

The investor entry equation (30) in steady state implies $I = 0$. Since (23) and (24) imply $\rho_t I_t = (1-\omega_o)\nu_{ot}\Sigma_{it} + \dot{I}_t$, it follows that $\Sigma_i = 0$ in steady state. Using (A.2), this implies the following steady-state free-entry condition for investors:

$$\omega_l\theta_l\nu_l\Sigma_l = \omega_o(1-\xi)\theta_o\nu_o\Sigma_h + (\rho+\lambda)C\,. \quad \text{(A.5)}$$

The steady-state rental-market surplus Σ_l follows from (13):

$$\Sigma_l = \frac{1}{\rho+\alpha_l+\beta+\lambda+(1-\omega_l)\nu_l+\omega_l\theta_l\nu_l}\,. \quad \text{(A.6)}$$

From (15), steady-state rent is $R = \omega_l\left(1+(1-\omega_l)(\theta_l\nu_l-\nu_l)\Sigma_l\right)$ and substituting for the surplus Σ_l from (A.6) implies:

$$R = \omega_l\left(\frac{\rho+\alpha_l+\beta+\lambda+\theta_l\nu_l}{\rho+\alpha_l+\beta+\lambda+(1-\omega_l)\nu_l+\omega_l\theta_l\nu_l}\right) = \omega_l(\rho+\alpha_l+\beta+\lambda+\theta_l\nu_l)\Sigma_l\,. \quad \text{(A.7)}$$

With $\Sigma_i = 0$, equation (A.1) implies the steady-state home-buyer surplus is

$$\Sigma_h = \frac{1+\gamma-(\rho+\alpha_h+\beta)C}{\rho+\alpha_h+\beta+(1-\omega_o)\nu_o+\omega_o(1-\xi)\theta_o\nu_o}\,. \quad \text{(A.8)}$$

By using (A.3), the steady-state price paid by home-buyers is

$$P_h = \frac{\omega_o}{\rho}\left(1+\gamma-(\rho+\alpha_h+\beta)C-(\alpha_h+\beta+(1-\omega_o)(1-(1-\xi)\theta_o)\nu_o)\,\Sigma_h\right) \\ = \frac{\omega_o\left(\rho+(1-\xi)\theta_o\nu_o\right)\Sigma_h}{\rho}\,, \quad \text{(A.9)}$$

where the latter expression is obtained by substituting from (A.8).

A.3 Calibration method

Imposed parameters The parameters η_o, η_l, ω_o, and κ are set directly.

Tenure-choice shock arrival rate In steady state, equation (35) implies $n = h$. From (36), this means $f_{l2h} = f_{h2l}$ in steady state, and the sum of both flows between tenure statuses is $f_{l2h} + f_{h2l} = 2\beta h(1-h)$. With targets for the homeownership rate h and $f_{l2h} + f_{h2l}$, the implied tenure-choice shock arrival rate is

$$\beta = \frac{f_{l2h} + f_{h2l}}{2h(1-h)}\,. \tag{A.10}$$

Ownership-market moving shock arrival rate In steady state, (32) implies $(\alpha_h + \beta)q_h = \nu_o(h - q_h)$, where $h = q_h + b_h$, and hence $q_h = \nu_o h/(\alpha_h + \beta + \nu_o)$. The equation from (37) for the own-to-own flow in steady state is $\alpha_h q_h = f_{h2h} - \beta h^2$. Substituting for q_h leads to $\alpha_h \nu_o h = (\alpha_h + \beta + \nu_o)(f_{h2h} - \beta h^2)$. The buying rate ν_o is pinned down by the target for buyers' time on the market using (38) to deduce $\nu_o = 1/T_{bo}$. With the target for f_{h2h} and h, β, and ν_o known, the equation can be solved for the ownership-market moving shock arrival rate:

$$\alpha_h = \frac{(\beta + \nu_o)(f_{h2h} - \beta h^2)}{\nu_o h - (f_{h2h} - \beta h^2)}\,. \tag{A.11}$$

Liquidity shock arrival rate Using (32) again and the definition $h = q_h + b_h$, the equation $(\alpha_h + \beta)(h - b_h) = \nu_o b_h$ implies $b_h = (\alpha_h + \beta)h/(\alpha_h + \beta + \nu_o)$. Since $b_h = (1-\xi)\theta_o u_o$:

$$b_h - u_o = \frac{(\alpha_h + \beta)\left((1-\xi)\theta_o - 1\right)h}{(\alpha_h + \beta + \nu_o)(1-\xi)\theta_o}\,. \tag{A.12}$$

In steady state, (34) implies $\lambda(q_l + u_l) = \theta_o \nu_o u_o - (\alpha_h + \beta)q_h$. Noting that $\theta_o \nu_o u_o = \nu_o b_o$ and substituting $(\alpha_h + \beta)q_h = \nu_o b_h$ from (32), it follows that $\lambda(q_l + u_l) = \nu_o b_o - \nu_o b_h = \nu_o b_i$. Equation (31) implies $q_l + u_l = 1 - h + b_h - u_o$, and therefore $\lambda = \nu_o b_i/(1 - h + b_h - u_o)$. Using $b_i = \xi b_h/(1-\xi)$ and the earlier expression for b_h, the liquidity shock arrival rate is given by:

$$\lambda = \frac{\xi \nu_o (\alpha_h + \beta)h}{(1-\xi)(\alpha_h + \beta + \nu_o)\left(1 - h + (b_h - u_o)\right)}\,. \tag{A.13}$$

The fraction ξ of investors among buyers is a calibration target. Ownership-market tightness can be deduced from the targets for time on the market using (38) to write $\theta_o = T_{bo}/T_{so}$. Together with $b_h - u_o$ from (A.12), this yields λ since β, α_h, and ν_o are already known.

Rental-market moving shock arrival rate In steady state, (32) implies $(\alpha_l + \beta + \lambda)q_l = \nu_l \theta_l u_l$ using the definition of θ_l. Since (31) implies $u_l = 1 - h + (b_h - u_o) - q_l$, it follows that q_l satisfies $(\alpha_l + \beta + \lambda + \theta_l \nu_l)q_l = \theta_l \nu_l (1 - h + (b_h - u_o))$. Equation (37) for own-to-own flows in steady state implies $(\alpha_l + \lambda)q_l = f_{h2h} - \beta(1-h)^2$ using $n = h$. Multiplying both sides by $\alpha_l + \beta + \lambda + \theta_l \nu_l$ and substituting for q_l using the previous equation yields $(\alpha_l + \lambda)\theta_l \nu_l (1 - h + (b_h - u_o)) = (\alpha_l + \beta + \lambda + \theta_l \nu_l)(f_{h2h} - \beta(1-h)^2)$. This can be solved for α_l as follows:

$$\alpha_l = \frac{(\theta_l \nu_l + \beta + \lambda)\left(f_{h2h} - \beta(1-h)^2\right) - \lambda \theta_l \nu_l \left(1 - h + (b_h - u_o)\right)}{\theta_l \nu_l \left(1 - h + (b_h - u_o)\right) - (f_{h2h} - \beta(1-h)^2)}\,. \tag{A.14}$$

The calibration targets include f_{h2h} and h, and $\theta_l \nu_l = 1/T_{sl}$ is implied by the equation for time-to-lease in (38). The parameters β and λ are known from (A.10) and (A.13) and $b_h - u_o$ from (A.12), so α_l is determined by the equation above.

Matching efficiency parameters Taking the difference between the population and housing stock equations in (31) implies $b_h - u_o = u_l - b_l$. Dividing both sides by u_l and using the definition of market tightness leads to $\theta_l = 1 - (b_h - u_o)/u_l$. Using (31) and the definition of h in (35) gives $q_l = 1 - h + (b_h - u_o) - u_l$. Hence, by substituting into $(\alpha_l + \beta + \lambda)q_l = \theta_l \nu_l u_l$ from (32) in steady state, it follows that $u_l = (\alpha_l + \beta + \lambda)(1 - h + (b_h - u_o))/(\alpha_l + \beta + \lambda + \theta_l \nu_l)$. This yields an expression for rental-market tightness using the earlier equation for θ_l:

$$\theta_l = \frac{(\alpha_l + \beta + \lambda)(1 - h) - \theta_l \nu_l (b_h - u_o)}{(\alpha_l + \beta + \lambda)\,(1 - h + (b_h - u_o))}\,. \tag{A.15}$$

This is pinned down given the targets for h and $T_{sl} = 1/(\theta_l \nu_l)$, the parameters β, λ, and α_l from (A.10), (A.13), and (A.14), and the expression for $b_h - u_o$ in (A.12). Note that ownership market tightness is directly determined by the targets for T_{bo} and T_{so} using $\theta_o = T_{bo}/T_{so}$ from (38). Therefore, both steady-state market tightnesses θ_o and θ_l are determined by the calibration targets.

The steady-state transaction speed ν_o for buyers in the ownership market is directly pinned down by the target for T_{bo} using (38). Since that equation also gives $\theta_l \nu_l = 1/T_{sl}$ and θ_l is known from (A.15), the steady-state rental-market transaction speed for tenants is $\nu_l = 1/(\theta_l T_{sl})$. The matching efficiency parameters μ_l and μ_o are thus set to be consistent with equation (6):

$$\mu_l = \nu_l \theta_l^{\eta_l} \quad \text{and} \quad \mu_o = \nu_o \theta_o^{\eta_o}\,, \tag{A.16}$$

where the parameters η_l and η_o have been targeted directly and θ_l and θ_o are known given the other calibration targets.

Discount rate The steady-state rent equation (A.7) implies $\omega_l \Sigma_l = R/(\rho + \alpha_l + \beta + \lambda + \theta_l \nu_l)$ and the steady-state price equation (A.9) implies $\omega_o \Sigma_h = \rho P_h/(\rho + (1 - \xi)\theta_o \nu_o)$. Substituting into the steady-state free-entry condition (A.5) for investors:

$$\frac{\theta_l \nu_l R}{\rho + \alpha_l + \beta + \lambda + \theta_l \nu_l} = \frac{\rho(1 - \xi)\theta_o \nu_o P_h}{\rho + (1 - \xi)\theta_o \nu_o} + (\rho + \lambda)C\,.$$

Dividing both sides by C, this equation can be restated in terms of the calibration targets for the price-to-rent ratio P_h/R and the ratio of transaction costs to house prices C/P_h:

$$\frac{\theta_l \nu_l \frac{R}{P_h} \frac{P_h}{C}}{\rho + \alpha_l + \beta + \lambda + \theta_l \nu_l} = \frac{\rho(1 - \xi)\theta_o \nu_o \frac{P_h}{C}}{\rho + (1 - \xi)\theta_o \nu_o} + \rho + \lambda\,. \tag{A.17}$$

Over the range $\rho \geq 0$, the left-hand side of (A.17) is strictly decreasing in ρ and approaches zero as ρ becomes large. The right-hand side is strictly increasing in ρ and is non-negative. This means that a valid solution $\rho > 0$ of (A.17) must be unique. Given the behaviour of the left- and right-hand sides, such a solution exists if the left-hand side exceeds the right-hand side when $\rho = 0$, that is, $\lambda(\alpha_l + \beta + \lambda + \theta_l \nu_l)(P_h/R)(C/P_h) < \theta_l \nu_l$, which can be checked.

Equation (A.17) can be solved analytically for the unique economically meaningful solution by reformulating it as a cubic equation. This is done by multiplying both sides by the two denominators appearing in (A.17), which are strictly positive for economically meaningful $\rho \geq 0$. After

rearranging, this leads to:

$$\rho^3 + a_2\rho^2 + a_1\rho + a_0 = 0\,, \quad \text{where} \tag{A.18}$$

$$a_2 = \alpha_l + \beta + 2\lambda + (1-\xi)\theta_o\nu_o\left(1 + \frac{P_h}{C}\right)\,,$$

$$a_1 = (1-\xi)\theta_o\nu_o\left(\lambda + (\alpha_l + \beta + \lambda + \theta_l\nu_l)\left(1 + \frac{P_h}{C}\right)\right) - \left(\theta_l\nu_l\frac{R}{P_h}\frac{P_h}{C} - \lambda(\alpha_l + \beta + \lambda + \theta_l\nu_l)\right)\,,$$

$$a_0 = -(1-\xi)\theta_o\nu_o\left(\theta_l\nu_l\frac{R}{P_h}\frac{P_h}{C} - \lambda(\alpha_l + \beta + \lambda + \theta_l\nu_l)\right)\,.$$

Using the cubic root formula, the solution for ρ is

$$\rho = -\frac{a_2 + K + \frac{a_2^2 - 3a_1}{K}}{3}\,, \quad \text{with} \tag{A.19}$$

$$K = \sqrt[3]{\frac{2a_2^2 - 9a_1a_2 + 27a_0 - \sqrt{\left(2a_2^3 - 9a_1a_2 + 27a_0\right)^2 - 4\left(a_2^2 - 3a_1\right)^3}}{2}}\,,$$

where the cube root K (which has three possible values) is selected so that the expression for ρ yields a positive real number (only one root can have this property).

Given the steady state for ρ, equation (18) implies the steady-state interest rate $r = \rho$.

Mean and standard deviation of credit frictions With r known, the targets for the interest-rate spreads $\hat{s}$ and $\bar{s}$ pin down $z = \hat{s}/r$ and $\mathbb{E}[\,x\,|\,x \leq z\,] = \bar{s}/r$. Using $n = h$ in steady state and equation (28), it follows that:

$$\frac{\hat{s}}{r} = \chi + \sigma\Phi^{-1}(h)\,, \tag{A.20}$$

where $\Phi^{-1}(\cdot)$ is the inverse of the standard Normal distribution function, and χ and σ are the mean and standard deviation of the unconditional distribution of draws of x. Using the properties of the Normal distribution, the mean of x conditional on it being below the threshold z is

$$\frac{\bar{s}}{r} = \mathbb{E}[\,x\,|\,x \leq z\,] = \chi - \sigma\frac{\phi\left(\frac{z-\chi}{\sigma}\right)}{\Phi\left(\frac{z-\chi}{\sigma}\right)} = \chi - \sigma\frac{\phi\left(\Phi^{-1}(h)\right)}{h}\,,$$

where $\phi(\cdot)$ is the standard Normal density function. The equation above uses $h = \Phi\left((z-\chi)/\sigma\right)$ and $(z-\chi)/\sigma = \Phi^{-1}(h)$ from $h = n$ and (28). Subtracting this equation from (A.20) cancels out χ and leaves $(\hat{s} - \bar{s})/r = \left(\Phi^{-1}(h) + \phi(\Phi^{-1}(h))/h\right)\sigma$, which is linear in σ and can be solved as follows:

$$\sigma = \frac{(\hat{s} - \bar{s})h}{\left(\phi\left(\Phi^{-1}(h)\right) + h\Phi^{-1}(h)\right)r}\,. \tag{A.21}$$

The standard deviation σ can therefore be calibrated using the targets for $\hat{s}$, $\bar{s}$, and h, together with the r derived earlier. Given σ, the unconditional mean χ is obtained using (A.20):

$$\chi = \frac{\hat{s}}{r} - \sigma\Phi^{-1}(h)\,. \tag{A.22}$$

Bargaining power In steady state, the equations in (27) imply that $(\rho+\beta)G = (1-\omega_o)\nu_o\Sigma_h - (1-\omega_l)\nu_l\Sigma_l$ and $(\rho+\beta)Y = \rho D$ with $r = \rho$. The steady-state tenure-choice threshold satisfying $G = zY$ is thus $(1-\omega_o)\nu_o\Sigma_h - (1-\omega_l)\nu_l\Sigma_l = \rho z D$. The steady-state rent and price equations (A.7) and (A.9) can be used to write $\omega_l\Sigma_l = R/(\rho + \alpha_l + \beta + \lambda + \theta_l\nu_l)$ and $\omega_o\Sigma_h = \rho P_h/(\rho + (1-\xi)\theta_o\nu_o)$.

Hence, substituting for Σ_l and Σ_h in the steady-state marginal home-buyer condition yields the following equation:

$$\left(\frac{1-\omega_o}{\omega_o}\right)\left(\frac{\rho\nu_o}{\rho+(1-\xi)\theta_o\nu_o}\right)P_h-\left(\frac{1-\omega_l}{\omega_l}\right)\left(\frac{\nu_l}{\rho+\alpha_l+\beta+\lambda+\theta_l\nu_l}\right)R=\rho zD\,.$$

Dividing both sides by R and rearranging to make $(1-\omega_l)/\omega_l$ the subject of the equation:

$$\frac{1-\omega_l}{\omega_l}\equiv\Omega=\left(\frac{\rho+\alpha_l+\beta+\lambda+\theta_l\nu_l}{\nu_l}\right)\left(\left(\frac{1-\omega_o}{\omega_o}\right)\left(\frac{\rho\nu_o}{\rho+(1-\xi)\theta_o\nu_o}\right)-\hat{s}\frac{D}{P_h}\right)\frac{P_h}{R}\,,$$
$$\text{and hence }\ \omega_l=\frac{1}{1+\Omega}\,. \tag{A.23}$$

This equation gives the calibrated value of ω_l given a value of ω_o and the targets P_h/R, D/P_h, and $\hat{s}=\rho z$ together with the other variables determined earlier. Note that this equation can only determine relative bargaining power across the two markets.

Mortgage size and transaction costs The parameters for the mortgage size D and transaction cost C can be determined from the targets for the loan-to-value ratio D/P_h and the ratio of transaction costs to prices C/P_h together with the steady-state value of P_h. Using (A.6) and (A.7), steady-state rents are $R=\omega_l(\rho+\alpha_l+\beta+\lambda+\theta_l\nu_l)/(\rho+\alpha_l+\beta+\lambda+(1-\omega_l)\nu_l+\omega_l\theta_l\nu_l)$. Hence, using this and the target for the price-to-rent ratio P_h/R:

$$D=\frac{D}{P_h}P_h\,,\ \text{ and }\ C=\frac{C}{P_h}P_h\,,\quad\text{with }\ P_h=\omega_l\left(\frac{\rho+\alpha_l+\beta+\lambda+\theta_l\nu_l}{\rho+\alpha_l+\beta+\lambda+(1-\omega_l)\nu_l+\omega_l\theta_l\nu_l}\right)\frac{P_h}{R}\,. \tag{A.24}$$

These can be calculated using the known value of ω_l and the other parameters determined so far.

Warm glow from homeownership Combining steady-state equations (A.6)–(A.9) implies the following expression for the price-to-rent ratio:

$$\frac{P_h}{R}=\frac{\omega_o\left(\rho+\alpha_l+\beta+\lambda+(1-\omega_l)\nu_l+\omega_l\theta_l\nu_l\right)\left(\rho+(1-\xi)\theta_o\nu_o\right)\left(1+\gamma-(\rho+\alpha_h+\beta)C\right)}{\omega_l\rho\left(\rho+\alpha_l+\beta+\lambda+\theta_l\nu_l\right)\left(\rho+\alpha_h+\beta+(1-\omega_o)\nu_o+\omega_o(1-\xi)\theta_o\nu_o\right)}\,.$$

Since all terms in this equation are known except γ, the equation can be rearranged to solve for γ:

$$\gamma=\frac{\omega_l\rho\left(\rho+\alpha_l+\beta+\lambda+\theta_l\nu_l\right)\left(\rho+\alpha_h+\beta+(1-\omega_o)\nu_o+\omega_o(1-\xi)\theta_o\nu_o\right)}{\omega_o\left(\rho+\alpha_l+\beta+\lambda+(1-\omega_l)\nu_l+\omega_l\theta_l\nu_l\right)\left(\rho+(1-\xi)\theta_o\nu_o\right)}\frac{P_h}{R}$$
$$+(\rho+\alpha_h+\beta)C-1\,. \tag{A.25}$$

Duration of the long-term bond The parameter δ that affects the duration of the long-term bond is chosen to match a specific duration M. In steady state, equation (17) implies $y=r=\rho$. The steady-state bond duration $J=1/(\delta+y)=1/(\delta+\rho)$ can therefore be solved for δ using the known value of ρ and the target for M:

$$\delta=\frac{1}{J}-\rho\,. \tag{A.26}$$

Mean reversion of the interest-rate shock A fraction $\Delta=e^{-\psi T}$ of the initial shock to interest rates remains after T years. Given a horizon T and a target for Δ, the mean-reversion parameter ψ is set as follows:

$$\psi=\frac{\log\frac{1}{\Delta}}{T}\,. \tag{A.27}$$

A.4 Solving the model

The system of differential equations solved to simulate the effects of an interest rate shock is:

$$R_t = \omega_l \left(1 + (1-\omega_l)(\theta_{lt}\nu_{lt} - \nu_{lt})\Sigma_{lt}\right) , \tag{A.28a}$$

$$(\rho_t + \alpha_l + \beta + \lambda + (1-\omega_l)\nu_{lt} + \omega_l\theta_{lt}\nu_{lt})\,\Sigma_{lt} = 1 + \dot{\Sigma}_{lt} , \tag{A.28b}$$

$$G_t = z_t Y_t , \tag{A.28c}$$

$$(\rho_t + \beta)G_t = (1-\omega_o)\nu_{ot}\Sigma_{ht} - (1-\omega_l)\nu_{lt}\Sigma_{lt} + \dot{G}_t \tag{A.28d}$$

$$(\rho_t + \beta)Y_t = r_t D + \dot{Y}_t , \tag{A.28e}$$

$$\begin{aligned}\rho_t P_{ht} = \omega_o\big(1 + \gamma - (\rho_t + \alpha_h + \beta)C - (\alpha_h + \beta)\Sigma_{ht} + (1-\omega_o)\big(\theta_{ot}\nu_{ot}\xi_t\Sigma_{it} \\ +(1-\xi_t)\theta_{ot}\nu_{ot}\Sigma_{ht} - \nu_{ot}\Sigma_{ht}\big)\big) + \dot{P}_{ht} ,\end{aligned} \tag{A.28f}$$

$$\begin{aligned}(\rho_t + \alpha_h + \beta + (1-\omega_o)\nu_{ot} + \omega_o(1-\xi_t)\theta_{ot}\nu_{ot})\,\Sigma_{ht} + \omega_o\xi_t\theta_{ot}\nu_{ot}\Sigma_{it} \\ = 1 + \gamma - (\rho_t + \alpha_h + \beta)C + \dot{\Sigma}_{ht} ,\end{aligned} \tag{A.28g}$$

$$\begin{aligned}(\rho_t + \lambda + (1-\omega_o)\nu_{ot} + \omega_o\xi_t\theta_{ot}\nu_{ot})\,\Sigma_{it} + \omega_o(1-\xi_t)\theta_{ot}\nu_{ot}\Sigma_{ht} \\ = \omega_l\theta_{lt}\nu_{lt}\Sigma_{lt} - (\rho_t + \lambda)C - \lambda I_t + \dot{\Sigma}_{it} ,\end{aligned} \tag{A.28h}$$

$$\rho_t I_t = (1-\omega_o)\nu_{ot}\Sigma_{it} + \dot{I}_t , \tag{A.28i}$$

$$\dot{b}_{it} = \kappa I_t , \tag{A.28j}$$

$$\dot{u}_{ot} = (\alpha_h + \beta)(h_t - b_{ht}) + \lambda(1 - h_t - \theta_{lt}u_{lt} + u_{lt}) - \theta_{ot}\nu_{ot}u_{ot} , \tag{A.28k}$$

$$\dot{u}_{lt} = (\alpha_l + \beta)(1 - h_t - \theta_{lt}u_{lt}) + \nu_{ot}b_{it} - (\theta_{lt}\nu_{lt} + \lambda)u_{lt} , \tag{A.28l}$$

$$\dot{h}_t = \beta(n_t - h_t) , \tag{A.28m}$$

$$\dot{b}_{ht} = \alpha_h(h_t - b_{ht}) + \beta n_t - (\nu_{ot} + \beta)b_{ht} , \tag{A.28n}$$

$$b_{ht} = (1-\xi_t)\theta_{ot}u_{ot} , \tag{A.28o}$$

$$b_{it} = \xi_t\theta_{ot}u_{ot} , \tag{A.28p}$$

$$((1-\xi_t)\theta_{ot} - 1)\,u_{ot} + (\theta_{lt} - 1)u_{lt} = 0 , \tag{A.28q}$$

$$n_t = \Phi\left(\frac{z_t - \chi}{\sigma}\right) , \tag{A.28r}$$

$$\nu_{lt} = \mu_l\theta_{lt}^{-\eta_l} , \tag{A.28s}$$

$$\nu_{ot} = \mu_o\theta_{ot}^{-\eta_o} , \tag{A.28t}$$

$$T_{sl,t} = \frac{1}{\theta_{lt}\nu_{lt}} , \tag{A.28u}$$

$$T_{so,t} = \frac{1}{\theta_{ot}\nu_{ot}} , \tag{A.28v}$$

$$T_{bo,t} = \frac{1}{\nu_{ot}} , \tag{A.28w}$$

$$(\delta + y_t)(r_t - y_t) = -\dot{y}_t , \tag{A.28x}$$

$$\rho_t = r_t , \tag{A.28y}$$

$$\dot{r}_t = -\psi(r_t - r) . \tag{A.28z}$$

Most of these equations are taken directly from (6), (7), (15), (16), (17), (18), (27), (28), (30), (35), and (38), as well as (A.1), (A.2), and (A.3) from Appendix A.1. Equation (A.28i) follows from (23), (24), and (25). Equations (A.28k), (A.28l), and (A.28n) follow from (33) and (34) together with the definitions of market tightness in (6) and the homeownership rate in (35), and the population

and housing stock in (31). These can be used to write $q_{ht} = h_t - b_{ht}$ and $q_{lt} = 1 - h_t - \theta_{lt} u_{lt}$. Equations (A.28o) and (A.28p) follow from the definition of ownership-market tightness θ_{ot} in (6) and the fraction ξ_t of investors among all buyers defined in (20). Equation (A.28q) is implied by the market tightness definition from (6) and the population and housing stock in (31).

There are 26 equations in 26 variables in (A.28). These are solved by discretizing the differential equations to difference equations at a daily time frequency. There are 6 state variables, h_t, b_{ht}, b_{it}, u_{ot}, u_{lt}, and r_t. The interest rate r_t is included among these because its initial value is equal to its steady state r plus an exogenous shock ζ. Time derivatives of these state variables in (A.28) are replaced by backward-looking differences divided by the length of a discrete time period. For example, $\dot{h}_t$ is replaced by $(h_t - h_{t-\epsilon})/\epsilon$, where ϵ is the length in years of a discrete time period, which is set to one day ($\epsilon = 1/365$). Time derivatives of non-state variables in (A.28) are replaced by forward-looking differences divided by the length of a discrete time period. For example, $\dot{V}_t$ is replaced by $(V_{t+\epsilon} - V_t)/\epsilon$. With an equivalent system of difference equations, (A.28) can be solved using standard methods to obtain the first-order perturbation around the steady state. The daily solution is time aggregated to report impulse responses at a monthly frequency.