Homeownership and the Cost of Living*

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June 2026

Abstract

How should price indices account for durable goods like housing, which are debt-financed, held for years, and resold? The U.S. Consumer Price Index equates owner costs with rental costs, which often diverge dramatically from the one-period user cost of owner-occupied housing that is based on interest and maintenance costs and subtracts expected home price appreciation. Heterogeneous preferences for owning and transaction costs can reconcile this divergence, but if owning and renting are not perfect substitutes, then rental costs may not capture the costs of owner-occupied housing. In this paper, we derive a price index that measures changes in welfare due to changes in housing costs with a money-metric value function. We allocate the welfare change across years using the time path of changes in non-durable consumption. To implement this index, we elicit households' willingness-to-pay (WTP) for homeownership in a customized survey and find large and heterogeneous WTP. We use the survey and other empirical moments to calibrate a dynamic model of tenure choice and to provide new estimates of the contribution of shelter to the rising cost of living in the U.S. since 2019. A permanent 2 percentage point (p.p.) increase in the mortgage rate causes the shelter price index in our calibrated model to increase by 2.6 p.p. above trend, unlike a rent-based index that (by construction) does not change. Aggregating over all shocks to shelter, the index falls much less than rent during 2019-2022 and rises less quickly than rent from 2022-2024.

*We thank Bnaya Dreyfuss for his incredible assistance with running our survey and Justine Nayral for her outstanding help with the measurement of the user cost. The authors gratefully acknowledge financial support from the Chae Macroeconomic Policy Fund at Harvard University.

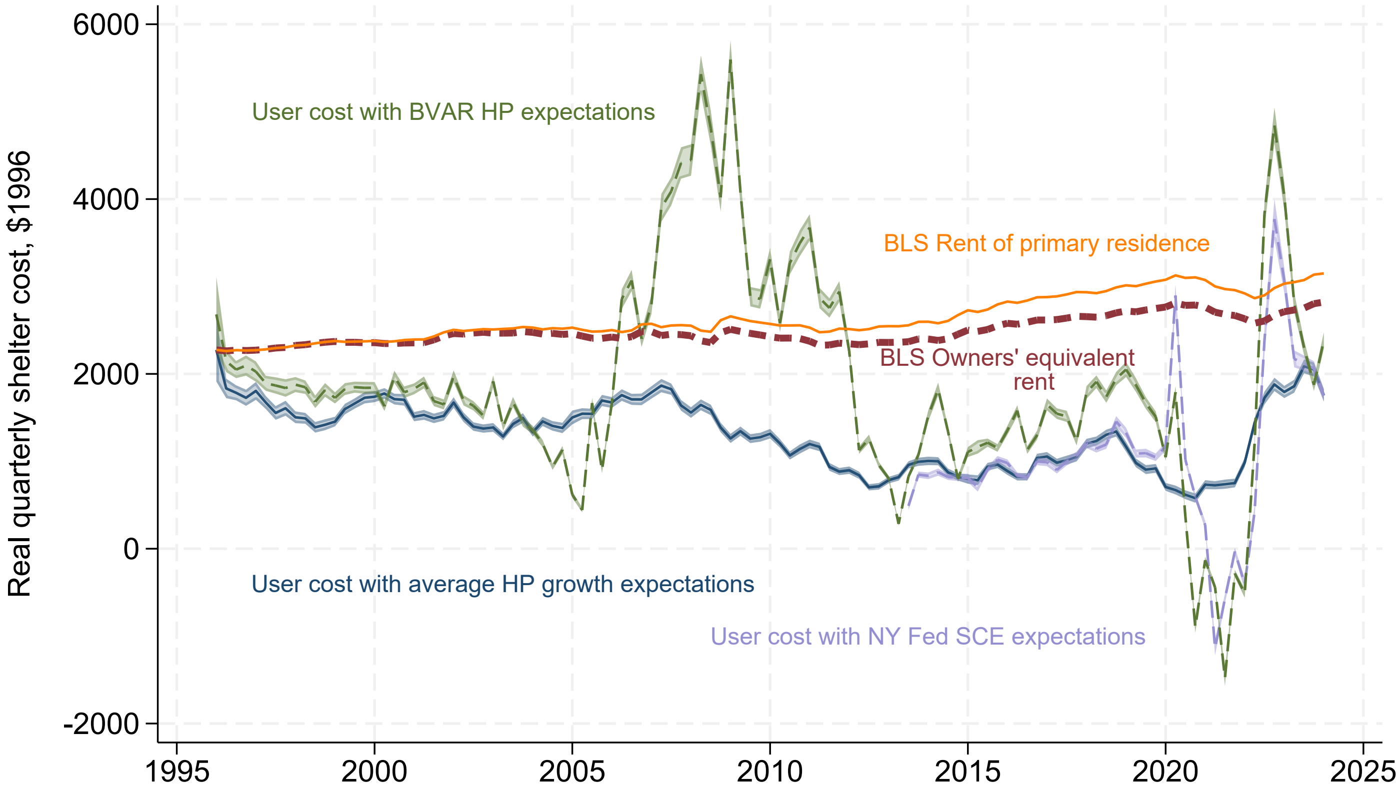
1 Introduction

How should price indices treat durable goods, like housing, that are often debt-financed, owned for many years, and eventually resold? A standard approach follows the logic of a static expenditure function in which durable goods are always rented. Yet, correcting nominal incomes with a rent-based cost of living adjustment may misstate the true change in well-being for a population that contains large numbers of highly indebted owners. Most obviously, an upward jump in mortgage rates may have no impact on observed rents but still lead owners, and especially new buyers, to face higher costs. In this paper, we reconsider the measurement of shelter costs in a consumer price index (CPI) and provide new estimates of their contribution to a rising cost-of-living in the U.S. during the recent inflation cycle.

The treatment of housing in the CPI has substantial importance for the overall path of inflation and hence outcomes ranging from monetary policy to social security cost-of-living adjustments. The cost of primary residences comprises nearly one-third of total expenditure in the current U.S. CPI, divided between a seemingly straightforward 7.5% of rental costs paid by renters and a more complex 25.1% of total spending associated with owners. The CPI measures shelter inflation for owners using the growth rate of actual rents reweighted to match the characteristics of owner-occupied properties (e.g., a higher share of single family properties), referred to as owners' equivalent rent (OER). Owners' equivalent rent differs conceptually from the traditional one-period user cost, which combines maintenance costs, either interest costs or the opportunity cost of forgone financial investment or both, and expected house price appreciation (Steiner, 1961; Poterba, 1984).

The conceptual case for using OER is that in frictionless models, the expected costs of renting must equal the expected costs of owning. Yet historical time series show that rents are far less volatile than user costs (Verbrugge, 2008). Figure 1 shows rental rates and one-period user costs for the U.S. over 1996-2025, scaled to match average rent in 1996Q1 (see Appendix A for details of the data construction). Both CPI rent of primary residence (solid orange line) and OER (dashed red line) trend up relatively smoothly. The remaining lines show the one-period user cost of housing with different assumptions for expected real house price growth. The solid blue line sets expectations to be the average growth rate from 1996-2025. The dashed green line bases

Figure 1: Rent, Owners' Equivalent Rent, and User Cost



Notes: See Appendix A for details of the user cost series. We set the dollar value of the rent and owners' equivalent rent series to equal average rent in the CEX in 1996Q1 and deflate all measures using the non-shelter CPI.

expectations on a Bayesian VAR described later in the paper. The dashed purple line pulls expectations from the Federal Reserve Bank of New York Survey of Consumer Expectations. The user cost measures exhibit more high frequency volatility than rent or OER. They also all rise sharply in 2022 when mortgage rates increased; the VAR and survey-based user costs rise particularly sharply because they embed a contemporaneous reduction in house price growth expectations. OER instead incorporates neither changes in mortgage rates nor changes in expectations. The user cost measures are also typically lower than the rent measures, because of sizable housing price appreciation over the time period.

We begin by noting that the time series divergence between rents and user costs reflects two key aspects missing from standard models. First, owning and renting are not perfect substitutes, and people differ in their preference for owning or renting. Second, the ownership decision is inherently dynamic, because of transaction costs and long-term contracts. Consequently, the one-period user cost does not equal the cost of owning for incumbent owners.[1] The purpose of our paper is to define and measure the contribution of shelter costs to the cost-of-living taking into account these two aspects of homeownership.

We first relax the assumption that rent and owning are perfect substitutes. We characterize shelter inflation in Section 2 in a model with no transaction costs, but where households differ in their non-pecuniary taste for owning, which we denote θ. These tastes may evolve over the lifecycle and could reflect a desire to freely customize the property or specific house or neighborhood characteristics associated with homeownership. The marginal buyer equates rental costs with her user cost minus her non-pecuniary utility from owning. Changes in homeownership rates imply that the identity of the marginal home buyer changes, rationalizing a time-varying wedge between user costs and rents.

We define shelter inflation as the required transfer to offset the change in money-metric utility when shelter costs change. In this simple framework, changes in rents correctly characterize shelter inflation when homeownership and hence the θ of the marginal buyer remains fixed. But shelter inflation is not in general independent of changes in mortgage rates. Higher rates directly increase the cost of owning, a first order contribution to shelter inflation. Higher rates also reduce the number of home owners and hence the consumer surplus of households that would have owned at lower rates but now rent. The loss in surplus is a second order term and depends on the change in homeownership and the distribution of tastes.

We next incorporate transaction costs and long-term mortgage contracts. In this case, no explicit per-period shelter price exists. As in Bajari, Benkard and Krainer (2005), the undisputed measure of intertemporal welfare is the value function consisting of the present value of utility from nondurable consumption and housing. In Section 3, we characterize this value function in money-metric terms. We then derive the per-period transfer required to offset changes in nondurable consumption and housing utility due to changes in shelter costs. That transfer represents the price index contribution from housing.

An increase in the cost of owning has two effects. First, the intertemporal budget constraint

[1]Two other possible explanations for the divergence of rents and user costs are the mismeasurement of expectations and time-varying risk premium. Neither can plausibly reconcile the time series behavior, nor undercut the direct contribution of a rising mortgage rate at the end of the sample.

implies that a change in the present value of spending on shelter requires a matching change in the present value of nondurable consumption. We allocate this present value across periods using agents' intertemporal marginal propensities to consume (Auclert, Rognlie and Straub, 2024). With consumption smoothing, this spending change generates a one-time persistent jump in the price index whenever shelter costs unexpectedly change. Without consumption smoothing, the price index response will depend on the path of changes in certainty-equivalent consumption. Second, housing utility falls if homeownership declines (assuming that the marginal homeowner has a preference for owning), which mirrors the decline in consumer surplus in the simple model in Section 2. The price index path thus preserves the interpretation of the minimum per-period expenditure required to keep total utility fixed, as in the static case.

We then use our theory to construct price indices. We provide direct evidence of heterogeneity in θ by eliciting preferences for homeownership in a customized survey, described in Section 4. The survey provides respondents with a comparison of the cost of owning or renting over ten years and asks how much (if any) terminal wealth they would forgo to own rather than rent (where hypothetical terminal wealth in the renting scenario fluctuates due to the returns on investment of their foregone down payment). The distribution of elicited willingness-to-pay to own (WTP) has a positive mean and is right skewed. As our model suggests, owners have higher average WTP than renters. We also find a hump-shaped WTP over the life-cycle, with a peak for household heads aged 45-54. A follow-up survey conducted one month later finds relatively stable individual preferences, which increases confidence in the survey.

In principle, the dynamic responses of nondurable consumption, homeownership, and the covariance of ownership with utility θ to changes in shelter cost are sufficient to compute the price index. But these are complex empirical objects. We therefore build a quantitative life-cycle model, disciplined by the survey and other key empirical moments, to assess welfare changes. Section 5 augments the static model of Section 2 with moving costs that generate long tenures, 30 year fixed-payment mortgages (with an option to refinance), and heterogeneity in the propensity to move and in liquidity constraints that vary with age. The decision to own a home reflects four forces: (i) preference for owning θ; (ii) the likelihood of receiving exogenous mobility-related shocks (since transaction costs are higher for owners), (iii) the ability to make a down payment, and (iv) the current and expected paths of costs associated with owning and renting.

We calibrate the model in Section 6. We use our survey to estimate a life-cycle process for the preference for owning, θ. We assume that θ typically increases with age but that preference may "crash" with an age-specific probability as individuals choose to downsize. We calibrate liquidity constraints to match age-specific population shares with assets sufficient to make a minimum down payment. We base several other parameters on external moments, including trend rent growth, housing transaction costs, and discount and mortgage rates. We estimate the remaining parameters jointly to minimize the distance between several key steady state moments of the model and their empirical counterparts. These internally estimated parameters include age-specific likelihoods of receiving a "nudge" to move, the transition rate between being subject to a nudge and not, and the flow cost of owning. The empirical moments include the willingness-to-pay (WTP) premium for owners from our survey, rent-to-rent, rent-to-own, own-to-rent, and own-to-own transition rates, and the overall homeownership rate.

Our first quantitative exercise evaluates the difference between our price index and alternatives when mortgage rates increase. In Section 7 we analyze a permanent two percentage point increase in the mortgage rate with rents remaining fixed. Both house prices and homeownership endogenously drop in the first year of the rate increase and continue to decline thereafter. Our shelter price jumps 2.6% above trend when the mortgage rate increases, mostly reflecting higher pecuniary costs. Other possible price indexes deliver sharply different messages about the change in consumer welfare from the rate increase. By construction, a price index based on OER does not change since rents do not change. The one-period user cost increases by 40%, reflecting the higher mortgage rate, its application to all rather than only new buyers, and the anticipated future housing price decline due to the slow transition from owning to renting.

Our second exercise is the construction of a historical cost-of-shelter index starting in 2019. For this exercise, we make the model exactly match time series of house prices, rents, mortgage rates, non-shelter inflation (which affects mortgage balances), and expectations of each obtained from financial markets or an auxiliary Bayesian Vector Autoregression. These variables determine tenure choices of the households in the model. To ensure consistency with the overall homeownership rate, we also give households time-varying "preference shocks" that affect the decision to own or rent but that do not directly affect the price index.

We report the historical price index in Section 8. Like real rents, the index falls in 2021-2022 and then rebounds in 2023-2024. However, our index falls by less than rent alone and rebounds commensurately less. This dampening reflects the fact that two-thirds of the population own rather than rent and hence experience no direct change in their shelter expenditure when rents fluctuate. Among owners, surprise non-shelter inflation erodes real mortgage balances and improves welfare in 2021 and, especially, 2022, while rising mortgage rates exert an inflationary force starting in 2022. However, rising mortgage costs directly affect new buyers only and hence take time to filter into the full population of owners.

We also report alternative indexes that remove the effect of surprises in real house prices or non-shelter inflation on incumbent owners. One perspective is that these changes affect asset valuations (of the house and mortgage rate) and do not belong in a consumption price index. Removing the contribution of the surprise increase in house prices shifts shelter inflation up, as it removes the benefit to incumbent owners that otherwise offsets the higher cost to new buyers. Removing the contribution of the surprise in non-shelter inflation also shifts shelter inflation up, as the gains to households from lower real mortgage balances no longer count in welfare.

Section 9 concludes by summarizing directions for future research.

A Short History of Shelter Indices and Other Related Literature. Price index statisticians have debated for a century how to treat housing. The BLS published its first national CPI in the Monthly Labor Review in 1921. Between 1921 and 1953, rents were a major component of the series, but homeownership costs such as mortgage payments and taxes were not. BLS justified this treatment in part because the original index focused on "moderate income" workers, who were poorer and less likely to own in a society in which the homeownership rate in 1940 was just 44%.

In 1953, the Monthly Labor Review announced the switch from the "Old Index," which only included households in which the primary earner made less than $2,000 per year ($24,000 in 2025 dollars) to the "New Index," which included households with earnings up to $10,000 ($122,000 in 2025 dollars). The inclusion of wealthier households more likely to own their primary residence and an overall homeownership rate that reached 61% in 1960 made the exclusion of owners' costs untenable. The "New Index" used an average of different housing related prices in the category of "homeowners' expenditures", including the sales price of the home (6.08% of the total spending bundle), real estate taxes (1.08%), mortgage interest rates (1.64%) and property insurance rates (0.2%). Repairs and maintenance were a distinct category, including spending by renters as well, and an astonishing 0.78% of the entire CPI spending bundle was allocated to "replacing the hot water heater." As the New Index replaced the Old, shelter's budget share rose from 11% to 18%.

The Stigler Commission of 1961 reviewed America's price indices and criticized the expenditure formula in the "New Index", charting a path that would eventually lead to the change to OER in 1983. The staff report on "Consumer Durables" favored a user cost approach that involved "depreciation," "interest," "incidental purchase costs," "taxes," "maintenance and repair" and "insurance", but also noted the theoretical equivalence to the rental rate (Steiner, 1961). Subsequent papers by economists affiliated with BLS and the Office of Housing and Urban Development explored both the user cost and OER, including key contributions by Dougherty and Order (1982) and Gillingham (1983), with Gillingham and Lane (1982) giving the official version for the BLS.[2] These papers recognized but did not resolve the time series differences between the user cost and rent. Given the additional implementation issues required to compute the user cost, such as house price expectations and discount rate assumptions, after 1983, BLS simply opted for OER.

The debate among statistical agencies remains unresolved. The most recent *Consumer Price Index Manual* of the United Nations calls the treatment of owner-occupied housing "one of the most difficult issues faced by CPI compilers" (International Monetary Fund et al., 2020, p. 245) and outlines four approaches in use internationally: user costs, rental equivalence, a "payments" approach that includes all expenditure specific to owner-occupiers, and an "acquisitions" approach similar to the treatment of other durables that includes net purchases of dwellings and new construction. The *Manual* notes that many countries make *ad hoc* adjustments to these approaches,

[2]Gillingham and Lane (1982) also concisely describe the formula used to incorporate housing prices and interest rates prior to the change to OER: "the weight for home purchase is the purchase price for homes bought in the survey year, less the sales price for homes sold, plus transactions costs for these purchases and sales," while "the weight for 'contracted mortgage interest cost' is the amount of interest that survey period borrowers promise to pay during the first half of the term of their mortgage loans," which "includes future payments". Determining the change in price meant that a "new selection of recently sold homes must be used each month" and "the average price of this month's set of homes must be compared-after adjustment for quality difference-to the average price for last month's set." For changes in mortgage rates, the Federal Home Loan Bank provided data on "all mortgages closed during the first 5 business days each month by a sample of savings and loans and other lenders," and then "the rate change is estimated using quality control cells similar to those used for house prices."

such as excluding the capital gain component of the user cost.[3] International Monetary Fund et al. (2025, chapter 10) discuss a fifth approach of using the maximum of OER and the user cost. In our view, this debate remains unsettled because of the absence of a theoretical framework that reconciles the behavior of rents and user costs and, more deeply, that durable goods such as housing do not neatly fit into the economic approach to consumer price indexes. Acknowledging that our full approach may pose implementation difficulties for statistical agencies that seek transparent methodologies easily communicated to the public, we hope that the conceptual framework will stimulate new practical resolutions.[4] Nonetheless, we find a substantial gap between our price index and a first-order approach that applies shelter cost changes to the steady state distribution of renters and owners, suggesting some caution in applying simpler variants.

The academic literature has recognized the tension between an intertemporal world and static price indexes but reached different conclusions. Alchian and Klein (1973) argued that a price index used to measure inflation must include asset prices. Reis (2005) offers a modern treatment of what he calls "dynamic inflation" but retains the assumption for durable goods of zero transaction costs, so that the one-period user cost applies. While we sympathize with the theoretical purity of including all asset prices in a dynamic world in which intratemporal and intertemporal prices receive equal treatment, we confine our measurement to shelter, where these considerations are unavoidable and which already receives special treatment in the CPI. Our price index that excludes surprise capital gains offers one potential bridge. Our approach of distributing the change in the value function across periods is the reverse of Baqaee, Burstein and Koike-Mori (2024), who seek to translate per-period price changes into changes in the value function. They allow for more flexibility in the consumption-savings problem but also restrict consideration of durables to the one-period user cost. Bolhuis et al. (2024) and Astin and Leyland (2023) argue that interest rates

[3] Dougherty and Order (1982) specifically criticize this approach on the grounds that it makes the cost of owner-occupied housing erroneously non-neutral to overall trend inflation, which would increase nominal mortgage rates as well as expected house price growth equally.

[4] The U.S. debate has remained relatively quiet since the change to OER. Notably, the Boskin Commission saw far less to criticize about the housing cost methodology and even recommended that "the price of durables, such as cars, should be converted to a price of annual services, along the same lines as the current treatment of the price of owner-occupied housing" (Boskin, 1996). The Boskin Commission highlighted two major issues with housing in the CPI: "not to revise the treatment of housing costs for 1984 and earlier years," which meant that "the level of the CPI-W is 4.7 percent above the CPI-U X1, a measure of the cost of living based on the same primary data sources and similar methodology, but with a consistent treatment of housing costs," and the CPI's "measure of shelter rent is upward biased by neglecting the increase in the quality of apartments per square foot."

affect the cost of living, but differ in whether the CPI should incorporate them directly.

Academics and practitioners have also debated how to measure shelter costs for renters, since most rental contracts are long-term. Under current practice, the CPI measures average rent growth for all renters (with a lag structure for sampling reasons). Ambrose, Coulson and Yoshida (2023) advocate for using rent growth of new tenants only. Our methodology can accommodate either extreme, depending on when agents change their nondurable consumption.

The link between the price index and the change in the intertemporal budget constraint builds on earlier results related to consumption out of housing wealth (Sinai and Souleles, 2005; Campbell and Cocco, 2007; Guren et al., 2020) or more general asset price fluctuations (Fagereng et al., 2024). Our measure accords with these papers in incorporating house price changes only insofar as agents will transact in the future and therefore adjust their consumption today. Furthermore, like Fagereng et al. (2024), our welfare measure includes the present value of changes in nondurable consumption expenditure; our analysis builds on theirs by including heterogeneity in the non-pecuniary component of shelter utility, by converting the value function change into a per-period price index, and by using a simulated model that allows measurement in real-time and in settings without the required data-intensive history of transactions *ex post*. Relative to Berger et al. (2017) and Greaney, Parkhomenko and Van Nieuwerburgh (2025), our quantitative model simplifies aspects of the consumption-saving problem such as life cycle dynamics or uninsurable idiosyncratic income risk in order to focus more sharply on housing dynamics in general equilibrium.

Like us, several articles have incorporated a preference for owning over renting into a tenure choice framework (Piazzesi and Schneider, 2016; Kaplan, Mitman and Violante, 2020). The closest treatment is in Greenwald and Guren (2025), who also use heterogeneity in this parameter to generate a downward-sloping demand curve for owner-occupied housing. We contribute to this modeling framework by using strategic survey questions (in the terminology of Ameriks et al. (2020)) to provide explicit discipline on the level of and heterogeneity in this preference. The non-pecuniary preference for owning due to e.g. customization or location preference likely qualitatively distinguishes housing from other durable goods such as cars. This feature, along with the much lower depreciation rate of housing, explains our focus on this particular type of durable, although our results could apply more broadly.[5]

[5] For example, the Bureau of Economic Analysis depreciates autos at a rate of 23% per year, furniture at 14%

Last, given its weight in the CPI, the debate over measurement of shelter costs inevitably touches on the practice of monetary policy. Indeed, one motivation for the 1983 change to OER may have been to remove the direct feedback from higher interest rates into inflation. While our measure restores this link, we think the appropriate response involves changing the monetary policy target rather than distorting measurement of the cost-of-living. For example, changes in mortgage rates bear similarity to classic cost-push shocks that policy may look through, similar to the existing focus on indexes that exclude food and energy. Our results also caution against the weight assigned to rent in a population where two-thirds of households own rather than rent their primary residence. Bianchi, McKay and Mehrotra (2025) make a distinct and complementary argument that monetary policy should down-weight rental inflation because housing is inelastically supplied.

2 Static Model with Preference Heterogeneity

This section presents an equilibrium model of house prices and homeownership where households have heterogeneous preferences for owning and renting. Our goal here is to examine the link between rents and the user cost of housing, and to develop formulas for measuring inflation when rent, interest rates, or other shelter-related variable change. To promote clarity, we omit elements such as moving costs, fixed rate mortgages, or liquidity constraints that we introduce in Section 5.

2.1 Setup

The economy consists of a continuum of agents indexed by their preference for owning θ, with $\theta \sim F_\theta(\theta)$. Each agent consumes one unit of housing and freely chooses whether to rent or own each period. We let $\mathcal{H}_t(\theta)$ denote an indicator function equal to 1 if an agent of type θ owns and 0 otherwise and $h_t = \int \mathcal{H}_t(\theta)\, dF_\theta(\theta)$ the homeownership rate.

Prices. We denote market rent by R_t. Since all housing units are identical, R_t also corresponds to owners' equivalent rent (OER). Owners make a down payment $(1-\ell_t)\, P_t^H$, where ℓ_t is the loan-to-value ratio and P_t^H the price of a house, and then make interest payments given mortgage rate i_t of $i_t \ell_t P_t^H$ and a payment f_t to cover property taxes, insurance, maintenance, and depreciation.

per year, and all consumer durable goods (which exclude housing) at 20% per year, in contrast to just over 1% per year for housing. The stock of housing also exceeds the value of all consumer durables by a factor of 3.

Owners then resell their house at the beginning of the next period, recouping $P_{t+1}^H - \ell_t P_t^H$. If agents discount the sale proceeds using a discount factor $\beta_{t,t+1}$, then the cost of owning can be written as the user cost $\rho_t P_t^H$, with:

$$\rho_t \equiv (1-\ell_t)(1-\beta_{t,t+1}) + \ell_t i_t + \frac{f_t}{P_t^H} - \beta_{t,t+1}\mathbb{E}_t\left[\frac{P_{t+1}^H - P_t^H}{P_t^H}\right]. \tag{1}$$

The user cost consists of a weighted average of the discount and mortgage rates, plus the flow carrying cost, less the expected discounted house price appreciation, all scaled by the house price. The bundling of home-buying with mortgage financing makes mortgage costs an inextricable component of the cost of homeownership.

Preferences. We normalize the consumption-equivalent utility benefit from renting to 0. Thus, flow net utility of renters is $U_t(\theta|\mathcal{H}_t(\theta)=0) = -R_t$. Agents differ in their non-pecuniary consumption-equivalent utility from owning. An agent of type θ receives consumption-equivalent utility $\theta\bar{R}_t$, where the scalar $\bar{R}_t$ denotes rent along the balanced growth path. Thus, an agent with $\theta = 0$ receives no additional utility from owning relative to renting. Positive values of θ may reflect owners' ability to customize their houses, a desire for neighborhoods dominated by owner-occupied housing, or privacy from landlord intrusion, among other factors. The net utility for an owner over the period in money-metric terms is therefore $U_t(\theta|\mathcal{H}_t(\theta)=1) = \theta\bar{R}_t - \rho_t P_t^H$. With probability δ_θ each period an agent draws a new θ from the distribution $F_\theta(\theta)$, which we assume is everywhere differentiable.

Supply. The details of the supply side do not matter to our main result in Proposition 2, since the price index requires only equilibrium prices. However, they allow us to characterize the balanced growth path and to consider equilibrium outcomes that involve changes in the supply curve, as we do in Lemma 2.

We treat market rents as exogenous and specify a supply curve between rental and owner-occupied units. The price of a rental unit depends on the inverse "capitalization rate" c_t:

$$c_t = \frac{P_t^R}{R_t}. \tag{2}$$

"Private equity firms" can convert a rental to an owner-occupied unit at a cost $g(h)$ proportional to the value of a rental building, with $g'(h) > 0$. The function $g(h)$ may reflect the cost of literal conversion from rental to owner-occupied, or, with depreciation, the cost of changing the mix of new residential investment across these categories.

2.2 Equilibrium

There are three equilibrium conditions. The first defines a cutoff value θ_t^* at which an agent is indifferent between renting and owning:

$$-R_t = \theta_t^* \bar{R}_t - \rho_t P_t^H \Longrightarrow \rho_t P_t^H = R_t + \theta_t^* \bar{R}_t. \tag{3}$$

According to equation (3), the user cost equals market rent shifted by $\theta_t^* \bar{R}_t$. With a degenerate distribution of θ and an interior value of the homeownership rate, this equation would require that market rent perfectly tracks the user cost.

With heterogeneity in θ, market rent can move differently from the user cost as the cutoff value θ^* varies. Thus, preference heterogeneity can resolve the divergence between the time series of rents and user costs. Section 5 will introduce additional sources of heterogeneity (in expected duration and liquidity) that will make the indifference condition multidimensional; at this point, the taste for homeownership (θ) provides the only source of heterogeneity.

The second equilibrium condition requires landlords to be indifferent between operating a building as a rental and converting it to an owner-occupied unit:

$$c_t R_t = P_t^R = P_t^H - g\left(h_t\right) c_t R_t \Longrightarrow P_t^H = \left(1 + g\left(h_t\right)\right) c_t R_t. \tag{4}$$

Combining equations (3) and (4) relates θ^* to the homeownership rate:

$$\theta_t^* = \left(R_t / \bar{R}_t\right) \left(\left(1 + g\left(h_t\right)\right) c_t \rho_t - 1\right). \tag{5}$$

Market clearing gives the third equilibrium condition:

$$h_t = 1 - F_\theta\left(\theta_t^*\right). \tag{6}$$

Equations (5) and (6) determine θ^* and h as functions of the conversion cost function $g(h)$, the capitalization rate c, the user cost component ρ, and the preference distribution F_θ. Let $X_t(\theta)$ denote shelter expenditure, with $X_t\left(\theta | \theta < \theta_t^*\right) = R_t$, $X_t\left(\theta | \theta \geq \theta_t^*\right) = R_t + \theta_t^* \bar{R}_t$. We have the following result (see Appendix B.1):

Proposition 1 *There exists a balanced growth path with* $\bar{R}_{t+1}/\bar{R}_t = 1+\mu$, $\ell_t = \ell$, $i_t = i$, f_t/P_t^H *fixed,* $c_t = c$, $\rho_t = \rho$, *and* $R_t = \bar{R}_t$. *Along this balanced growth path, the cutoff* θ^*, *the homeownership rate* h, *and detrended shelter expenditure* $X_t(\theta)/\bar{R}_t$ *for each type* θ *are all constant.*

2.3 Shelter Inflation

With $\theta \neq 0$, renting and owner-occupied housing become distinct varieties in the overall category of shelter. Following the economic approach to price indexes (see e.g. International Monetary Fund et al., 2025, chapter 5) or "Konüs index", we define the change in the composite price of shelter as the pecuniary transfer required to keep utility fixed as costs change.[6] Using equation (3), equilibrium utility is:

$$U_t(\theta) = \begin{cases} -R_t, & \theta < \theta_t^* \Rightarrow \mathcal{H}_t(\theta) = 0, \\ (\theta - \theta_t^*)\bar{R}_t - R_t, & \theta \geq \theta_t^* \Rightarrow \mathcal{H}_t(\theta) = 1. \end{cases} \tag{7}$$

We first define the price change for a single type with $\theta_{t+1} = \theta_t$ as the transfer required to keep utility fixed when shelter costs change:

$$P_{t+1}(\theta) - P_t(\theta) = U_t(\theta) - U_{t+1}(\theta). \tag{8}$$

Using equations (3) and (7):

$$P_{t+1}(\theta) - P_t(\theta) = \begin{cases} R_{t+1} - R_t, & \mathcal{H}_t(\theta) = \mathcal{H}_{t+1}(\theta) = 0, \\ R_{t+1} - R_t + \left(\theta_{t+1}^*\bar{R}_{t+1} - \theta_t^*\bar{R}_t\right) - \theta\left(\bar{R}_{t+1} - \bar{R}_t\right), & \mathcal{H}_t(\theta) = \mathcal{H}_{t+1}(\theta) = 1, \\ R_{t+1} - R_t + (\theta - \theta_t^*)\bar{R}_t, & \mathcal{H}_t(\theta) = 1, \mathcal{H}_{t+1}(\theta) = 0, \\ R_{t+1} - R_t - \left(\theta - \theta_{t+1}^*\right)\bar{R}_{t+1}, & \mathcal{H}_t(\theta) = 0, \mathcal{H}_{t+1}(\theta) = 1. \end{cases}$$

The first line gives the required transfer for types who rent in both periods, the second line the transfer for types who own in both periods, the third line is the transfer for types who own in t and rent in $t+1$, and the fourth line provides the transfer for types who rent in t and own in $t+1$.

[6] The economic approach to index number theory typically expresses inflation using the difference in the expenditure required to achieve utility $U_t(\theta)$ at the old and new prices. This approach is equivalent to ours if there exists an outside good C_t with price normalized to 1, since the difference $U_t(\theta) - U_{t+1}(\theta)$ then equals the change in expenditure required to keep total utility inclusive of the outside good fixed. Section 3 explicitly introduces an outside good. We also defer discussion of changes to other factors that affect allocations, such as shifts in the distribution of preferences for owning.

The aggregate price change is the total transfer:

$$P_{t+1} - P_t = \int_\theta P_{t+1}(\theta) - P_t(\theta)\, dF_\theta(\theta)\,. \tag{9}$$

The reshuffling of θs as agents take new draws from $F_\theta(.)$ creates winners and losers but does not change the required aggregate transfer: equation (9). We can now state the main results of this section concerning shelter inflation:

Proposition 2 *If there is a change so that $\theta^*_{t+1} \geq \theta^*_t$, then the aggregate transfer to keep utility fixed is:*

$$P_{t+1} - P_t = \overbrace{\left(R_{t+1} - R_t\right)}^{\text{Rent change}} + \overbrace{\left(h_{t+1}\theta^*_{t+1}\bar{R}_{t+1} - h_t\theta^*_t\bar{R}_t\right)}^{\text{Additional owner costs}} - \overbrace{\left(\mathbb{E}_\theta\left[\mathcal{H}_{t+1}(\theta)\,\theta\bar{R}_{t+1}\right] - \mathbb{E}_\theta\left[\mathcal{H}_t(\theta)\,\theta\bar{R}_t\right]\right)}^{\text{Non-pecuniary utility change}},$$

where: $\mathcal{H}_t(\theta) = \mathbb{I}\{\theta \geq \theta^*_t\}$.

The first term in Proposition 2 is the change in market rent. The second term is the change in the additional costs of owning, due to changes in θ^* or a user cost-rent ratio above one. The third term is the change in non-pecuniary utility for agents who previously owned and now rent.

One can also arrive at Proposition 2 by simply defining the date t price as the income amount equivalent to shelter utility U_t: $P_t = -U_t = -\int U_t(\theta)\, dF_\theta(\theta)$. With this definition and Proposition 1, we have the following result:

Lemma 1 *Gross inflation on the balanced growth path is:*

$$\frac{P_{t+1}}{P_t} = 1 + \mu.$$

Thus, OER correctly captures shelter inflation on the balanced growth path.

Lemma 2 elucidates the implications in three other special cases.

Lemma 2 *(i) Suppose $\theta = \bar{\theta}$ for all agents. Then:*

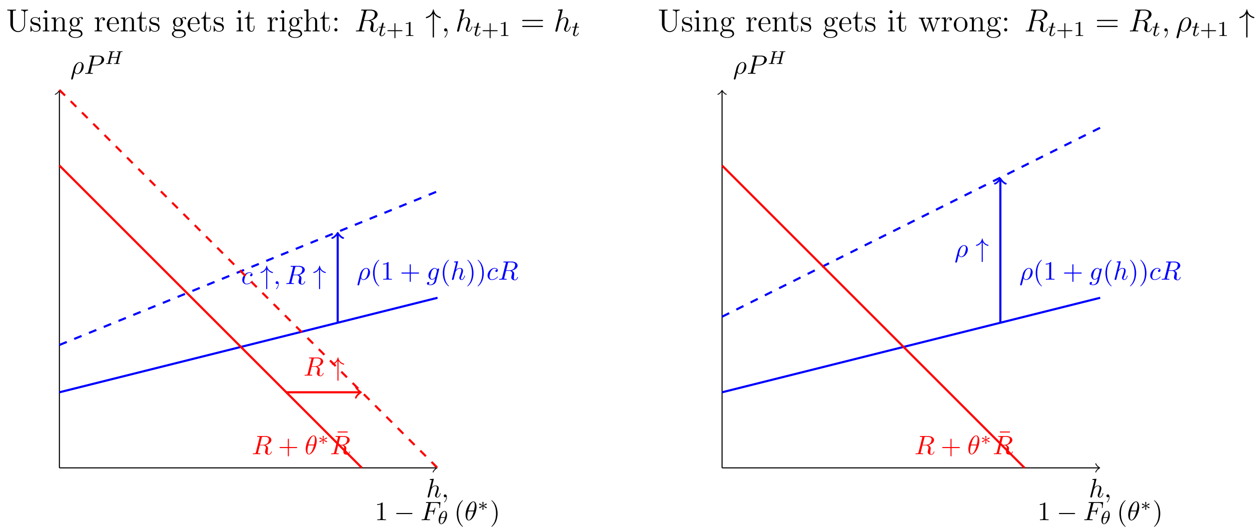
$$P_{t+1} - P_t = R_{t+1} - R_t. \tag{10}$$

(ii) Suppose $R_{t+1} \geq R_t$, $g(.), \rho, \bar{R}$ do not change, and c adjusts such that $h_{t+1} = h_t$.[7] Then:

$$P_{t+1} - P_t = R_{t+1} - R_t. \tag{11}$$

[7] That is, given initial θ^*_t, h_t, $c_{t+1} = \frac{1+\theta^*_t\bar{R}_{t+1}/R_{t+1}}{(1+g(h_t))\rho_t}$.

Figure 2: Illustration of Lemma 2



(iii) Suppose $i_{t+1} > i_t$ unexpectedly and (in expectation) permanently and $g(.), c, R, \bar{R}$ do not change. Then:

$$P_{t+1} - P_t = \overbrace{h_{t+1}\left(\theta^*_{t+1} - \theta^*_t\right)\bar{R}}^{\textit{Owner costs}} + \overbrace{\left(h_t - h_{t+1}\right)\mathbb{E}_\theta\left[\theta - \theta^*_t | \theta^*_t \leq \theta < \theta^*_{t+1}\right]\bar{R}}^{\textit{Extensive margin consumer surplus}}. \tag{12}$$

Part (i) removes preference heterogeneity by fixing $\theta = \bar{\theta}$ for all agents. In this case, for any interior homeownership rate utility is $-R_t$ whether an agent owns or rents (see equation (7)) and using OER again gets the change in the shelter price right (the second and third terms in Proposition 2 cancel). However, equation (3) shows that this case cannot reconcile the time series differences between rent and the user cost.

Heterogeneity in θ can reconcile the time series of user costs and rent, but that heterogeneity also introduces additional terms into the price index, which are captured by parts (ii) and (iii) of Lemma 2. Part (ii) considers a change in market rents with no change in homeownership and zero trend rent growth. In this simple model, using OER for owners then still gets the contribution of shelter inflation right, because the absence of transaction costs forces the user cost to rise as well.[8] The left panel of Figure 2 demonstrates that when homeownership doesn't change, the shift right in the downward-sloping line exactly equals the change in the user cost.

[8] When $\bar{R}_{t+1} = \bar{R}_t$, rent change on the balanced growth path is zero, as is total shelter inflation. Non-zero trend rent growth introduces the additional term $\mathbb{E}_\theta\left[\theta | \theta \geq \theta^*_{t+1}\right]\left(\bar{R}_{t+1} - \bar{R}_t\right)$ coming from the change in non-pecuniary utility for owners. This term arises because trend growth implies rents grow faster than the rest of the economy (the numeraire) and a balanced growth path requires non-pecuniary utility from owning to be a fixed proportion of trend rent and hence a growing share of the total economy.

Part (iii) of Lemma 2 and the right panel of Figure 2 consider a change in the user cost, due to an unexpected and (in expectation) permanent increase in the mortgage rate. Using OER now gets shelter inflation wrong, since by assumption market rents have not changed.[9] Intuitively, a slight rewriting of the latter two terms in Proposition 2 shows two contributions: $h_{t+1}\left(\theta^*_{t+1}-\theta^*_t\right)$, the increase in the user cost for those that continue to own after the interest rate increase, and $(h_t - h_{t+1})\,\mathbb{E}_\theta\left[\theta-\theta^*_t|\theta^*_t \leq \theta < \theta^*_{t+1}\right]\bar{R}_t$, the foregone consumer surplus as agents who previously owned now rent. The latter term is second order. The reason is selection; the agents induced to change tenure had less *ex ante* surplus, which in this frictionless model means θ close to θ^*_t. This logic echoes the standard result that substitution across products has a second-order effect on the price index (Deaton and Muellbauer, 1980).

3 Price Index with Transaction Costs and Dynamics

Conventional price indexes arise from the problem of a static expenditure function as in Section 2. The analog in a dynamic setting with transaction costs is the change in the value function. However, this object is not directly observable, nor is it comparable to conventional price indexes, which measure the transfer required to hold period utility — not the present value of utility — fixed when prices change.

This section has four objectives. First, we nest a dynamic tenure choice decision in a joint maximization problem with non-shelter consumption in order to rigorously define consumption-equivalent non-pecuniary utility from owning. Since our focus remains on tenure choice and the welfare implications of changes in shelter costs, we make assumptions in the main text that keep the choice of non-shelter consumption relatively simple. Second, we characterize the effect of shelter costs on the value function in terms of the paths of non-shelter consumption expenditure and tenure choice and the distribution of the preference-for-owning θ. Third, we convert the value function change into a per-period price index impulse response comparable to the impulse response of a static price index. The impulse response depends on the change in lifetime expenditure

[9] Of course, in general equilibrium a change in the user cost could affect rents (Gete and Reher, 2018; Abramson, De Llanos and Han, 2025). Our simple supply side rules out this general equilibrium channel and takes the path of rents as exogenous in order to focus on the welfare implications of a divergence between the user cost and rents highlighted by Figure 1. To do otherwise would require introducing construction of new rental housing and endogenous total shelter demand. If rents did change, the right side of the equation in part (iii) of Lemma 2 would simply add a term $R_{t+1} - R_t$.

on shelter, the intertemporal marginal propensities to consume out of non-housing wealth, the change in non-pecuniary utility due to any change to the overall homeownership rate, and changes to the efficiency of allocation of homeownership across individuals with varying preference for owning. Fourth, we obtain the shelter price path as the sum of past impulse responses and, with consumption smoothing, shelter inflation as the annuitized value of the revision to lifetime shelter expenditure plus a non-pecuniary component. The next sections measure these objects using a quantitative model calibrated to our custom survey and other moments of the data.

3.1 Adding Dynamics and A Non-Shelter Good

We enrich our tenure choice framework to incorporate dynamics and a non-shelter good. Dynamics arise because in reality home buyers obtain long-term fixed rate mortgages and renters and owners face moving costs, including broker fees for renters and selling commissions for owners. Our quantitative model in Section 5 will include these elements. We let s denote the time since the last shelter change. We let a bold vector $\mathbf{y}_t = (y_{t-\infty}, \ldots, y_t, \ldots, y_{t+\infty})$ denote the path of a variable y as well as expectations for its future path from date t onward. Then given a sequence of shelter costs and mortgage market parameters $\mathbf{W}_t$ (e.g. $\mathbf{W}_t = \left[\mathbf{R}_t, \mathbf{P}_t^H, \mathbf{i}_t\right]$), an agent with previous tenure $\mathcal{H}_{t-1}$ and current tenure $\mathcal{H}_t$ of duration s_t has date t shelter outlays of $X\left(\mathcal{H}_{t-1}, \mathcal{H}_t, s_t; \mathbf{W}_t\right)$.[10] The dependence of current outlays on past choices defines the problem as dynamic. Households behave as if they know the future realizations in $\mathbf{W}_t$ with perfect foresight and we let $\mathbb{E}_t[Y_{t+j}]$ denote the date t expectation of a future variable Y conditional on $\mathbf{W}_t$.[11]

Households consume a composite non-housing good C_t with price normalized to one in all periods and have non-housing wealth A_{t-1}.[12] Period utility over the non-housing good is $u(C_t)$. Non-pecuniary utility from homeownership in utils is $v_t(\tilde{\theta})$ with $v_t'(.) > 0$; we will shortly derive consumption-equivalent utility from homeownership as used elsewhere in the paper. Households

[10]For example, X_t equals the mortgage payment, later denoted $d_{t|t-s}$, for an owner who obtained a mortgage s periods ago, the down payment $(1-\ell_t)\,P_t^H$ for someone who transitions from renting ($\mathcal{H}_{t-1} = 0$) to owning ($\mathcal{H}_t = 1, s_t = 0$), or $M_{t|t-s} - (1-\psi_{1-})\,P_t^H + (1+\psi_{0+})\,R_t$ for someone who transitions from owning to renting with remaining mortgage balance $M_{t|t-s}$, real estate commission ψ_{1-}, and broker fee ψ_{0+}.

[11]The assumption of perfect foresight is without loss of generality for first order perturbations of $\mathbf{W}_t$ around a deterministic balanced growth path, due to certainty equivalence. We will not however restrict our measurement exercise to only infinitesimal shocks.

[12]In the quantitative model in Section 5 we relax the assumption that the price of the non-shelter good is fixed. With nominal fixed rate mortgages, surprise inflation affects welfare by eroding real mortgage debt (Doepke and Schneider, 2006). In Section 8 we directly feed in the path and expectations of non-shelter inflation.

discount future utility using the subjective discount factor $\tilde{\beta}$. As in Section 2, $\beta_{t,t+j}$ denotes the inverse of the gross real interest rate between dates t and $t+j$. We also generalize to additional dimensions of heterogeneity such as the expected duration before moving and liquidity constraints, which we write compactly as a vector of exogenous types Θ_t. Households have expectations over their future idiosyncratic type based on an underlying Markov process. Let Θ^t denote a history of Θ up to date t. Households enter date t with their exogenous type Θ_t, assets $A_{t-1} \equiv A\left(\Theta^{t-1}\right)$, and previous tenure choice $\mathcal{H}_{t-1}$ of duration s_{t-1}. Let $\Omega_t = \left(A_{t-1}, \mathcal{H}_{t-1}, s_{t-1}, \Theta_t\right)$ denote this set of initial conditions. A household with current Ω_t chooses plans for consumption, assets, and tenure at each future date and idiosyncratic state, $C\left(\Theta^{t+j}\right)$, $A\left(\Theta^{t+j}\right)$, $\mathcal{H}\left(\Theta^{t+j}\right)$, and $s\left(\Theta^{t+j}\right)$, to solve:

$$\tilde{V}_t(\Omega_t) \equiv \tilde{V}(\Omega_t, \mathbf{W}_t) = \max_{\{C(\Theta^{t+j}),\mathcal{H}(\Theta^{t+j}),s(\Theta^{t+j})\}_{j=0}^{\infty}} \sum_{j=0}^{\infty} \tilde{\beta}^j \mathbb{E}_t \left[u\left(C\left(\Theta^{t+j}\right)\right) + \mathcal{H}\left(\Theta^{t+j}\right) v_{t+j}(\tilde{\theta}_{t+j}) | \Omega_t \right],$$

$$\text{s.t.} \;\; C\left(\Theta^{t+j}\right) + X(\mathcal{H}\left(\Theta^{t+j-1}\right), \mathcal{H}\left(\Theta^{t+j}\right), s\left(\Theta^{t+j}\right); \mathbf{W}_{t+j}) + A\left(\Theta^{t+j}\right) \leq \frac{A\left(\Theta^{t+j-1}\right)}{\beta_{t+j-1,t+j}} \;\; \forall \Theta^{t+j},$$

$$\left(\mathcal{H}\left(\Theta^{t+j-1}\right), s\left(\Theta^{t+j-1}\right), \mathcal{H}\left(\Theta^{t+j}\right), s\left(\Theta^{t+j}\right)\right) \in \Gamma\left(\Theta_{t+j}\right) \;\; \forall \Theta^{t+j},$$

where $\Gamma\left(\Theta_t\right)$ represents constraints on the law of motion for tenure.[13]

To clearly separate the contribution of shelter to welfare from the more general consumption-savings problem (and with an eye toward the already difficult measurement challenge tackled below), we make the simplifying assumption that households have access to a complete set of Arrow-Debreu securities indexing the realizations of all individuals' Θs. Appendix C develops the more general incomplete markets case without this insurance, which we refer to as we obtain results below. With this assumption, a household's non-housing consumption evolves deterministically and hence depends only on the date t state variables, which we write as $C_{t+j}\left(\Omega_t, \mathbf{W}_t\right)$. We have the following result:

Proposition 3 *Consider an economy in which households can trade claims to consumption conditional on the realization of any particular set of histories for all households $\xi^{t+j} = \{\Theta^{t+j}\}$, with Arrow-Debreu prices of the form $p(\xi^{t+j}) = \pi(\xi^{t+j})\beta_{t,t+j}$, where $\pi(\xi^{t+j})$ denotes the state probability. Then there exists an Arrow-Debreu equilibrium in which the present value of utility*

[13] For example, Γ imposes the constraint that $s_{t+1} \in \{s_t + 1, 0\}$, or that a renter whose Θ encodes a liquidity constraint cannot transition to ownership.

for households from non-shelter consumption depends only on non-housing assets and the present value of shelter expenditure, i.e.:

$$\tilde{V}_t(\Omega_t) = \tilde{V}_t^C\left(A_{t-1} - V_t^X(\Omega_t)\right) + \tilde{V}_t^\theta(\Omega_t), \tag{13}$$

where:

$$\tilde{V}_t^C\left(A_{t-1} - V_t^X(\Omega_t)\right) \equiv \max_{\{C_{t+j}\}(\Omega_t,\mathbf{W}_t)} \sum_{j=0}^{\infty} \tilde{\beta}^j u\left(C_{t+j}(\Omega_t,\mathbf{W}_t)\right) \quad s.t.$$

$$\sum_{j=0}^{\infty} \beta_{t,t+j}(C_{t+j}(\Omega_t,\mathbf{W}_t)) + V_t^X(\Omega_t,\mathbf{W}_t) \leq A_{t-1}, \tag{14}$$

$$V_t^X(\Omega_t) \equiv \mathbb{E}_t\left[\sum_{j=0}^{\infty} \beta_{t,t+j} X\left(\mathcal{H}_{t+j-1}(\Omega_t,\mathbf{W}_t), \mathcal{H}_{t+j}(\Omega_t,\mathbf{W}_t), s_{t+j}(\Omega_t,\mathbf{W}_t); \mathbf{W}_{t+j}\right)|\Omega_t\right], \tag{15}$$

$$\tilde{V}_t^\theta(\Omega_t) \equiv \mathbb{E}_t\left[\sum_{j=0}^{\infty} \tilde{\beta}^j \mathcal{H}_{t+j}(\Omega_t,\mathbf{W}_t)\, v\left(\tilde{\theta}_{t+j}\right)|\Omega_t\right], \tag{16}$$

$$\{\mathcal{H}_{t+j}(\Omega_t,\mathbf{W}_t), s_{t+j}(\Omega_t,\mathbf{W}_t)\} =$$

$$\arg\max_{\{\mathcal{H}_{t+j}(\Theta^{t+j}),s_{t+j}(\Theta^{t+j})\}} \mathbb{E}_t\left[-\sum_{j=0}^{\infty} \beta_{t,t+j} X\left(\mathcal{H}_{t+j-1}(\Theta^{t+j}), \mathcal{H}_{t+j}(\Theta^{t+j}), s_{t+j}(\Theta^{t+j}); \mathbf{W}_{t+j}\right)|\Omega_t\right]$$

$$+ \frac{1}{u'(C_t(\Omega_t,\mathbf{W}_t))}\mathbb{E}_t\left[\sum_{j=0}^{\infty} \tilde{\beta}^j \mathcal{H}_{t+j} v_{t+j}\left(\tilde{\theta}_{t+j}\right)|\Omega_t\right] \quad s.t.$$

$$\left(\mathcal{H}\left(\Theta^{t+j-1}\right), s\left(\Theta^{t+j-1}\right), \mathcal{H}\left(\Theta^{t+j}\right), s\left(\Theta^{t+j}\right)\right) \in \Gamma\left(\Theta_{t+j}\right) \ \forall \Theta^{t+j}, \tag{17}$$

where $C_t(\Omega_t, \mathbf{W}_t)$ in (17) comes from the solution to the consumption/savings problem in (14). Furthermore, if aggregate output grows deterministically at μ, there is an outside agent who receives all rental payments, mortgage payments, and moving costs as income and also participates in the insurance market, and all agents have utility over non-shelter consumption $u(C) = \frac{C^{1-\gamma}}{1-\gamma}$, then the Arrow-Debreu prices will take the form $p(\xi^{t+j}) = \pi(\xi^{t+j})\beta^j$, where $\beta = \tilde{\beta}/(1+\mu)^\gamma$. Finally, if $v_t(\tilde{\theta}) = \bar{R}_t^{1-\gamma}v(\tilde{\theta})$, $R_t = \bar{R}_t$, $P_t^H/\bar{R}_t$ is constant, and i_t is constant, then $\mathcal{H}_{t+j}(\Theta^{t+j})$, $s_{t+j}(\Theta^{t+j})$, and $X(\mathcal{H}_{t+j-1}(\Theta^{t+j-1}), s_{t+j-1}(\Theta^{t+j-1}))/\bar{R}_t$ all converge to stationary distributions.

The first part of Proposition 3 takes a partial equilibrium perspective and decomposes the household's joint optimization problem into an iteration over the choice of consumption in equations (14) to (16), taking as given the state-contingent tenure choices, and the state-contingent tenure choice in equation (17), taking as given the path of consumption. The term $\tilde{V}_t^C(.)$ contains the present value of utility from non-durable consumption and depends on initial assets and

$V_t^X(.)$, the present value of shelter expenditure. The term $\tilde{V}_t^\theta(.)$ contains the present value of non-pecuniary utility from shelter. The second part of Proposition 3 closes the output market in such a way that aggregate consumption is deterministic and invariant to shelter costs. With full risk sharing, each agent's consumption therefore also grows at μ, and the Arrow-Debreu prices are separable in the state probabilities and a real interest rate that does not depend on shelter costs.

3.2 Money-Metric Changes in Welfare

Suppose at date t there is an unexpected change to the path of house prices, mortgage rates, or rents, denoted by $d\mathbf{W}_t \equiv \mathbf{W}_t - \mathbb{E}_{t-1}\mathbf{W_t}$. Define $dY_t\left(\Omega_t, d\mathbf{W}_t\right) = Y\left(\Omega_t, \mathbf{W}_t\right) - \mathbb{E}_{t-1}\left[Y\left(\Omega_t, \mathbf{W}_t\right)\right]$ as the (possibly discrete) unexpected change in any object Y. We assume the marginal utility of a dollar $\partial \tilde{V}_t^C\left(A_{t-1} - V_t^X\left(\Omega_t\right)\right)/\partial A_{t-1}$ remains fixed in the neighborhood of shelter cost changes that we consider.[14] Then applying the d operator to equations (13) and (14) and dividing through by $\partial \tilde{V}_t^C\left(.\right)/\partial A_{t-1}$, we arrive at the welfare change in potentially measurable consumption-equivalent terms:

Proposition 4 *The welfare change in consumption-equivalent units is:*

$$dV_t\left(\Omega_t, d\mathbf{W}_t\right) = -dV_t^X\left(\Omega_t, d\mathbf{W}_t\right) + dV_t^\theta\left(\Omega_t, d\mathbf{W}_t\right), \tag{18}$$

where $dV_t(.) = d\tilde{V}_t(.)/\left(\partial \tilde{V}_t^C\left(.\right)/\partial A_{t-1}\right)$ *and* $dV_t^\theta(.) = d\tilde{V}_t^\theta(.)/\left(\partial \tilde{V}_t^C\left(.\right)/\partial A_{t-1}\right)$. *Furthermore, the contribution of consumption-equivalent utility from owning can be written:*

$$dV_t^\theta\left(\Omega_t, d\mathbf{W}_t\right) = \sum_{j=0}^{\infty} d\mathbb{E}_t\left[\beta_{t,t+j}\mathcal{H}_{t+j}\left(\Omega_t, \mathbf{W}_t\right)\left(\frac{v_{t+j}\left(\tilde{\theta}_{t+j}\right)}{u'\left(C_{t+j}\left(\Omega_t, \mathbf{W}_t\right)\right)}\right)|\Omega_t\right]. \tag{19}$$

Equation (18) shows the total change in money-metric welfare consists of two components. The first component, $-dV_t^X\left(\Omega_t, d\mathbf{W}_t\right)$, is the change in the present value of shelter outlays. This component closely resembles the main result in Fagereng et al. (2024). The second component, $dV_t^\theta\left(\Omega_t, d\mathbf{W}_t\right)$, is the change in the consumption-equivalent non-pecuniary utility from owning.

[14] In the case of infinitesimal perturbations dW_t, this assumption holds if $V_t^X(.)$ and $\tilde{V}_t^\theta$ are differentiable. Continuity of the space of types θ or, as in our implementation in Section 5, discrete θ and pecuniary i.i.d. shocks that augment $X(\mathcal{H}_{t+j-1}, \mathcal{H}_{t+j}, s_{t+j}; \mathbf{W}_{t+j})$ guarantee differentiability. For non-infinitesimal perturbations, this assumption introduces an approximation, again for the purpose of focusing on shelter alone rather than the full consumption-saving problem.

The second part of Proposition 4 uses the consumption Euler equation and envelope condition to unpack the utility component into the discounted sum of changes to the non-pecuniary utility from homeownership, expressed in consumption-equivalent terms by dividing by the marginal utility of non-shelter consumption.

3.3 Consumption-Equivalent Utility

The term $v_{t+j}\left(\tilde{\theta}_{t+j}\right)/u'\left(C_{t+j}\left(\Omega_t,\mathbf{W}_t\right)\right)$ in equation (19) maps naturally into the willingness-to-pay to own. To make this connection clear, let $u'(C)=C^{-\gamma}$ and define $v_t(\tilde{\theta})=\bar{R}_t^{1-\gamma}v(\tilde{\theta})$, so that the warm glow from owning scales with the power function of trend rent. Let $b\left(\Omega_t,\mathbf{W}_t\right)\equiv C_t\left(\Omega_t,\mathbf{W}_t\right)/\bar{R}_t$ denote the ratio of non-durable consumption to trend rent. Then consumption-equivalent utility from owning takes the form:

$$\bar{R}_t^{1-\gamma}v\left(\tilde{\theta}\right)/u'\left(C_t\left(\Omega_t,\mathbf{W}_t\right)\right)=\bar{R}_t^{1-\gamma}v\left(\tilde{\theta}\right)C_t(\Omega_t,\mathbf{W}_t)^{\gamma}=v\left(\tilde{\theta}\right)b\left(\Omega_t,\mathbf{W}_t\right)^{\gamma}\bar{R}_t=\theta\bar{R}_t, \tag{20}$$

where $\theta\equiv v\left(\tilde{\theta}\right)b\left(\Omega_t,\mathbf{W}_t\right)^{\gamma}$ characterizes the non-pecuniary utility from owning. With risk-sharing and consumption smoothing, $b\left(\Omega_t,\mathbf{W}_t\right)$ does not vary over time for an individual (as long as $\mathbf{W}_t$ remains fixed), and hence θ is a time-invariant transformation of $v\left(\tilde{\theta}\right)$.

Using equation (20), we could in principle use repeated surveys of willingness-to-pay together with the path of homeownership and shelter outlays to directly evaluate equations (18) and (19). In practice, we do this exercise in the next sections by combining our custom survey with a quantitative model.

3.4 Price Index Impulse Response

Translating the change in the value function into contributions to a per-period price index requires distributing $dV_t\left(\Omega_t,d\mathbf{W}_t\right)$ across periods. Many possible paths of offsetting transfers exist. Two natural paths to consider use the timing of the household's change in shelter outlays or the timing of the change in non-shelter consumption expenditure. These paths have a close connection, since a household receiving transfers to offset shelter outlays period-by-period and facing unchanged interest rates would change its consumption plan to exactly offset the period-by-period change in non-shelter consumption. This result holds even in general consumption/savings problems, because a sequence of transfers that restores the household's previous income will lead it to choose exactly the same non-shelter consumption path as before the shelter cost change. We choose to directly assign transfers to when non-shelter consumption would otherwise change, plus the per-period change to consumption-equivalent utility from homeownership changes. That way, the price index moves exactly when the agent's period utility would otherwise change, as in the static case. Effectively, we also force recipients to consume the transfers immediately.[15]

To characterize the impulse response of non-shelter consumption expenditure, note that the intertemporal budget constraint requires a change in the path of non-shelter consumption expenditure equal in present value to $-dV_t^X\left(\Omega_t, d\mathbf{W}_t\right)$. In particular:

$$dC_{t+j}\left(\Omega_t, d\mathbf{W}_t\right) = -\underbrace{\left(\frac{\partial C_{t+j}\left(\Omega_t, \mathbf{W}_t\right)}{\partial A_{t-1}}\right)}_{\equiv m_j} dV_t^X\left(\Omega_t, d\mathbf{W}_t\right). \tag{21}$$

The term in parentheses is the horizon j intertemporal marginal propensity to consume out of non-housing wealth, labeled m_j. As in Auclert, Rognlie and Straub (2024), it depends on the details of the utility function and the interest rate available to the agent.[16] Imposing balanced growth path consumption growth of μ, $dC_t\left(\Omega_t, d\mathbf{W}_t\right) = db_t\left(\Omega_t, d\mathbf{W}_t\right)\bar{R}_t$ and $m_j = \left(1-\beta\left(1+\mu\right)\right)\left(1+\mu\right)^j$.

We can now define the response of the price of shelter to changes to $\mathbf{W}_t$.

Proposition 5 *Let $dP_{t+j}\left(\Omega_t, d\mathbf{W}_t\right)$ denote the $t+j$ non-housing consumption-equivalent transfer that offsets the utility change due to $d\mathbf{W}_t$. Then:*

$$dP_{t+j}\left(\Omega_t, d\mathbf{W}_t\right) = \overbrace{m_j dV_t^X\left(\Omega_t, d\mathbf{W}_t\right)}^{\textit{Non-shelter consumption change}} - \overbrace{d\mathbb{E}_t\left[\mathcal{H}_{t+j}\left(\Omega_t, \mathbf{W}_t\right)\theta_{t+j}|\Omega_t\right]\bar{R}_{t+j}}^{\textit{Housing utility change}}. \tag{22}$$

Let $G_t\left(\Omega_t\right)$ denote the (endogenous) date t distribution of types and $\mathbb{E}_{\Omega_t}$ the cross-sectional average using the measure $G_t\left(\Omega_t\right)$. The aggregate transfer required to keep consumption-equivalent utility fixed is:

$$dP_{t+j}\left(d\mathbf{W}_t\right) = \mathbb{E}_{\Omega_t}\left[m_j dV_t^X\left(\Omega_t, d\mathbf{W}_t\right) - d\mathbb{E}_t\left[\mathcal{H}_{t+j}\left(\Omega_t, \mathbf{W}_t\right)\theta_{t+j}|\Omega_t\right]\bar{R}_{t+j}\right]. \tag{23}$$

[15]That is, even with consumption-smoothing preferences, the transfer will fluctuate over time due to the compensation for the non-pecuniary component of shelter utility. In the more general setting with uncertainty and incomplete markets presented in Appendix C, the timing of transfers matters to the consumption path beyond just their present value. In this case, we think of the transfers as dollar-equivalent utils that do not otherwise affect the consumption/saving problem.

[16]Technically, writing equation (21) with the intertemporal marginal propensity to consume requires a consumption welfare function that is homogeneous of degree one, such that consumption in each period scales with total wealth. The appearance of the marginal propensity to consume out of non-housing wealth echoes Proposition 1 in Berger et al. (2017). Equation (21) differs in that it applies to the present value of shelter outlays rather than the house price and in a setting with non-convex moving costs.

The balanced growth path price is the income equivalent of flow shelter utility:

$$\bar{P}_t = \mathbb{E}_{\Omega_t}\left[\bar{X}\left(\Omega_t\right) - \mathcal{H}_t\left(\Omega_t\right)\theta\right]\bar{R}_t, \tag{24}$$

where $\bar{X}\left(\Omega_t\right)$ *and* $\mathcal{H}_t\left(\Omega_t\right)$ *denote detrended shelter expenditure and homeownership choice on the balanced growth path, respectively. The date* $t+j$ *price level is* $P_{t+j} = \bar{P}_{t+j} + dP_{t+j}$.

Equation (22) characterizes the transfer path for a single *ex ante* type. By construction, the present value of the path of transfers equals the change in the value function:

$$\sum_{j=0}^{\infty} \beta_{t,t+j} dP_{t+j}\left(\Omega_t, d\mathbf{W}_t\right) = -dV_t\left(\Omega_t, d\mathbf{W}_t\right).$$

Equation (23) characterizes the aggregate transfer path. The first term contains the average change in expenditure on the non-shelter good due to the shelter price change at date t. The second term contains the average change in consumption-equivalent utility. Equation (23) mirrors Proposition 2 but applies to price paths rather than the static change in the price.

The aggregate price consists of the balanced growth path price and the additional transfer. The balanced growth path price is the income equivalent of shelter utility. Shelter inflation on the balanced growth path is simply $1+\mu$. Equivalently, gross inflation between t and $t+j$ comprises the trend component $(1+\mu)^j$ and the deviation from trend $dP_{t+j}/\bar{P}_{t+j}$.

For further insight into the non-pecuniary utility term, $\mathbb{E}_{\Omega_t}\left[d\mathbb{E}_t\left[\mathcal{H}_{t+j}\left(\Omega_t, \mathbf{W}_t\right)\theta_{t+j}|\Omega_t\right]\bar{R}_{t+j}\right]$, we apply the following decomposition. Let $\theta_t^* = F_\theta^{-1}\left(1-h_t\right)$ denote the cutoff θ for owning that would obtain if there were no transaction costs or other sources of heterogeneity, as in Section 2. Then:

$$\begin{aligned}
\mathbb{E}_{\Omega_t}\left[\mathcal{H}_t\left(\Omega_t, \mathbf{W}_t\right)\theta_t\right] &= h_t \mathbb{E}_\theta\left[\theta_t\right] + \mathrm{Cov}_{\Omega_t}\left(\mathcal{H}_t\left(\Omega_t, \mathbf{W}_t\right), \theta_t\right) \\
&= h_t \mathbb{E}_\theta\left[\theta_t | \theta_t > \theta_t^*\right] + \left(\mathrm{Cov}_{\Omega_t}\left(\mathcal{H}_t\left(\Omega_t, \mathbf{W}_t\right), \theta_t\right) - \mathrm{Cov}_\theta^*\left(\mathcal{H}_t, \theta_t; h_t\right)\right),
\end{aligned} \tag{25}$$

where $\mathrm{Cov}_\theta^*\left(\mathcal{H}_t, \theta_t; h_t\right) \equiv h_t\left(\mathbb{E}_\theta\left[\theta_t|\theta_t > \theta_t^*\right] - \mathbb{E}_\theta\left[\theta_t\right]\right)$ denotes the covariance given a homeownership rate h_t and perfect sorting. According to equation (25), changes to the non-pecuniary component reflect two forces. The first force, corresponding to changes in the first term of equation (25), is the change in non-pecuniary utility that would obtain with perfect sorting, as in Section 2. The second force, corresponding to changes in the second term, reflects changes in allocative efficiency of homeownership due to additional sources of heterogeneity and long-term contracts. Such misallocation may for example arise due to "mortgage lock" that induces some incumbent owners with rates below new contract rates to remain homeowners despite experiencing a decline in θ while renters experiencing an increase in θ do not buy because of the rise in rates.

We make three additional remarks. First, the formulation in equation (22) nests the case of an agent who owns their home and never expects to move. This agent has a change $dV_t(\Omega_t, d\mathbf{W}_t) = dV_t^X(\Omega_t, d\mathbf{W}_t) = 0$. Since this agent does not change her non-shelter consumption expenditure, she experiences zero inflation despite the change in house prices, as in Sinai and Souleles (2005) and Fagereng et al. (2024).

Second, at the cost of additional complexity, the intertemporal marginal propensities to consume could differ across types due to incomplete insurance markets. In that case, the deviation in the path of certainty equivalent non-shelter consumption expenditure provides the sufficient statistic for distributing the change in welfare across time (see Appendix C).

Third, the shelter price index in equation (23) differs from a static price index in that it can depend on expected future price changes. A renter expecting to purchase in the future and therefore affected by future house prices or mortgage rates provides one example. Likewise, house price appreciation enters into equation (22), while the traditional CPI excludes asset price changes. Such intertemporal dependence is unavoidable in a dynamic setting with a durable good. Of course, if every sale by a household with a capital gain also involves a purchase by a household at a higher price, then price appreciation partly washes out in the aggregate index in equation (23), (as in Bajari, Benkard and Krainer, 2005). This irrelevance will not hold exactly, however, because the consumer price index does not value the transfers to non-households, including to banks in the form of higher mortgage payments when the price increases and to the purchaser or seller of rental housing when homeownership changes. We provide alternative price indexes in Section 8 that remove the effect of surprise changes in house prices on incumbent owners by fixing the schedule of terminal payoff amounts at the time of purchase. Even then, however, house price appreciation still matters because it necessitates a higher mortgage payment by new buyers.

3.5 Historical Price Index

The analysis so far considers news about house prices, rents, or mortgage costs that arrives at a single date. A historical cost-of-shelter index must account for news arriving at many dates. Let $P_{-1} = \bar{P}_{-1}$ denote an initial date at which the price equals the balanced growth path level and normalize $\bar{R}_{-1} = 1$. Using equation (23), define the date t price deviation due to news at date 0:

$$dP_{t|0} = \mathbb{E}_{\Omega_0}\left[m_t dV_0^X\left(\Omega_0, d\mathbf{W}_0\right) - \left(\mathbb{E}_0\left[\mathcal{H}_t\left(\Omega_0, \mathbf{W}_0\right)\theta_t|\Omega_0\right] - \mathbb{E}_{-1}\mathbb{E}_0\left[\mathcal{H}_t\left(\Omega_0, \mathbf{W}_0\right)\theta_t|\Omega_0\right]\right)\bar{R}_t\right].$$

If the realized and expected costs change again at date 1, the new sequence of expected required transfers from date 1 forward, relative to the balanced growth path, consists of the deviations expected at date 0 plus additional deviations due to the news:

$$dP_{t|1} = dP_{t|0} + \mathbb{E}_{\Omega_1}\left[m_{t-1} dV_1^X\left(\Omega_1, d\mathbf{W}_1\right) - \left(\mathbb{E}_1\left[\mathcal{H}_t\left(\Omega_1, \mathbf{W}_1\right)\theta_t|\Omega_1\right] - \mathbb{E}_0\mathbb{E}_1\left[\mathcal{H}_t\left(\Omega_1, \mathbf{W}_1\right)\theta_t|\Omega_1\right]\right)\bar{R}_t\right].$$

This "summing of impulse response functions" avoids double or under-counting the effect of changes in shelter costs at date 1 forward that already affect the date 0 price level due to consumption smoothing. The process iterates forward and "telescopes", yielding the following proposition.

Proposition 6 *Suppose $P_{-1} = \bar{P}_{-1}$ and normalize $\bar{R}_{-1} = 1$. Consider a sequence of news surprises between date 0 and date t. The realized date t transfer, equal to the deviation from the balanced growth path of non-shelter consumption and non-pecuniary utility from homeownership, is:*

$$dP_t \equiv dP_{t|t} = \sum_{j=0}^{t}\mathbb{E}_{\Omega_{t-j}}\left[m_j dV_{t-j}^X\left(\Omega_{t-j}, d\mathbf{W}_{t-j}\right)\right] - \left(\mathbb{E}_{\Omega_t}[\mathcal{H}_t\left(\Omega_t, \mathbf{W}_t\right)\theta_t] - \mathbb{E}_{-1}\mathbb{E}_{\Omega_t}[\mathcal{H}_t\left(\Omega_t, \mathbf{W}_t\right)\theta_t]\right)\bar{R}_t. \tag{26}$$

With isoelastic utility over non-shelter consumption and a constant interest rate $1/\beta - 1$, the detrended change in the transfer depends only on consumption news at date t and the change in the non-pecuniary term:

$$\begin{aligned}\frac{P_t}{\bar{R}_t} - \frac{P_{t-1}}{\bar{R}_{t-1}} &= \left(1 - \beta\left(1+\mu\right)\right)\mathbb{E}_{\Omega_t}\left[dV_t^X\left(\Omega_t, d\mathbf{W}_t\right)\right]/\bar{R}_t \\ &\quad - \left(\mathbb{E}_{\Omega_t}[\mathcal{H}_t\left(\Omega_t, \mathbf{W}_t\right)\theta_t] - \mathbb{E}_{\Omega_{t-1}}[\mathcal{H}_{t-1}\left(\Omega_{t-1}, \mathbf{W}_{t-1}\right)\theta_{t-1}]\right).\end{aligned} \tag{27}$$

Thus, with isoelastic utility and consumption smoothing, the date t (de-trended) change in the price index equals the annuity value of the change in net shelter outlays plus the change in the non-pecuniary term. In particular, news at date 0 causes a jump in the price index as required by the change in shelter costs and the change in utility coming from changes in the homeownership rate. Thereafter, consumption smoothing implies that shelter inflation contains only changes to the utility term, unless further unexpected shocks to shelter costs occur. Intuitively, isoelastic utility makes non-shelter consumption a fixed fraction of wealth net of shelter outlays; non-shelter consumption and hence the pecuniary part of the price index then jumps only with unexpected news that changes net non-shelter wealth. This helpful analytic result does not hold without isoelastic utility or in an environment with uncertainty and incomplete markets, in which case the price tracks revisions to the certainty equivalent value of consumption (see Appendix C).

4 Survey Evidence on Preferences for Owning

The results in the previous section in principle allow for measuring welfare changes directly, using paths of non-shelter consumption and utility from owning. We now take a step in this direction with a survey of the preference for owning versus renting. In practice, we combine information from the survey with additional, equilibrium moments of the data to calculate welfare changes.

4.1 Benchmarking

We surveyed 1000 individuals in January 2025 using the online platform Prolific, selected to be nationally representative by age, gender, and race. To assess possible reporting error, we re-surveyed a subset of the original respondents five weeks later.[17]

Tables D.1 to D.3 compare the demographics of our survey respondents to the general population of household heads and their partners in the Current Population Survey and Survey of Income and Program Participation. Our survey over-weights college-educated respondents, but otherwise contains reasonable balance over age, gender, marital status, and number of children. Crucially, our survey contains a representative share of owners and renters and homeownership

[17] We require participants to own their property or live in privately rented accommodation. We exclude three individuals who restarted the survey after being screened out on this question, leaving a maximum of 997 observations in the main survey. Pre-registrations of the main and follow-up surveys are available at https://aspredicted.org/jxpb-q9m9.pdf and https://aspredicted.org/5nzv-z2r2.pdf, respectively.

by age profile. We re-weight the sample to exactly match the SIPP age distribution of household heads and spouses given our focus below on this dimension. We confirm that this reweighting does not affect our main results.

Table D.4 compares the rent and self-reported OER in our survey to the values reported in the Consumer Expenditure Survey. The distribution of OER is quite similar. Our survey contains a similar median but slightly less variance of rent than the CEX.

Figures D.1 to D.4 compare the reasons why people last moved reported in our survey to similar questions asked in the Survey of Income and Program Participation (SIPP), American Housing Survey (AHS), and Current Population Survey Annual Social and Economic Supplements (CPS-ASEC), respectively. Our survey, the SIPP, and the CPS-ASEC offered the response "Wanted to own home, not rent" and in all three surveys this response was selected more than any other by current owners. Of course, wanting to own does not distinguish financial from preference reasons, a task we turn to next. We also find suggestive evidence of preferences related to family structure as most important for changes from owning to renting.

4.2 Willingness-to-Pay to Own

We solicit respondents' willingness-to-pay (WTP) by asking them what additional financial windfall from not owning and investing in the market they would be willing to forgo in order to own. Appendix D provides screenshots of the relevant part of the survey. For current owners, we frame this scenario as a comparison between buying and renting and total wealth 10 years later, holding other aspects of life the same. For current renters, we add to the comparison a hypothetical inheritance of $25,000 to ensure that a down payment constraint does not prevent them from choosing to own. We show both groups a side-by-side comparison of living situation (own and pay down mortgage or rent), initial investment (down payment or invest in diversified portfolio), and terminal wealth composition (proceeds from sale net of mortgage repayment or investment portfolio, plus any additional savings). We then instruct the respondent to imagine that total wealth in both the owning and renting scenarios is the same after ten years and ask whether they would have chosen to buy or rent or are indifferent between the two options. For those opting to buy, we ask for the maximum additional wealth in the rental scenario at which they would still choose to buy (and symmetrically if they opted to rent).[18]

Three additional design details merit mention. First, we ask the WTP question after a series of questions about why the person last moved and why they currently own or rent. This sequencing may prime respondents to think about tenure choice. We view such priming as likely to stimulate more accurate responses. Nonetheless, our main findings remain robust in the follow-up validation, which did not first ask about reasons for tenure choice. Second, we randomized two aspects of this procedure: (i) whether we specify that the respondent would buy or rent exactly the same property or not, (ii) whether the respondent enters the maximum WTP using a slider or via a repeated incrementing loop. We control below for these features. Respondents told they would own or rent the identical house have slightly lower WTP; using a slider or ascending price list has no discernible impact. Third, about 18% of respondents chose the maximum possible WTP on the slider or loop; for these respondents we implemented a short (2 minute) follow-up survey about one week later to solicit a numeric value (94% response rate). We use the reported values for these respondents and winsorize the WTP distribution in our preferred specification to mitigate the influence of extreme responses.

Figure 3 reports the distribution of annualized WTP (i.e. WTP after ten years, divided by ten) in our baseline sample as a fraction of the sample average of rent or equivalent rent of $2000 per month.[19] Overall, WTP is right-skewed, with a modal value near zero but a long right tail. Strikingly, current renters are much more likely to have negative or zero WTP while current owners account for most of the positive mass.

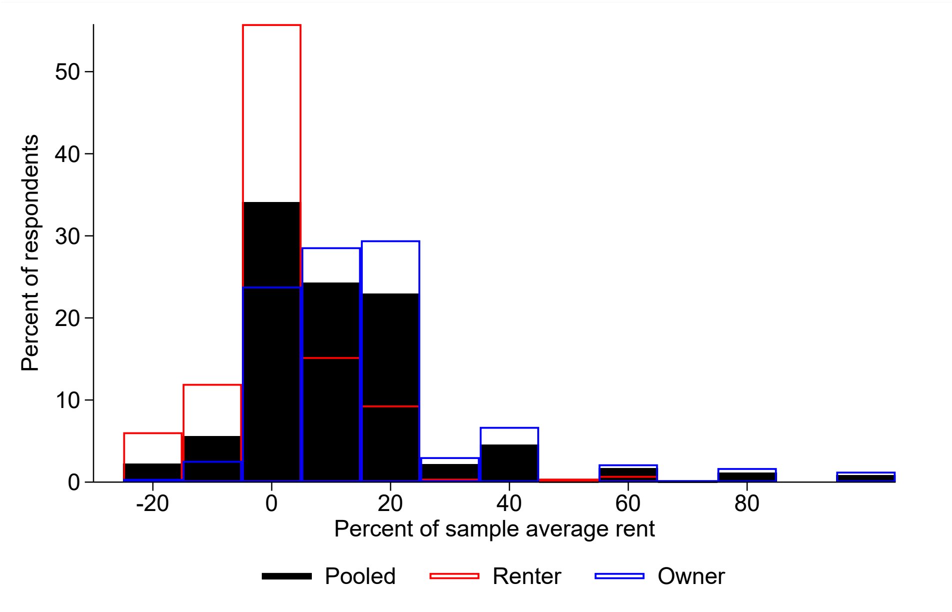
Table 1 reports regressions of WTP as a function of tenure, for various samples and weighting schemes. Column (1) includes all respondents with annualized WTP$\leq$ \$25k.[20] Owners exhibit a 13.4p.p. higher WTP/rent than renters and this difference is highly statistically significant. Columns (2)-(7) instead winsorize WTP/rent at the 2.5% and 97.5% level. Column (3) excludes

[18] The framing in terms of wealth after ten years is intended to focus the choice on non-pecuniary components. For example, in a different part of the survey some owners report that they prefer to own to avoid the uncertainty of rent fluctuations. Ideally, a comparison of *ex post* terminal wealth will not depend on such *ex ante* uncertainty.

[19] For readability, the figure excludes twelve individuals in the baseline sample with annualized WTP above $25,000. The mean WTP/rent among these individuals is 1062% and ten of the twelve are owners.

[20] Our full sample includes 15 individuals with annualized WTP$>$ \$25k, of whom twelve own and three rent. Thus, including these individuals increases the coefficient multiplying Owner, but also substantially increases the standard errors. Table D.5 repeats Table 1 when scaling WTP by the respondent's own rent or equivalent rent and finds similar results.

Figure 3: WTP Distribution



Notes: The figure reports the histogram of willingness-to-pay in our baseline sample as a share of the sample average of rent or equivalent rent. For readability the figure excludes twelve individuals with values of 125 or above.

respondents who fail the first attention check ("Type Attention is Key" into a text box), those who report in a follow-up screen that their selected WTP does not represent their true valuation (because either they clicked the wrong answer or were confused by the question), and those reporting own rent or equivalent rent less than \$500 or greater than \$15,000. Column (4) additionally excludes 18-24 year-olds, as our life cycle calibration in Section 6 will begin at age 25. There are relatively few 18-24 year-olds in our sample, as most individuals in this group are not household heads, so the result changes little. Column (5) does not filter respondents by our baseline criteria but instead weights by respondents' self-reported confidence in their response (the observation difference from column (2) reflects respondents who did not answer this question). Column (6) does not re-weight by age. Column (7) also excludes respondents who failed a second attention check during the selection of their main reason for owning or renting. Finally, column (8) winsorizes more aggressively at the 10% and 90% level. Reassuringly, the owner WTP premium remains of similar magnitude and highly statistically significant across all of these sample restrictions.

Figure 4 unpacks some of the heterogeneity in WTP by reporting values by age range. WTP increases in age up to the 45-54 year-old bin, falls slightly among 55-64 year-olds, and falls further among those 65+. The differences are economically meaningful; for example, the average 45-54

Table 1: Willingness-to-pay to Own and Homeownership

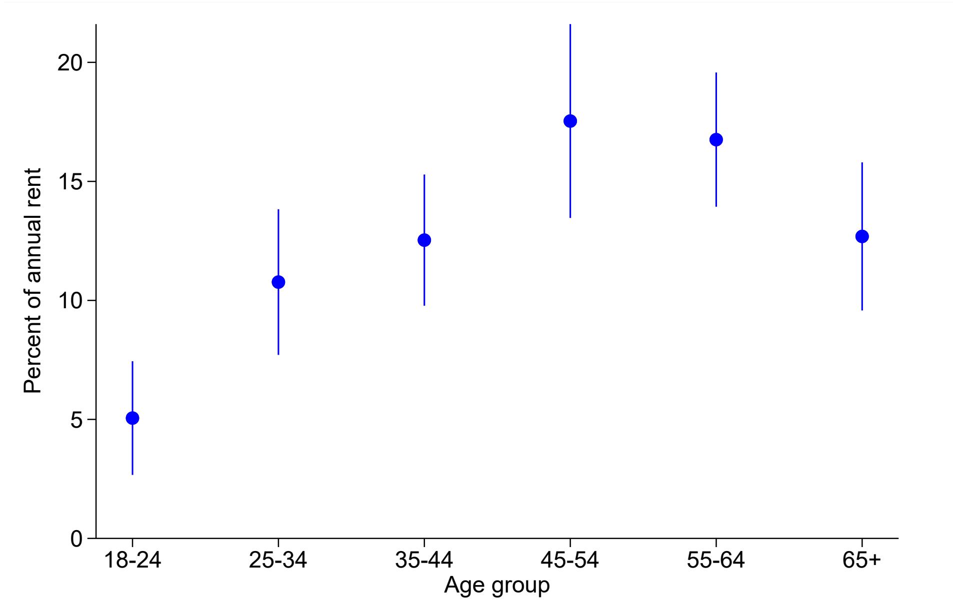
Dep. var.:	WTP to own/Sample average rent (%)							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Owner	13.4**	13.4**	15.8**	16.0**	15.7**	15.2**	16.9**	12.3**
	(1.0)	(1.1)	(1.5)	(1.5)	(1.7)	(1.4)	(1.7)	(0.9)
Identical house	- 1.7	- 1.6	- 2.9+	- 2.9+	- 1.9	- 3.4*	- 2.2	- 1.6
	(1.2)	(1.4)	(1.6)	(1.7)	(2.1)	(1.6)	(1.9)	(1.1)
Loop	1.1	2.5	2.6	2.7	2.6	1.4	2.3	1.7
	(1.4)	(1.6)	(2.0)	(2.0)	(2.2)	(1.9)	(2.1)	(1.2)
Constant	2.0*	2.7**	2.9*	2.8*	4.3**	4.1**	2.8*	3.3**
	(0.8)	(0.9)	(1.2)	(1.2)	(1.3)	(1.1)	(1.3)	(0.8)
WTP$< 25k$	✓							
Winsorized 2.5/97.5		✓	✓	✓	✓	✓	✓	
Winsorized 10/90								✓
Baseline sample			✓	✓		✓	✓	✓
No 18-24 year-olds				✓				
Confidence weighted					✓			
No age reweight						✓		
Addl. attention check							✓	
Observations	982	997	699	655	959	699	548	699

Notes: The dependent variable is the willingness-to-pay (WTP) to own scaled by the sample average of rent. Column (1) excludes respondents who reported a WTP greater than $25,000 per year. Columns (2)-(7) winsorize the dependent variable at the 2.5 and 97.5 quantiles. Column (8) winsorizes the dependent variable at the 10 and 90 percentiles. Baseline sample excludes respondents who failed the first attention check or reported No (confused) or No (misclicked) to the question on valuation accuracy. Confidence weighted weights by self-reported confidence in the answer. No age reweight does not reweight the sample to match the SIPP age distribution. The additional attention check excludes respondents who failed the second attention check. The variable Identical house is an indicator for the hypothetical specifying an identical property in terms of location, size, quality, and features. Loop is an indicator for answering the WTP question using a loop instead of a slider. Heteroskedastic-robust standard errors in parentheses.

year-old has a WTP 7p.p. higher than the average 25-34 year-old. Factors such as family size and neighborhood preference may plausibly explain the rising desire to own in the first part of the life cycle, while the decline among older individuals coincides with some households choosing to downsize as their children become adults. We use both the overall ownership premium documented in Table 1, and the life-cycle pattern documented in Figure 4, to discipline our quantitative model.

Appendix D.5 describes the follow-up survey. In brief, about 5 weeks after the main survey we made a new survey available to a randomly-selected 300 respondents from the main survey and received 230 responses, for a response rate of 77%. We did not inform respondents the surveys were linked and masked the connection by asking a series of questions about different trade-offs around living arrangements, such as the WTP for greater outdoor space or a shorter commute.

Figure 4: Mean WTP By Age Group



Notes: The figure reports the mean and 90% confidence interval of WTP by age in the baseline sample corresponding to column (3) of Table 1.

We also include a simpler version of the WTP to own question. The correlation coefficient between the WTP to own in the original and follow-up surveys was 0.50. Our calibration will treat the imperfect correlation as reflecting naive response error and adjust the survey moments accordingly, as described in Appendix D.5.

5 Quantitative Model

While the results in Section 3 in principle allow for measuring welfare changes directly in the data with repeated surveys and consumption responses, these expenditure and tenure changes and covariances with utility from owning involve high information requirements. In this section, we develop a quantitative life-cycle model to generate these patterns. Section 6 calibrates the model using the survey evidence from Section 4 and other moments of the data.

5.1 Additional Elements

We extend the model in Section 2 to incorporate long-term mortgage contracts, moving costs, non-shelter inflation, and additional sources of heterogeneity.[21] The supply side remains the same as in Section 2, with exogenous rents, the capitalization of rentals giving $P_t^R = c_t R_t$, and a conversion cost $g(h)$.[22]

Long-term contracts and moving costs. Home buyers obtain nominal fixed payment amortizing 30-year mortgages with loan-to-value at origination of ℓ_t. The modeling of nominal contracts requires allowing for non-shelter inflation. Let P_t^C denote the price of the non-durable consumption good and $\pi_{t,t+j}^C \equiv P_{t+j}^C / P_t^C - 1$ denote cumulative non-shelter inflation. We treat P_t^C as exogenous and define all other variables, including rent R, the house price P^H, the mortgage balance M, and the overall shelter price index P relative to it. The fixed payment for a home purchased at date t with nominal mortgage interest rate i_t^C is $d_t^C \equiv i_t^C P_t^C M_{t|t} / \Big(1 - \big(1 + i_t^C\big)^{-30}\Big)$, with origination mortgage balance of $M_{t|t} = \ell_t P_t^H$. Defining the *ex post* real mortgage rate at date t for an owner who bought at date $t-s$ as $i_{t|t-s} \equiv (1 + i_{t-s}^C)/(1 + \pi_{t,t+1}^C) - 1$ and the real mortgage payment as $d_{t|t-s} = d_{t-s}^C / P_t^C$, the real mortgage balance evolves recursively until full payoff at $s = 30$:

$$M_{t+1|t-s} = (1 + i_{t|t-s}) M_{t|t-s} - d_{t+1|t-s}. \tag{28}$$

A fraction ξ of owners receive the option to refinance each period, which if exercised resets the nominal interest rate and loan-to-value, with the agent paying in or cashing out the difference from their current mortgage. Owning also involves a flow cost f_t to cover maintenance, depreciation, taxes, and insurance. Agents incur fixed costs when moving: moving into a new rental requires a "broker fee" of $\psi_{0+} R_t$ and selling a home involves a "real estate commission" of $\psi_{1-} P_t^H$.

Additional heterogeneity. We introduce three additional dimensions of heterogeneity in addition to the preference for owning θ. First, while all agents have the option to move each period,

[21] We do not distinguish between new contract and existing rents. Because renters move frequently, we expect that any such difference would matter relatively little to decision rules.

[22] Given data on homeownership, house prices, and rents, implementing the price index (23) requires specifying a supply side only to determine expectations of future house prices and rents. Thus, survey data on household expectations of these variables would allow computation of welfare in our model in a partial equilibrium setting that exactly matches the survey expectations. This step could appeal to statistical agencies charged with measuring shelter costs. In computing the historical index below, we side-step the supply-side by obtaining such expectations from statistical forecasts.

some agents receive an additional "nudge". These nudges take the form of a one-time payment ψ_λ to remain in the same house and reflect job opportunities, the location of children and grandchildren, or other life events that favor relocation independent of the preference for owning or renting. Relative to forced moves, nudges divorce the own-to-own mobility rate in the model's steady state from along the transition, which will be important for capturing the effect of rising mortgage rates on "rate lock" of owners who choose not to sell to keep their low mortgage rate. The probability of receiving a nudge differs across agents, with an agent of type λ having probability λ. Fixing θ, higher λ pushes agents toward renting, since in our calibration moving costs are higher for owners than for renters, $\psi_{1-}P_t^H > \psi_{0+}R_t$.

Second, agents differ in their ability to buy. An agent with $\zeta = 1$ cannot make a down payment or qualify for a mortgage and hence cannot buy, while unconstrained agents have $\zeta = 0$.

Third, we add a life-cycle dimension, indexed by age a. An agent's age affects her transition probabilities to obtain a new θ, λ, or ζ.

Timing. Refinances and moves occur at the beginning of the period. Renters then pay rental costs and owners pay their mortgage and realize utility. Finally, agents age and draw new values of θ, λ, ζ according to the age-specific transition probabilities.

5.2 Value Functions

Let $\Theta = \{\theta, \lambda, \zeta, a\}$ denote the vector of types and $\mathbf{W}_t$ continue to denote the path of aggregate prices and mortgage market parameters. We work directly with value functions in units of nondurable consumption and non-pecuniary utility $\theta\bar{R}_t$. This choice fully separates the housing tenure decision from the consumption-savings problem. We denote by $V_t^{\mathcal{H}}(\Theta, s)$ the value function (evaluated at the time of rent/mortgage payments) for an agent of type Θ with tenure $\mathcal{H}$ who last moved s periods ago.[23]

We start by defining the value when acquiring a new residence. Let $V_t^{0+}(\Theta)$ and $V_t^{1+}(\Theta)$

[23]Note that $V_t^{\mathcal{H}}(\Theta, s)$ refers to date t tenure $\mathcal{H}_t$ and duration s_t, whereas Section 3 worked with value functions in terms of the entering state variables $\mathcal{H}_{t-1}$ and s_{t-1}. If all households with the same entering state make the same date t tenure decision, then $V_t^{\mathcal{H}}(\Theta, s)$ coincides with $V_t(\Omega_t, \mathbf{W}_t)$ as defined in equation (18). With the additional i.i.d. shocks described below, the relationship becomes $V_t(\Omega_t, \mathbf{W}_t) = \mathbb{E}_t V_t^{\mathcal{H}}(\Theta, s)$.

denote the values when moving to a rental or owned home, respectively:

$$\overbrace{V_t^{0+}(\Theta)}^{\text{Move to rent}} = \overbrace{-\psi_{0+} R_t}^{\text{Broker fee}} + \overbrace{V_t^0(\Theta, 0)}^{\text{New rental value}}, \tag{29}$$

$$\underbrace{V_t^{1+}(\Theta)}_{\text{Move to own}} = \underbrace{-(1-\ell_t) P_t^H}_{\text{Down payment}} - \underbrace{\infty \times \zeta}_{\text{Liquidity restriction}} + \underbrace{V_t^1(\Theta, 0)}_{\text{New owner value}}. \tag{30}$$

The element $\infty \times \zeta$ encodes the liquidity constraint as an infinite shadow cost of making a down payment. The value of moving, $V_t^+(\Theta)$, is the maximum over renting and buying:

$$V_t^+(\Theta) = \max\left\{V_t^{0+}(\Theta), V_t^{1+}(\Theta)\right\}. \tag{31}$$

We next define the value of a refinance option as the maximum over refinancing and declining the refinancing option, where refinancing pays out (or in) the change in the mortgage balance net of the refinancing fee and resets the effective tenure in the house s to 0:

$$V_t^{\text{refi}}(\Theta, s) = \max\left\{(1-\psi_r)\,\ell_t P_t^H - M_{t|t-s} + V_t^1(\Theta, 0), V_t^1(\Theta, s)\right\}. \tag{32}$$

The value functions for renting and owning encompass utility net of costs at date t plus the expected discounted continuation value, where y' denotes next period's value of $y \in \{\lambda, \xi, \Theta\}$:

$$\begin{aligned}
\text{Rent:}\quad V_t^0(\Theta, s) &= -R_t + \beta_t \mathbb{E}_{\Theta'|\Theta}\big[\lambda' \max\left\{V_{t+1}^+(\Theta'), V_{t+1}^0(\Theta', s+1) - \psi_\lambda\right\} \\
&\quad + (1-\lambda') \max\left\{V_{t+1}^+(\Theta'), V_{t+1}^0(\Theta', s+1)\right\}\big],
\end{aligned} \tag{33}$$

$$\begin{aligned}
\text{Own:}\quad V_t^1(\Theta, s) &= \theta \bar{R}_t - d_{t|t-s} - f_t \\
&\quad + \beta_t \mathbb{E}_{\Theta'|\Theta}\big[\lambda'(1-\xi')\left(\max\left\{(1-\psi_{1-}) P_{t+1}^H - M_{t+1|t-s} + V_{t+1}^+(\Theta'), V_{t+1}^1(\Theta', s+1) - \psi_\lambda\right\}\right) \\
&\quad + \lambda'\xi' \max\left\{(1-\psi_{1-}) P_{t+1}^H - M_{t+1|t-s} + V_{t+1}^+(\Theta'), V_{t+1}^{\text{refi}}(\Theta', s+1) - \psi_\lambda\right\} \\
&\quad + (1-\lambda')(1-\xi') \max\left\{(1-\psi_{1-}) P_{t+1}^H - M_{t+1|t-s} + V_{t+1}^+(\Theta'), V_{t+1}^1(\Theta', s+1)\right\} \\
&\quad + (1-\lambda')\,\xi' \max\left\{(1-\psi_{1-}) P_{t+1}^H - M_{t+1|t-s} + V_{t+1}^+(\Theta'), V_{t+1}^{\text{refi}}(\Theta', s+1)\right\}\big].
\end{aligned} \tag{34}$$

For renters, flow utility is the cost of rent and the continuation value is the maximum over the moving value and remaining in the same unit for an additional period otherwise, possibly paying the additional cost to stay. For owners, flow utility is the non-pecuniary component less the mortgage payment and flow cost of owning. Their continuation value if selling combines net sale proceeds $(1-\psi_{1-}) P_{t+1}^H - M_{t+1|t-s}$ and the moving value $V_{t+1}^+(\Theta')$, which they compare to

$V_{t+1}^{\text{refi}}(\Theta', s+1)$ if given the option to refinance and to the value $V_{t+1}^{1}(\Theta', s+1)$ of remaining in the same unit for an additional period otherwise, again possibly paying the additional cost to stay.

Finally, we augment each discrete choice in a max operator in equations (31) to (34) with i.i.d. Type 1 EV(σ_ε) idiosyncratic shocks received each period. These shocks reflect transitory, idiosyncratic forces such as the inherent randomness of housing search in the case of equation (31) (e.g. negotiating a slightly higher or lower transaction price). They also add computational tractability by making the value functions differentiable even when θ takes discretized values. For example, in the case of moving, they imply a fraction $\exp\left(V_t^{1+}(\Theta)/\bar{R}_t\sigma_\varepsilon\right) / \left(\exp\left(V_t^{0+}(\Theta)/\bar{R}_t\sigma_\varepsilon\right) + \exp\left(V_t^{1+}(\Theta)/\bar{R}_t\sigma_\varepsilon\right)\right)$ of movers of type Θ choose to buy if $\zeta = 0$.

6 Calibration

This section describes our calibration. We treat 2019 as the model steady state and a period lasts one year. Section 6.1 explains the life-cycle component. Section 6.2 uses the survey evidence from Section 4 to parameterize the age-specific θ transition process. Section 6.3 uses moments from the Survey of Consumer Finances (SCF) to parameterize the life-cycle process for the liquidity constraint ζ. Section 6.4 sets several parameters using other external evidence. Section 6.5 selects the remaining parameters to match moments calculated from the model's steady state.

Tables 2 and 3 list the full set of parameters and moments.

6.1 Life Cycle Process

All individuals belong to one of five age bins: 25-34, 35-44, 45-54, 55-64, or 65+. These bins match the age information contained in our survey.[24] Individuals born at age 25 draw from initial θ, ζ, and λ distributions, as described below, and make a tenure choice. Since we have an annual calibration, each period an individual ages up to the next group with probability 0.1 for ages below 65+. Individuals 65 and over die with probability 0.065, which gives a 65+ population share of 27% as in the SIPP. At death, an owner sells her home and is replaced by a "child" aged 25. Value functions incorporate the utility of offspring, such that the infinite horizon maximization

[24] Our survey contains a sixth age bin, 18-24. However, only 6.3% of our baseline sample and 2.8% of household heads in the SIPP belong to this age group (Table D.2). Since we do not model an endogenous rate of household formation, we choose to start individuals at age 25.

Table 2: Parameters

Name	Description	Value	Source
	Panel (a): θ process $\mathbb{E}\left[\theta'\vert\theta,a\right] = (1-\delta_\theta(a))\left(\theta+\Delta_\theta\right) + \delta_\theta(a) N\left(m_\theta, \sigma_\theta\right)$		
Δ_θ	Growth if no re-draw	0.006	Table 3 Panel (a)
$\delta_\theta(a)$	Re-draw probability	$0.003 \times a^2$	Table 3 Panel (a)
m_θ	Mean of starter distribution	0.050	Table 3 Panel (a)
σ_θ	S.d. of starter distribution	0.126	Table 3 Panel (a)
	Panel (b): ζ process $\mathbb{P}\left[\zeta'=0\vert\zeta=1,a\right] = \Phi\left(z_0 + z_1 \times (a)\right)$		
ζ_0	Unconstrained at birth	0.631	Table 3 Panel (b)
z_0	Probit intercept	-1.684	Table 3 Panel (b)
z_1	Probit slope	-0.122	Table 3 Panel (b)
	Panel (c): Externally calibrated		
μ	Growth rate of rents	0.01	2000-2019 rent growth less non-shelter inflation
ψ_{0+}	Fee for new rental	$R/12$	1 month rent
ψ_{1-}	Fee for selling home	$0.05P^H$	Broker fee
ℓ	Loan-to-value at origination	0.87	Adelino, Schoar and Severino (2018)
τP^H	Taxes and insurance	$0.023P^H$	CEX
π	Non-shelter inflation rate	0.014	2019 expectation from Federal Reserve Bank of Cleveland (2026)
i	Real mortgage rate	0.026	Freddie-Mac 30 year mortgage rate - π
$1/\beta - 1$	Discount rate	0.026	Same as i
ξ	Refinance opportunity	0.234	Berger et al. (2025)
o^R	Rental operating cost	0.242	BEA I-O Use
c	Rental inverse cap. rate	15.16	Net cap. rate 0.05
γ_1	Slope of conversion supply curve	5.5	Greenwald and Guren (2025) + c
γ_0	Intercept of conversion cost	$P^H/P^R - \gamma_1 h$	$P^H/R = 14.6$ (CEX)
	Panel (d): Internally estimated with full model steady state		
$[\lambda_{25-34}, \lambda_{35-44}, \lambda_{45-54}, \lambda_{55-64}, \lambda_{65+}]$	Mobility nudge hazard by age	[0.651,0.438, 0.341,0.278,0.193]	Table 3 Panel (c)
$p_{\lambda+}$	No mobility nudge to mobility nudge transition probability	.029	Table 3 Panel (c)
$p_{\lambda-}$	Mobility nudge to no mobility nudge transition probability	.123	Table 3 Panel (c)
σ_ε	Idiosyncratic cost shock	0.018	Table 3 Panel (c)
$f - \tau P^H$	Residual carrying cost	$0.402R$	Table 3 Panel (c)
ψ_λ	Forced mobility avoidance cost	$1.20R$	Table 3 Panel (c)

Table 3: Targeted Moments

Moment	Description	Source	Data	Model
	Panel (a): θ process moments			
$\mathbb{E}_\theta\left[\theta \mid a \subseteq (25,34]\right]$	Age 25-34 mean θ	Survey	10.8	9.9
$\mathbb{E}_\theta\left[\theta \mid a \subseteq (35,44]\right]$	Age 35-44 mean θ	Survey	12.5	14.3
$\mathbb{E}_\theta\left[\theta \mid a \subseteq (45,54]\right]$	Age 45-54 mean θ	Survey	17.5	16.5
$\mathbb{E}_\theta\left[\theta \mid a \subseteq (55,64]\right]$	Age 55-64 mean θ	Survey	16.8	16.1
$\mathbb{E}_\theta\left[\theta \mid a \geq 65\right]$	Age 65+ mean θ	Survey	12.7	13.4
$SD\left[\theta \mid a \subseteq (25,34]\right]$	Age 25-34 St. dev. θ	Survey	13.9	13.9
	Panel (b): ζ process moments			
$\mathbb{P}_\Theta\left[\zeta = 1 \mid a \subseteq (25,34]\right]$	Age 25-34 constrained share	SCF, Zillow	27.7	28.0
$\mathbb{P}_\Theta\left[\zeta = 1 \mid a \subseteq (35,44]\right]$	Age 35-44 constrained share	SCF, Zillow	23.1	21.9
$\mathbb{P}_\Theta\left[\zeta = 1 \mid a \subseteq (45,54]\right]$	Age 45-54 constrained share	SCF, Zillow	16.9	18.2
$\mathbb{P}_\Theta\left[\zeta = 1 \mid a \subseteq (55,64]\right]$	Age 55-64 constrained share	SCF, Zillow	15.9	15.8
$\mathbb{P}_\Theta\left[\zeta = 1 \mid a \geq 65\right]$	Age 65+ constrained share	SCF, Zillow	13.8	13.5
	Panel (c): Full steady state moments			
$\mathbb{P}_\Theta[\mathcal{H}' = 0, s' = 0 \mid \mathcal{H} = 0, a \subseteq (25,34]]$	Age 25-34 rent-to-rent rate	SIPP	21.3	21.3
$\mathbb{P}_\Theta[\mathcal{H}' = 0, s' = 0 \mid \mathcal{H} = 0, a \subseteq (35,44]]$	Age 35-44 rent-to-rent rate	SIPP	14.2	14.2
$\mathbb{P}_\Theta[\mathcal{H}' = 0, s' = 0 \mid \mathcal{H} = 0, a \subseteq (45,54]]$	Age 45-54 rent-to-rent rate	SIPP	11.3	11.3
$\mathbb{P}_\Theta[\mathcal{H}' = 0, s' = 0 \mid \mathcal{H} = 0, a \subseteq (55,64]]$	Age 55-64 rent-to-rent rate	SIPP	9.6	9.6
$\mathbb{P}_\Theta[\mathcal{H}' = 0, s' = 0 \mid \mathcal{H} = 0, a \geq 65]$	Age 65+ rent-to-rent rate	SIPP	7.3	7.3
$\mathbb{P}_\Theta[\mathcal{H}' = 1 \mid \mathcal{H} = 0]$	Rent-to-own	SIPP	4.8	4.8
$\mathbb{P}_\Theta[\mathcal{H}' = 0 \mid \mathcal{H} = 1]$	Own-to-rent	SIPP	1.5	1.4
$\mathbb{P}_\Theta[\mathcal{H}' = 1 \mid \mathcal{H} = 1]$	Own-to-Own	SIPP	2.8	2.8
$\mathbb{E}_\Theta[\theta \mid \mathcal{H} = 1] - \mathbb{E}_\Theta[\theta \mid \mathcal{H} = 0]$	WTP premium for owners	Survey	12.3	12.3
$\mathbb{E}_\Theta[\mathcal{H}]$	Homeownership rate	HVS	66.7	66.3

problem at the start of Section 3 and the value functions (33) and (34) continue to hold inclusive of transitions from age 65 to age 25. However, because newborns make a fresh tenure choice, the decisions of the old do not affect the utility of their offspring.

6.2 Life Cycle θ Process Using Survey

Newly-born individuals draw θ from a normal distribution $N(m_\theta, \sigma_\theta)$. An agent of age a either has her θ grow by Δ_θ or "crash" with age-specific probability $\delta_\theta(a) = \delta_{\theta,0} a^2$, for $a \in \{1,2,3,4,5\}$, in which case she draws a new θ from $N(m_\theta, \sigma_\theta)$. Thus, $\mathbb{E}\left[\theta' \mid \theta, a\right] = (1 - \delta_\theta(a))(\theta + \Delta_\theta) + \delta_\theta(a) m_\theta$. The growth component Δ_θ captures life-cycle changes such as family size or neighborhood preference, while the crash component $\delta(a)$ captures down-sizing motives later in life as well as other idiosyncratic changes. Absent the age dimension, when $\Delta_\theta = 0$ this process nests the i.i.d. redraw process in Section 2. When $\sigma_\theta = 0$, it generates an (approximately) exponential distribution with minimum value m_θ and scale parameter $\Delta_\theta/\delta_\theta$.

We choose the parameters $\Delta_\theta, \delta_\theta, \mu_\theta, \sigma_\theta$ to match the five age-specific means of θ shown in Figure 4 and listed in Panel (a) of Table 3 as well as the standard deviation of θ in the 25-34 year-old age bin.[25] Despite the relative parsimony of the calibration, it matches well the hump-shaped age profile of average θ.

6.3 Life Cycle ζ Process Using SCF

Liquidity constraints that prevent some individuals from buying are an important feature of reality. At the same time, for the reasons outlined at the start of Section 3, we do not wish to incorporate a full consumption-saving problem.[26] We therefore calibrate a simple life-cycle process for being liquidity constrained, $\zeta = 1$. A newborn is constrained with probability $1 - \zeta_0$. Each period a constrained individual becomes unconstrained with age-specific probability $\mathbb{P}[\zeta' = 0|\zeta = 1, a] = \Phi(z_0 + z_1 \times a)$, where Φ denotes the cumulative normal distribution and z_0 and z_1 are parameters.

We define liquidity constraints in the data as having financial assets plus home equity less than 3.5% of the average value of a home in the bottom third of the home price distribution. The 3.5% threshold is the minimum downpayment for an FHA mortgage.[27] We measure financial assets and home equity by age group using the 2019 SCF.[28] We obtain the value of a home in the bottom third of the price distribution from the Zillow All Homes—Bottom Tier series. We choose ζ_0, z_0, z_1 to best match the fraction of constrained individuals in each age bin shown in Panel (b) of Table 3.

[25] Using the information in our follow-up survey, we adjust the standard deviation for the presence of measurement error, as described in Appendix D.5. In brief, the correlation between WTP in the original and follow-up survey is 0.5. If individuals report their true θ plus i.i.d. measurement error, then the naive standard deviation exceeds the true standard deviation by a factor of $\sqrt{2}$.

[26] Our focus on post-2019 dynamics also makes the details of credit constraints arguably less important than during the early 2000s, when more complicated changes to lending standards such as in enforcement of a payment-to-income constraint played an important role (Greenwald, 2018).

[27] Since little else in our model depends on heterogeneity in the down payment, we model all purchasers as starting with a single loan-to-value ℓ. However, the proper comparison to the liquid asset distribution is the minimum down payment in the data of 3.5% applied to the value of a starter home.

[28] We use the definitions of financial assets and home equity given by the variables `FIN` and `HOMEEQ` in https://www.federalreserve.gov/econres/files/bulletin.macro.txt.

6.4 Externally-calibrated Parameters

We externally set the growth rate of rents to 1% at an annualized rate, the value of real (deflated by the non-shelter CPI) rent growth over 2000-2019. The values for ψ_{0+} and ψ_{1-} correspond to a broker fee of 1 month rent when moving into a new rental and a sales commission of 5% when selling a house. We set the loan-to-value at origination to 0.87, which has remained about the median value throughout the 2000s (Adelino, Schoar and Severino, 2018). We set the nominal mortgage rate i^C to the 2019 average 30 year mortgage rate of 4.0%, non-shelter inflation π^C to 1.4% by combining one-year ahead expected overall and rental inflation, and the real discount rate equal to the steady state real mortgage rate of $i \approx i^C - \pi^C$.[29] A fraction $\xi = 23.4\%$ of owners have the opportunity to refinance each year (Berger et al., 2025). We split the carrying cost of owning into a component that scales the current house price, τP^H, and a remainder $f - \tau P^H$ that scales trend rent. We calibrate the part that scales the house price using the CEX such that owners pay $\tau = 2.3\%$ of the current value of their home every year in property taxes and insurance, and estimate the residual component below.

The specification of the supply-side matters to the general equilibrium impulse responses reported in Section 7, but not for the historical index exercise in Section 8, which takes all prices as given. We assume $P_t^H/P_t^R = 1 + g(h_t) = \gamma_0 + \gamma_1 h_t$, where $P_t^R = c_t R_t$ is the price of a rental unit. We obtain $P^H/P^R = 0.96$ by combining a price-rent ratio of $P^H/R = 14.6$ using self-reported values in the CEX with a gross inverse capitalization rate of $c = (1 - o^R)/0.05 = 15.16$, where 0.05 is the net capitalization rate and $1 - o^R = 75.8\%$ is the ratio of gross operating surplus to gross output in the tenant occupied housing sector (U.S. Bureau of Economic Analysis, 2025, 2017 detailed Use table).[30] Greenwald and Guren (2025) estimate $\partial \log \left(P_t^H/R_t\right)/\partial \log h_t$ following shocks to mortgage availability that plausibly keep c_t fixed. Using their value of 3.8 together with $P^H/P^R = 0.96$ and $h = 0.667$ gives $\gamma_1 = 5.5$. Given this value, we set γ_0 to achieve $P^H/R = 14.6$.

[29] We obtain the value for non-shelter inflation by combining the 2019 one-year ahead expected CPI inflation rate of 1.75% from Federal Reserve Bank of Cleveland (2026) and an expected growth rate of real (relative to non-shelter inflation) rent of 1%: $1.75\% \approx (1/3) \times (1.4 + 1)\% + (2/3) \times 1.4\%$.

[30] The commercial real estate sector typically quotes capitalization rates as net operating income divided by market value, or $(1 - o^R)R/P^R$ in our notation. The value of 0.05 comes from CoStar for high quality rental properties.

6.5 Internally-calibrated Parameters

We estimate the remaining ten parameters jointly using ten steady state moments of the full model: eight transition hazards, the WTP premium for owners in column (8) of Table 1, and the homeownership rate. We minimize the equal-weighted distance between the logs of the model and data transition rates and the levels of the premium and homeownership moments. Overall, the model matches the targeted moments quite well.

Eight of the estimated parameters pertain to the moving nudge propensity, λ, and the size of the nudge, ψ_λ. Individuals have either $\lambda = 0$ or an age-specific λ_a. Individuals of all ages with $\lambda = 0$ transition to their λ_a with probability $p_{\lambda+}$ while individuals with $\lambda > 0$ transition to $\lambda = 0$ with probability $p_{\lambda-}$, giving a fraction $p_{\lambda+}/(p_{\lambda+} + p_{\lambda-})$ of individuals of any age with $\lambda > 0$. Due to moving costs, in steady state individuals in our model only undergo rent-to-rent or own-to-own moves when nudged. Furthermore, the lower transaction costs involved in rent-to-rent transitions mean that for any ψ_λ large enough to generate own-to-own transitions, renters essentially always move when nudged. Thus, age-specific hazard rates for completing a rent-to-rent move estimated in the SIPP (see Appendix E for details), $\mathbb{P}_\Theta\left[\mathcal{H}' = 0, s = 0 | \mathcal{H} = 0, a\right]$, tightly discipline the age-specific values $\{\lambda_a\}$. Specifically, with λ_a varying flexibly by age, the model hits these targets almost exactly for any population share $p_{\lambda+}/(p_{\lambda+} + p_{\lambda-})$. The values imply a declining hazard in age. Given probabilities of receiving a nudge and the idiosyncratic variance, the own-to-own rate disciplines the cost of not moving given a nudge, ψ_λ. At the estimated value of $1.2\times$ annual rent, nearly all owners and renters move in steady state given a nudge.[31]

Conditional on the already-calibrated θ and ζ processes, the parameters $p_{\lambda+}$ and $p_{\lambda-}$ together with the idiosyncratic cost standard deviation σ_ε determine the scale of gross flows across owning and renting. Intuitively, agents only change tenure when their type changes or when receiving a large enough idiosyncratic cost shock coincident with a nudge. The hazard rates for switching from owning to renting and renting to owning, $\mathbb{P}_\Theta\left[\mathcal{H}' = 1 | \mathcal{H} = 0\right]$ and $\mathbb{P}_\Theta\left[\mathcal{H}' = 0 | \mathcal{H} = 1\right]$, therefore discipline these parameters. In addition, these parameters affect the overall degree of sorting into homeownership by θ, since $p_{\lambda+}/(p_{\lambda+}+p_{\lambda-})$ determines the population share subject to nudge shocks and σ_ε the within-type tenure variance. The regression coefficient from column (8) of

[31] The value of ψ_λ is poorly identified from the right, as any value of ψ_λ above $1.2R$ would also induce all nudged owners and renters to move in steady state. We therefore perform sensitivity analysis with respect to this parameter.

Table 1, which translates into $\mathbb{E}_\Theta[\theta|\mathcal{H}=1]-\mathbb{E}_\Theta[\theta|\mathcal{H}=0]$, therefore also disciplines these parameters. We obtain a fraction $p_{\lambda+}/(p_{\lambda+}+p_{\lambda-})\approx 0.2$ with $\lambda>0$ and a standard deviation of the idiosyncratic cost draw equivalent to about 2 months of rent.

The final parameter is the second component of the flow cost of owning, $f-\tau P^H$, which represents maintenance and depreciation costs. These costs do not scale with the house price out of steady state. All else equal, a higher total carrying cost f reduces homeownership and a lower flow cost increases homeownership. Thus, we additionally target the homeownership rate.[32] We obtain a value of $f-\tau P^H = 40\%$ of annual rent. Together with τ, owners pay a steady state cost of $f/P^H = 0.40\times R/P^H+\tau = 5.1\%$ of the house price every year. This value closely matches the sum of property taxes, insurance, and maintenance of 3.5% in the CEX and depreciation of residential buildings of 1.3% per year in the NIPA, despite not targeting maintenance and depreciation directly.[33]

6.6 Additional Model Moments and Validation

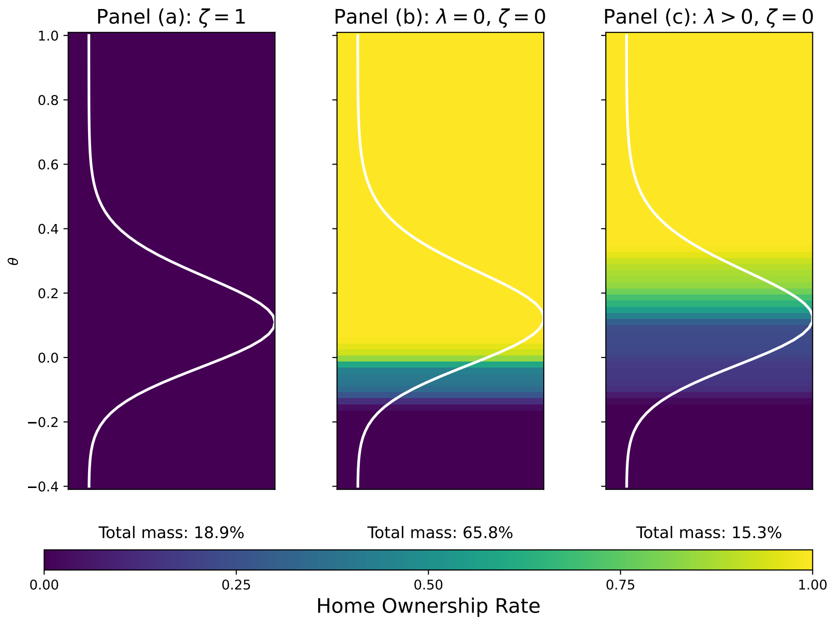
Figure 5 illustrates the sorting into homeownership in steady state. Panel (a) contains the 19% of the population that is liquidity constrained, who by construction all must rent. Panel (b) contains the 66% of the population that is neither liquidity constrained nor subject to nudges to move. Essentially all of these agents own if their θ is positive. Some agents with θ slightly negative also own, as they anticipate a growing θ as they age. Panel (c) contains the remaining share of the population, who are not liquidity constrained but are subject to nudges. These agents value homeownership less because transaction costs of owners exceed those of renters. High θ agents with $\lambda>0$ still own, especially among older cohorts with lower λ_a, but those with lower θ rent.

Figure 6 reports homeownership rates by age in the model and in the 2019 HVS. Nothing in the model's calibration directly targets moments associated with homeownership by age; the only age-related targets concern the age profile of θ directly from our survey, the age profile of liquidity

[32] In environments without birth and death, the tenure transition hazards imply a homeownership rate due to the stock/flow relationship $(1-h)\,\mathbb{P}_\Theta[\mathcal{H}'=1|\mathcal{H}=0]=h\mathbb{P}_\Theta[\mathcal{H}'=0|\mathcal{H}=1]$. This relationship does not hold in our environment because individuals born at age 25 have much higher likelihood of renting than individuals dying at age 65+. Thus, the homeownership rate moment contains additional variation beyond the transition hazards.

[33] Depreciation of residential fixed assets in the NIPA is 1.3% per year. This value applies only to the structures part of residential property and excludes routine maintenance expenditure. Our calculation of the user cost in Figure 1 adds 1p.p. per year of depreciation on top of maintenance as recorded in the CEX, following the approach in Garner and Verbrugge (2009).

Figure 5: Steady State Homeownership Heat Map



Notes: The figure shows the fraction of agents who own, by θ. Panel (a) restricts to agents with $\zeta = 1$ who cannot buy. Panel (b) restricts to agents with $\zeta = 0$ and not immediately subject to a mobility nudge, $\lambda = 0$. Panel (c) restricts to agents subject to a mobility nudge. The white curves overlaying each figure display the density of agents.

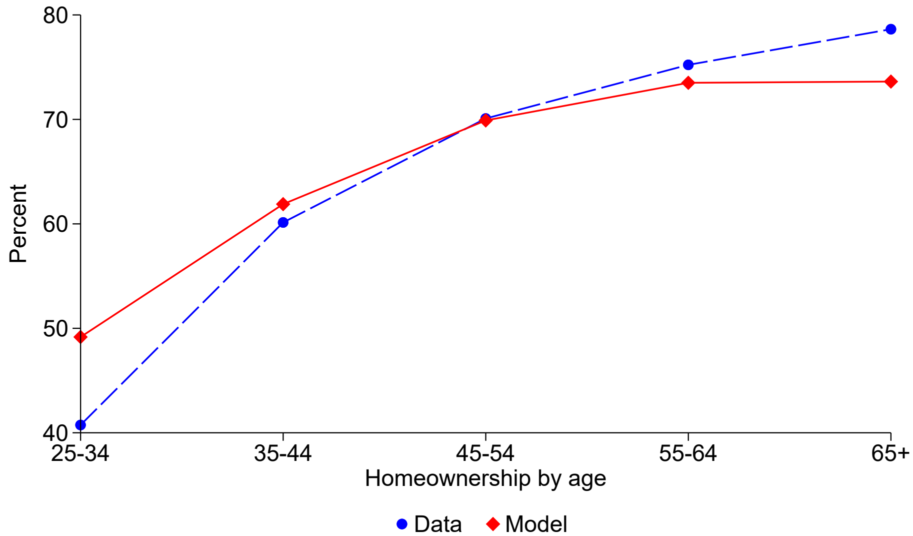
constraints directly from the SCF, and the age profile of rent-to-rent mobility from the SIPP. The moments associated with homeownership — the rent-to-own and own-to-rent transition rates and homeownership — are not age-specific. Nonetheless, the model reproduces the upward-sloping, concave relationship between homeownership and age in the data. This success occurs because the increasing, concave relationship between θ and age, the decline in nudge rates in age, and the decline in liquidity constraints in age all cause homeownership to rise.

7 Application: Mortgage Rate Hike

In this section we consider an unexpected, permanent 2p.p. increase in the mortgage rate i starting from the model's steady state, motivated by the sudden increase in rates in 2022 in the U.S. We show that the shelter price path impulse response using our approach differs sharply from alternatives including owners' equivalent rent and the one period user cost.

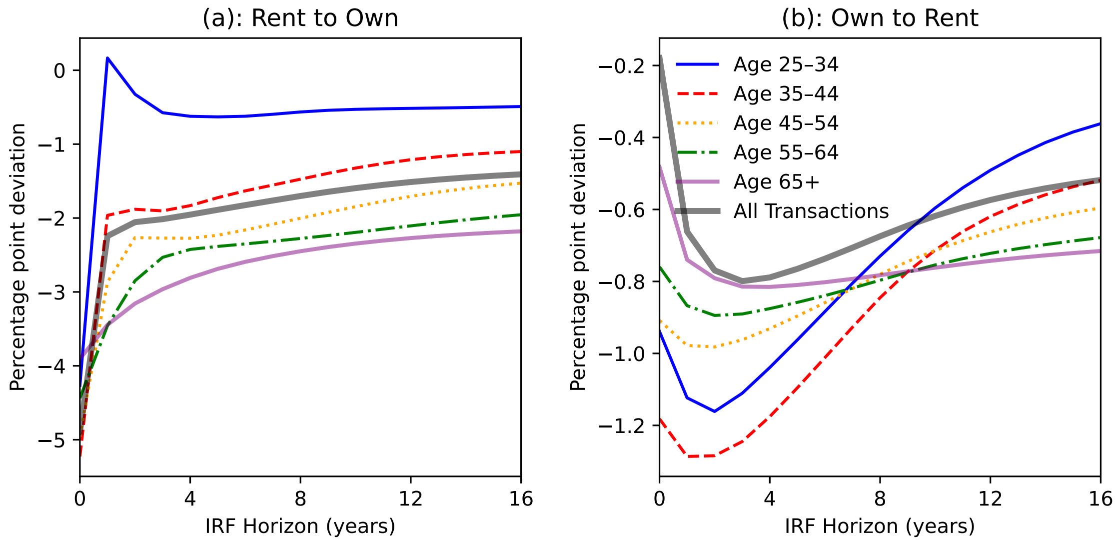
Figure 7 shows the responses of transition rates across tenure status by age. With homeownership more expensive, rent-to-own transitions fall. Perhaps surprisingly, own-to-rent transitions

Figure 6: Homeownership by Age in Model and Data



Notes: The figure plots the homeownership rate by age in the model and in the 2019 Housing Vacancy Survey.

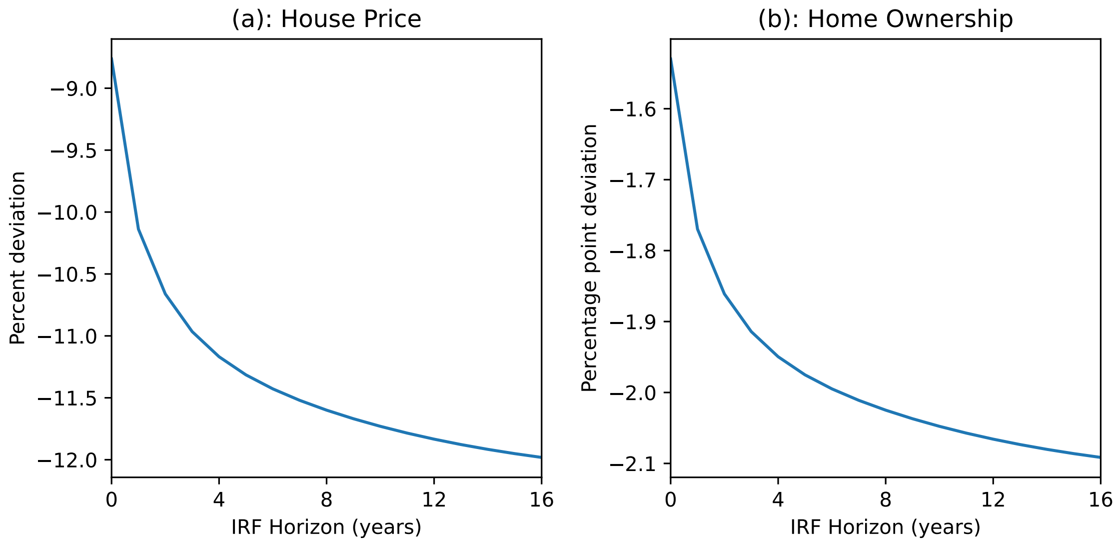
Figure 7: Mobility Rates



Notes: The figure shows the percentage point deviations from the balanced growth path of own-to-rent and rent-to-own flows in response to a 2 percentage point increase in the mortgage rate, by age bin.

also fall. The decline in own-to-rent and the non-instantaneous adjustment of these flows reflect mortgage rate lock (Liebersohn and Rothstein, 2025; Batzer et al., 2024; Fonseca and Liu, 2023); agents with low mortgage rates and who have not experienced a θ decline or λ shock remain in their own homes. Indeed, even some homeowners receiving the λ nudge to move now prefer to pay the ψ_λ cost and keep their low mortgage rates.

Figure 8: House Price and Home Ownership



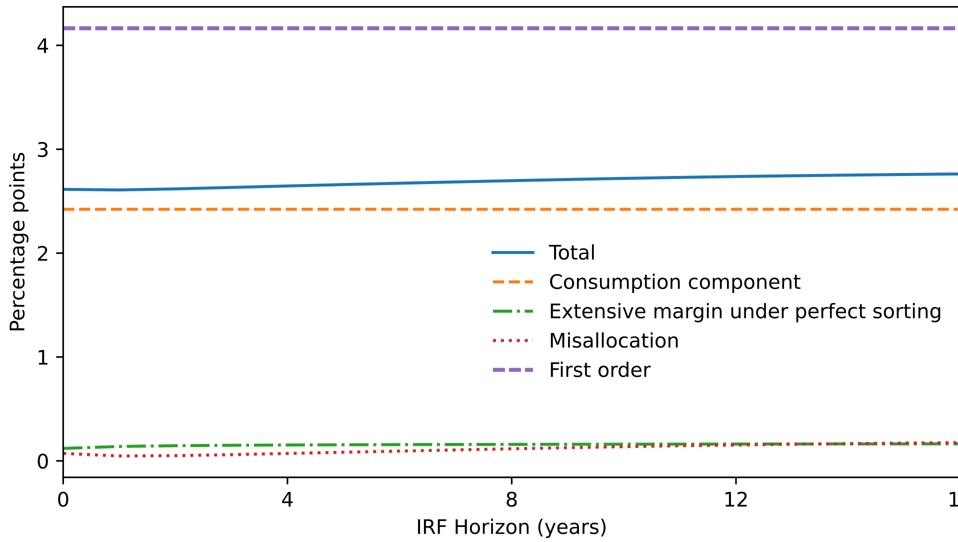
Notes: The left panel shows the percent deviation from the balanced growth path of the house price in response to a 2 percentage point increase in the mortgage rate. The right panel shows the percentage point deviation of the homeownership rate.

Figure 8 shows the resulting paths of house prices and homeownership. Given our relatively simple supply side, these are tightly linked. Both house prices and homeownership fall on impact and continue to decline over several years. Of course, households anticipate the falling house prices. The reason they do not all sell ahead of the decline is that those with high enough θ value remaining as owners enough to offset the expected capital loss.

The solid blue line in Figure 9 shows the deviation in the overall shelter price relative to trend expenditure, $dP_{t+j}/\mathbb{E}_{\Theta,\mathcal{H},s}\left[\bar{X}\left(\mathcal{H}_{t+j},s\right)\right]\bar{R}_{t+j}$ using the notation of Proposition 5. The price deviation jumps 2.6p.p.[34] The dashed orange line shows the contribution from the required decline in nondurable consumption (the first term in equation (23)), which accounts for most of the increase. The dash-dotted green line and dashed red line show the contribution from foregone utility due to changes in homeownership (the second term), split as in equation (25) into a component reflecting the decline in homeownership with efficient sorting (dash-dotted green line) and the change in

[34] Figure G.1 of the online Appendix shows the price index jump under alternative calibrations of the cost of not moving given a nudge, ψ_λ, and the slope of the supply curve, γ_1. The price index response varies by less than 10% of the 2.6p.p. baseline jump for values of ψ_λ ranging up to 2.4× annual rent, or double the baseline value of ψ_λ. In fact, at the baseline value of γ_1, a higher ψ_λ slightly weakens the price index response, as the general equilibrium additional decline in house prices as some owners switch to renting overwhelms the direct, partial equilibrium higher cost to affected owners. The price index varies up to 15% of the baseline value of 2.6p.p. for values of γ_1 ranging from 3.5 to 7.5. We have also explored the consequences of a fall in the mortgage rate, which has larger effects due to the convex relationship between mortgage rates and house prices.

Figure 9: Shelter Inflation Relative to the Balanced Growth Path

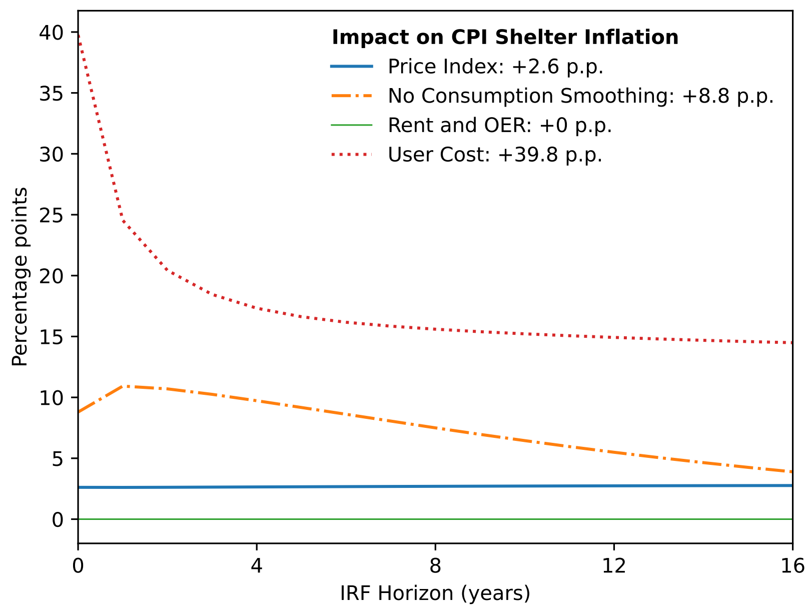


Notes: The solid blue line shows the deviation of the shelter price from the balanced growth path in units of trend expenditure on shelter. The dashed orange line shows the contribution from the required change in nondurable consumption. The dash-dotted green line shows the contribution from the change in homeownership with perfect sorting by θ. The dotted red line shows the contribution from the change in misallocation of who owns by θ. The dashed purple line shows the first-order approximation to the price index, in which no one re-optimizes their tenure decision.

misallocation. These terms are small in this exercise. The dashed purple line shows the first-order approximation to the price index, which applies the changes in the mortgage rate and house price to the balanced growth path distribution of households. This approximation is the analog of the first term of equation (12) in the simple model without transaction costs. The welfare loss is necessarily greater without household re-optimization, and the difference of nearly 1p.p. in the price index is substantial. Thus, simpler approximations to the welfare change may prove inadequate.

Figure 10 compares our price index response, again shown in the blue solid line, to several alternatives. The dashed green line shows shelter costs using rent and OER, which does not change since rents remain unchanged by construction. The dash-dotted orange line shows the price index if we had not imposed smoothing of nondurable consumption and instead allocated changes in spending to the period in which they occur. This index starts off much higher, reflecting the gradual decline in house prices. By construction the infinite-horizon integrals of the blue and dash-dot orange lines equate, but the transition dynamics differ sharply. Finally, the dotted red line shows the one-period user cost. The user cost rises far more than our index, reflecting both the fact that the higher interest payment applies immediately to all owners and the anticipation

Figure 10: Inflation Under Alternative Shelter Price Indexes



Notes: The figure shows several measures of deviations of shelter costs from the balanced growth path in units of trend expenditure on shelter. The solid blue line shows our preferred price as defined in equation (23). The dashed green line shows rent and owners' equivalent rent, which remains unchanged by construction. The dash-dot orange line shows the price without imposing smoothing of nondurable consumption. The dotted red line shows the one-period user cost. The legend reports shelter inflation in the first year using each measure.

of further house price declines.

8 Cost-of-shelter Index 2019-2024

The previous section showed that our approach to measuring the cost-of-shelter can differ sharply from rent growth or the one-period user cost. We now construct historical shelter cost changes consistent with observed data on house prices, rents, mortgage rates, expectations of each of these, and the homeownership rate.

The first step of this process requires choosing a base year in which the economy starts on the balanced growth path with the steady state allocation of household types to tenure choice by duration. The year 2019 is a natural choice, as Chodorow-Reich, Guren and McQuade (2024) argue it marks the return to normalcy following the 2000s housing cycle and it provides several of our calibration moments.

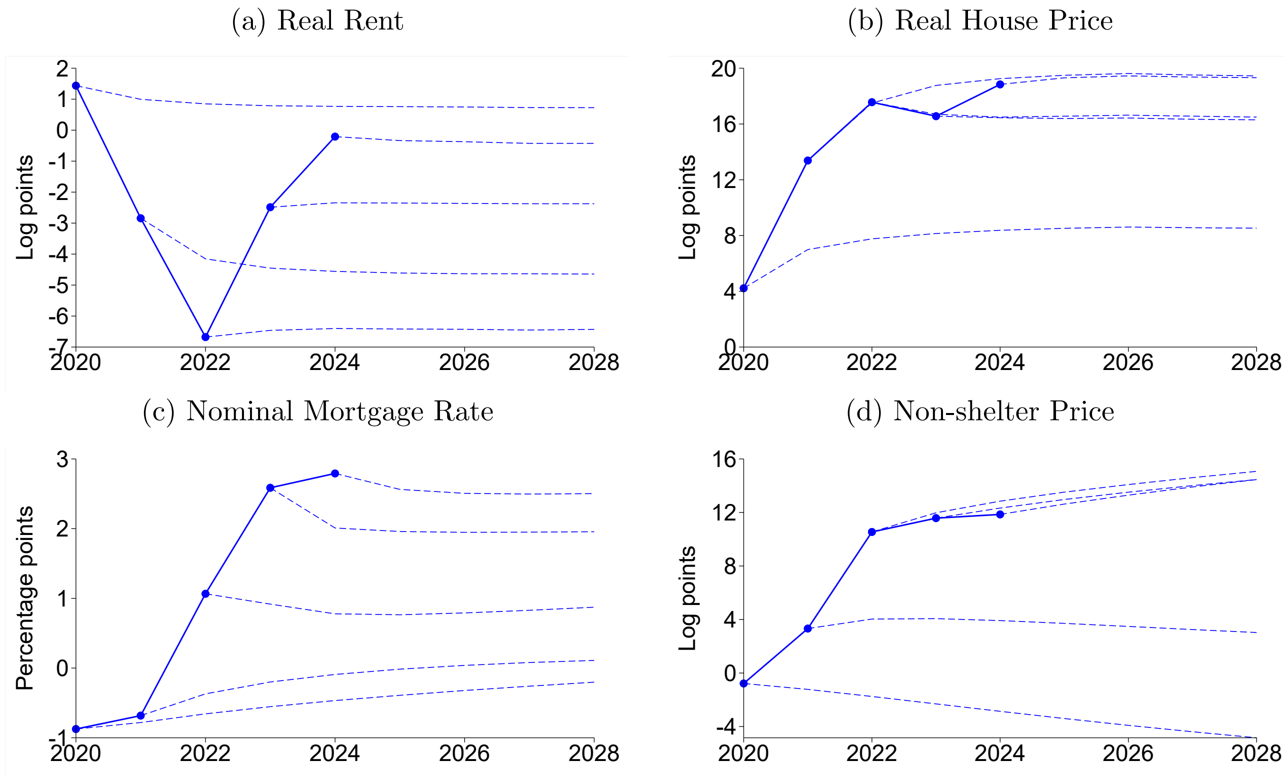
In each successive year thereafter, we feed into the model the actual real (deflated by non-shelter

CPI) house price and rent, nominal mortgage rate, and non-shelter inflation (which affects real mortgage balances), as well as expectations into the infinite future of these variables. Expectations of house prices and rents out fifty years come from rolling Bayesian VARs, after which we gradually bring expectations back to the model's balanced growth path. Appendix F provides additional details of these steps. The Bayesian VAR yields house price expectations reasonably consistent with survey expectations (see Figure F.2 and also the close comovement of the user costs based on the two measures of expectations in Figure 1), but with the necessary advantage of providing the entire term structure of expectations each year. The realized house prices and these auxiliary forecasts can be made internally consistent with rational expectations by assuming a complying set of realizations of and expectations about the intercept of the supply curve γ_0, but we do not need to solve for this path for what follows. The expectations of mortgage rates come from rolling regressions of the nominal mortgage rate on 15 years of Treasury forward rates from Board of Governors of the Federal Reserve System (2026). Non-shelter inflation expectations come from Federal Reserve Bank of Cleveland (2026), adjusted for rent expectations from the Bayesian VAR. Figure 11 reports the realizations of these variables as well as expectations through 2028.

We also give households sequences of additional utility from owning (beyond their θ), chosen to match the path of homeownership. These residual demand shocks affect tenure choice, but do not directly affect welfare or the price index.[35] Demand systems almost always require such auxiliary "taste" shocks to match the dynamics of expenditure and prices. In our setting, they may represent increased desire for homeownership due to the higher prevalence of work-from-home post-COVID, or decreased utility from renting due to post-COVID lower amenities from living in the dense city center. Without them, the large swings in prices and mortgage rates in the data together with the effective slope of the demand curve coming from our calibration would generate counterfactual changes in homeownership. Our approach of computing the welfare change as if

[35] Specifically, we first compute a (possibly negative) fictitious uniform transfer to owners at date t such that homeownership at date t would match the data. This step tags the share of each type (equivalently, the type-specific cutoff value of the idiosyncratic taste shock) that must change tenure to match the homeownership rate. We then assume that any shock to the change in utility from owning exactly offsets the change in costs, thereby leaving each marginal household indifferent between their current status and switching tenure. Thus, changes to match the path of homeownership do not directly affect welfare. Equivalently, let $\hat{V}_t$ denote the aggregate value function at date t inclusive of all date t shocks other than the residual demand shock and $d\hat{G}_t(\Theta, \mathcal{H}, s)$ the (endogenous) distribution of types before applying the residual demand shock. We compute the welfare change between $t-1$ and t using $\hat{V}_t - \mathbb{E}_{t-1}V_t$ and only then update the date t distribution from $d\hat{G}_t(\Theta, \mathcal{H}, s)$ to $dG_t(\Theta, \mathcal{H}, s)$.

Figure 11: Deviations of Shelter Costs from Balanced Growth Path



Notes: The figure shows the realized values (solid lines) and forecasts (dashed lines) of real rent, real house prices, nominal mortgage rates, and the non-shelter price, in deviations from the 2019 steady state. Real rents and house prices are de-trended using growth of 1% per year. The non-shelter price is de-trended using non-shelter inflation of 1.4% per year.

the residual demand shocks did not exist falls in the tradition of *divisia* indexes that weight prices changes using observed expenditure shares, where here obtaining the correct expenditure shares requires matching the path of homeownership.[36]

Given the actual real house price and rent, nominal mortgage rate, non-shelter inflation, residual demand shocks, and expectations of these variables, $\mathbb{E}_t \mathbb{W}_\infty$, households make their decisions about whether to rent or own. Iterating forward in this fashion, we obtain the distribution of owning and renting by duration and type for each year after 2019. By construction, these distributions also match total homeownership. Together with the realizations of prices and expectations, they form the necessary ingredients to produce the historical cost-of-shelter in Proposition 6.[37]

[36]The literature has debated the proper treatment of shocks to the distribution of tastes or preferences. Baqaee and Burstein (2022) argue against including taste shocks in a price index on the grounds that doing so requires assumptions on cardinal utility. An example from our setting: the price index would differ depending on whether higher homeownership reflects a "push" from lower utility from renting or a "pull" from higher utility from owning. In contrast, Redding and Weinstein (2019) make precisely such assumptions in order to capture the covariance between taste shocks and price changes.

[37]This procedure does not necessarily exactly match refinancing behavior in the data. Nevertheless, 66% of

The solid black line with filled disks in Figure 12 shows the historical price index $dP_t/\bar{P}_t$, plotted in real terms (that is, relative to actual non-shelter CPI) and detrended by the growth rate of real rent of 1% per year. The price index rises above trend in 2020, falls until 2022, and then rises again in 2023-2024. The dashed line with filled triangles shows the historical price index path using only the pecuniary, V^X, component of welfare. The close co-movement of the solid and dashed lines implies that changes in $\mathbb{E}_\Theta[\mathcal{H}\theta]$ contribute relatively little directly to fluctuations in the overall price, consistent with the decomposition shown for the impulse response in Figure 9.[38]

The dotted line with filled diamonds shows for comparison the path of de-trended BLS real rent, which falls sharply in 2020-2022 (when non-shelter inflation surged) before rebounding in 2023-2024. The path of rent has the same qualitative shape as our shelter price index and both roughly return to trend by 2024, but our measure has less volatility in the intervening years. Among other forces, this dampening reflects the basic fact that two-thirds of the population own rather than rent and hence experience no direct change in their shelter expenditure when rents fluctuate. This property differs from the simple model (see Lemma 2), because transaction costs, long-term contracts, and additional heterogeneity imply there is no longer a single cutoff θ^* and hence the cost of owning does not simply co-move with changes in rents.

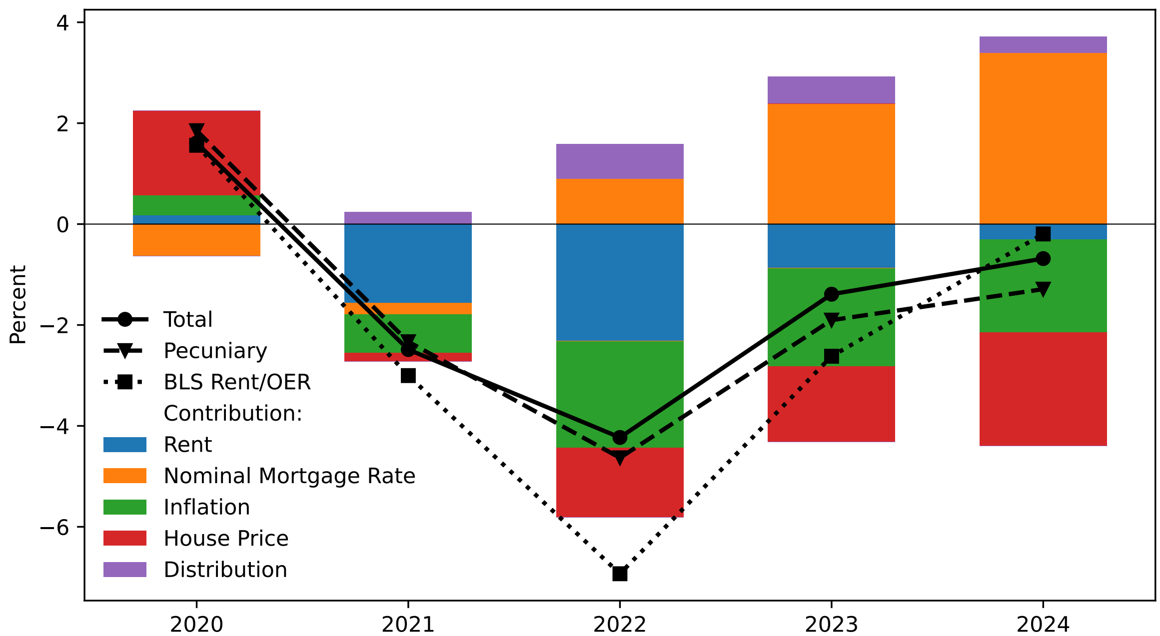
To more formally decompose the drivers of the overall price index, the bars show the contributions of groups of shocks when added sequentially, starting from the balanced growth path.[39] We start with rent. The V-shaped contribution of rent mirrors the path of real rent itself, but with even less amplitude than our overall index. Next, the orange bars show the additional contribution of the nominal mortgage rate. The rise in mortgage rates between 2021 and 2024 causes an increase in the price index of more than 3p.p., similar to the impulse response plotted in Figure 9.

mortgages in the model-generated data have $s \leq 4$ in 2021, meaning they either moved or refinanced within the past four years. According to Federal Housing Finance Agency (2026), the actual share in 2021Q4 was 57%, or 73% if weighted by origination loan amount. This alignment both validates our calibration of the refinance propensity and means that the model has approximately the right share of homeowners subject to mortgage rate lock when rates start to rise in 2022.

[38]The fact that fluctuations in $\mathbb{E}_\Theta[\mathcal{H}\theta]$ make a relatively small direct contribution to the price index does not mean that θ heterogeneity does not matter to the exercise. Figure G.2 of the online appendix compares the baseline price index to alternative versions without heterogeneity in θ, either keeping the parameters fixed at their baseline values or re-estimating them to match the moments in Table 3 but with a fixed θ and without the owner premium moment. In both alternatives, the price index falls much more in 2021 and does not recover as much as in our baseline calibration. The difference stems from the stronger sorting into homeownership along the λ dimension that occurs when θ heterogeneity is absent.

[39]Appendix Figure G.3 reports the contributions of the same groups of shocks when added one-at-a-time to the balanced growth path. These contributions differ because of interactions among the groups of shocks.

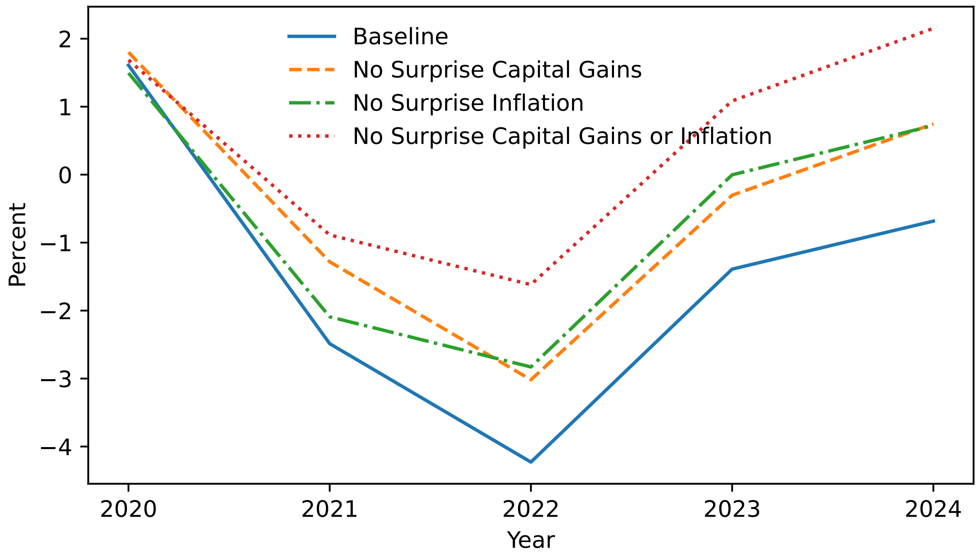
Figure 12: Historical Shelter Inflation and its Components



Notes: The figure shows the overall welfare price index, the price index stemming only from pecuniary changes to V^X, BLS rent, and contributions to the overall price index. The indexes and each component are plotted relative to non-shelter CPI and de-trended by real rent growth of 1% per year. The contributions labeled Rent, Nominal Mortgage Rate, Inflation, and House Price display the increment to the price index with the realized and expected deviations of the variable listed "stacked" on top of the previous variables. The contribution labeled Distribution shows the additional effect on welfare at date t that arises because the $t-1$ distribution of owners and renters differs due to the residual demand shocks.

The green bars show the additional contribution of non-shelter inflation. In 2021 and, especially, 2022, the surprise in realized non-shelter inflation erodes real mortgage balances, while higher expected non-shelter inflation dampens the rise in the real mortgage rate relative to the nominal rate. Both forces benefit indebted homeowners and pull down the price index (the erosion of real mortgage debt of incumbent owners accounts for most of the contribution, as real mortgage rates for new buyers still rose substantially). The red bars add the contribution of higher real house prices. Higher real prices contribute positively to shelter inflation in 2020, because they increase mortgage payments for new buyers. Thereafter, the sign flips. The reason stems from the interaction of higher real house prices and non-shelter inflation; high prices benefit sellers immediately, while non-shelter inflation erodes the higher mortgage balances of buyers. The net effect benefits households, even though a rise in real house prices on its own makes households worse off. Finally, the small contribution labeled "Distribution" refers to the effect on welfare at date t that arises

Figure 13: Alternative Treatment of Asset Prices



Notes: The figure shows the overall welfare price index and the index when removing the effect of surprises in real house prices or non-shelter inflation on incumbent owners. The indexes are plotted relative to non-shelter CPI and de-trended by real rent growth of 1% per year.

because the $t-1$ distribution of owners and renters differs due to the residual demand shocks.

The role of surprise changes to house prices and non-shelter inflation has generated much of the controversy in the historical debate over the treatment of shelter in cost-of-living indexes. While they clearly matter to dynamic welfare, these changes affect asset valuations (of the house and the mortgage) that arguably do not belong in a consumption price index. Figure 13 addresses this perspective by reporting price indexes that exclude the effect of surprise changes on incumbent owners. Specifically, we recompute the welfare change as if each date t home buyer also signed a financial contract at the time of purchase that fixed the real mortgage payment and, for each horizon j, the date $t+j$ terminal payoff amount (house price net of remaining mortgage balance) to equal the $t+j$ payoff amount expected at date t. In this way, changes in house prices or expected inflation still affect the welfare of new buyers (or refinancers), but not of incumbent owners during their current ownership spell.

Removing the surprise increase in house prices shifts the overall price index up. Intuitively, under our dynastic preferences, unexpected house price growth has a minor effect on the welfare of incumbent owners, who recognize that their capital gain coincides with a higher purchase price for their offspring. Taking the capital gain out leaves only the higher purchase price and associated higher mortgage payment for their offspring.

Removing surprise non-shelter inflation also shifts the overall price index up, with most of the difference in 2021 and, especially, in 2022. Non-shelter inflation in 2022 exceeded the 2020 forecast by more than 13%, thereby eroding the real mortgage debt of incumbent owners. Comparing the effect of leaving out surprise inflation to the inflation contribution in Figure 12 confirms that most of the overall inflation contribution comes from surprise inflation on incumbent owners, with the remainder the dampening of *ex ante* real relative to nominal mortgage rates for new buyers. Together, both surprise components reduce cumulative shelter inflation by about 2p.p. between 2019 and 2022.

9 Conclusion

We have argued that a proper cost-of-living price index should account for the costs associated with owning a home and peoples' preferences for owning instead of renting. Furthermore, it should reflect the inherently dynamic considerations involved in shelter payments when transaction costs and fixed rate mortgages link costs over time. To meet these requirements, we have implemented a new shelter price index that smooths changes in the value function due to changes in shelter costs. In response to an increase in mortgage rates, our shelter price index departs from both owners' equivalent rent, which does not directly respond by construction, and the one-period user cost, which is highly volatile. Over the period 2019-2024, our shelter index exhibits important quantitative differences from rents.

A reconsideration of shelter inflation opens many questions beyond those pursued here. How should the 1930-1960 integration of mortgage markets and resulting drastic increase in homeownership (Angelova and D'Amico, 2024) affect measurement of real income growth in that period? What are the welfare consequences of the upward trend in the age of first-time home-buying in the U.S.? How would inflation and, perhaps, monetary policy vary in a setting with primarily variable rather than fixed rate mortgages? We leave these applications to future work.

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Appendix:
Homeownership and the Cost of Living

Gabriel Chodorow-Reich, Edward Glaeser, Xavier Jaravel, Avi Lipton

Appendix A details the construction of the user cost in Figure 1. Appendix B contains proofs of the propositions. Appendix C extends the framework of Section 3 to accommodate uncertainty and incomplete markets. Appendix D reports additional results from the survey, including benchmarking to other sources and the interpretation of the follow-up survey. Appendix E describes our analysis of the SIPP. Appendix F describes the Bayesian VAR used to generate auxiliary forecasts of house prices and rents. Appendix G contains additional results from the calibrated model.

A Construction of the User Costs in Figure 1

This appendix describes the computation of the user costs displayed in Figure 1, which have five main components: the cost of the mortgage, after interest deduction; the opportunity cost of investing the down-payment in financial markets; out of pockets costs; property taxes; and expected capital gains on housing.

Following Garner and Verbrugge (2009), we compute the user cost as follows:

$$uc_t = P_t^h \left(i_t^{\text{Mortgage}}(1-\tau_t^{\text{Fed}})(1-M_t) + i_t^{\text{Opportunity Cost}} M_t(1-\tau_t^{\text{Cap}}) + \tau_t^{\text{Property}}(1-\tau_t^{\text{Fed}}) + \phi_t^h - \mathbb{E}_t\pi_t^h \right),$$

where t indexes quarters and with the following components:

- P_t^h is the property value, which we measure at the household level in the Consumer Expenditure Survey. As in Garner and Verbrugge (2009), we use a regression approach to impute missing observations at the household level.

- i_t^{Mortgage} is the 30-year fixed mortgage rate; in each quarter, we compute the average value in the Freddie Mac's Primary Mortgage Market Survey.

- $i_t^{\text{Opportunity Cost}}$ capture the return on financial investment, which we set equal to the market yield on 10-year U.S. Treasury securities, retrieved from the Federal Reserve Bank of St. Louis, plus a 5% equity premium (Jordà et al., 2019).

- τ_t^{Fed} denotes marginal federal income tax rates, which we obtain from the Tax Foundation; indeed, mortgage interest is deductible for debt costs, whereas for equity, investors only receive after-tax interest earnings.

- τ_t^{Cap} denotes taxes rates on capital gains, set at 15%.

- ϕ_t^h are out-of-pocket costs scaled by the house price, defined as the sum of depreciation, maintenance and repair, and real estate insurance. Maintenance and repair, and real estate insurance are estimated using the CEX. Following Garner and Verbrugge (2009), depreciation is set at 1% of property value.[1]

- τ_t^{Prop} is the property tax, which we measure in the American Community Survey (ACS), dividing the property tax paid by the dwelling value;[2] we estimate property taxe rates at the MSA, state and federal levels, and then assign them to households in the CEX at the smallest available geographical unit.

- M_t is the down-payment ratio, measured in the American Housing Survey (AHS).

- $\mathbb{E}_t\pi_t^h$ is the expected changes in house prices. We report three versions of expected house price inflation. Version 1 (average HP growth) uses the 1996-2024 average realized house price change according to the Freddie Mac House Price Index (FMHPI). Version 2 (NY Fed

[1] Garner and Verbrugge (2009) explain: "to ensure that our estimates line up with comparable measures from the Bureau of Economic Analysis (BEA) and from the Census, we add 1 percent of home value to our maintenance and repair estimates, which may be interpreted as adding an estimate of depreciation, or as an estimate of deferred major maintenance."

[2] Property taxes expenses are often missing in the CE and those present match hardly official statistics.

SCE) uses the median one-year ahead house price expectation in the Federal Reserve Bank of New York Survey of Consumer Expectations (SCE). In this survey, respondents are asked by how much the average home price will change nationwide over the next 12 months. This measure of inflation is available only from the third quarter of 2013 only. Version 3 (BVAR HP) uses expectations from the Bayesian VAR described in Appendix F.

Importantly, the user cost does not include transaction costs (broker fees, etc.).

B Model Proofs

B.1 Proof of Proposition 1

We need to verify that equations (3), (4) and (6) hold with $h_t = h, \theta_t^* = \theta^*$. Dividing both sides of equation (3) by $R_t = \bar{R}_t$ and imposing constant ρ gives:

$$\frac{\rho P_t^H}{\bar{R}_t} = 1 + (\theta_t^* - 1). \tag{B.1}$$

From equation (4), constant c and $g(h)$ imply a constant ratio P_t^H / R_t and hence the left hand side of equation (B.1) is constant. From equation (5), constant h also implies constant θ^* and hence the right hand side of equation (B.1) is also constant.

B.2 Proof of Proposition 2

The change in the price is given by the sum of the terms in equation (8) multiplied by their respective population shares. This is simply:

$$\begin{aligned}
P_{t+1} - P_t = {} & (1 - h_t)(R_{t+1} - R_t) \\
& + h_{t+1}\left(R_{t+1} - R_t + \left(\theta_{t+1}^* \bar{R}_{t+1} - \theta_t^* \bar{R}_t\right)\right) - \int_{\theta_{t+1}^*}^{\infty} \theta \left(\bar{R}_{t+1} - \bar{R}_t\right) dF_\theta(\theta) \\
& + (h_t - h_{t+1})\left(R_{t+1} - R_t - \theta_t^* \bar{R}_t\right) + \int_{\theta_t^*}^{\theta_{t+1}^*} \theta \bar{R}_t dF_\theta(\theta) \\
= {} & (R_{t+1} - R_t) + h_{t+1}\theta_{t+1}^* \bar{R}_{t+1} - h_t \theta_t^* \bar{R}_t - \mathbb{E}_\theta\left[\mathcal{H}_{t+1}(\theta)\,\theta\right] \bar{R}_{t+1} + \mathbb{E}_\theta\left[\mathcal{H}_t(\theta)\,\theta\right] \bar{R}_t.
\end{aligned}$$

We could also have arrived at this expression by defining:

$$P_t = -U_t = R_t + h_t \theta_t^* \bar{R}_t - \mathbb{E}_\theta\left[\mathcal{H}_t(\theta)\,\theta\right] \bar{R}_t.$$

B.3 Proof of Proposition 3

The structure of the proof is:

1. Rewrite the consumption-savings problem with an Arrow-Debreu securities market.

2. Assume a form for the Arrow-Debreu prices and show that the full optimization problem can then be split into choices of a deterministic consumption path and tenure choices.

3. Show that tenure choices depend only on own histories.

4. Write the welfare function in the form of equations (14) to (17).
5. Close the output market and introduce the outside agent.
6. Endogenize the functional form of the Arrow-Debreu prices.
7. Show that with isoelastic utility the risk-free bond price does not depend on shelter costs and tenure decisions converge to a stationary distribution.

B.3.1

Index individual households by k. Let $\Theta_{k,t+j}$ be individual k's exogenous state at date $t+j$. Let $\xi_{t+j} = \{\Theta_{k,t+j}\}_k$ denote the set of exogenous individual states of every individual household. Let $\xi^{t+j} = (\xi_t, \xi_{t+1}, ..., \xi_{t+j})$ be a particular history of states between $t, t+j$ with density $\pi(\xi^{t+j})$. Let $\Theta_k^{t+j} = (\Theta_{k,t}, \Theta_{k,t+1}, ...\Theta_{k,t+j})$ be individual k's history at date $t+j$. Individual k enters date t with exogenous future state-contingent income $y(\Theta_{k,t+j})$ and Arrow-Debreu claims to future income in state ξ^{t+j} of $A_{k,t-1}(\xi^{t+j})$. Let $\Xi^{t,t+j}$ be the full set of possible histories between t and $t+j$.

At date t, every household k can purchase claims to state contingent consumption $C_k(\xi^{t+j})$ at price $p(\xi^{t+j})$ in terms of date t consumption. They also make shelter choices $\mathcal{H}_k(\xi^{t+j}), s_k(\xi^{t+j})$. Household k solves:

$$\tilde{V}_{k,t} = \max_{\{C_k(\xi^{t+j}),\mathcal{H}_k(\xi^{t+j}),s_k(\xi^{t+j})\}} \sum_{j=0}^{\infty} \tilde{\beta}^j \int_{\xi^{t+j}\in\Xi^{t+j}} \pi(\xi^{t+j}) \left(u(C_k(\xi^{t+j})) + v_{t+j}(\tilde{\theta}_k(\Theta_{k,t+j}))\mathcal{H}_k(\xi^{t+j})\right) \quad \text{s.t.}$$

$$\sum_{j=0}^{\infty} \int_{\xi^{t+j}\in\Xi^{t+j}} p(\xi^{t+j})(C_k(\xi^{t+j}) + X(\mathcal{H}_k(\xi^{t+j-1}), \mathcal{H}_k(\xi^{t+j}), s_k(\xi^{t+j}); \mathbf{W}_t))$$
$$\leq \underbrace{\sum_{j=0}^{\infty} \int_{\xi^{t+j}\in\Xi^{t+j}} p(\xi^{t+j})(y(\Theta_{k,t+j}) + A_{k,t-1}(\xi^{t+j})),}_{A_{k,t-1}}$$
$$(\mathcal{H}_k(\xi^{t+j-1}), s_k(\xi^{t+j-1}), \mathcal{H}_k(\xi^{t+j}), s_k(\xi^{t+j})) \in \Gamma(\Theta_{k,t+j}).$$

B.3.2

Fix a particular choice of tenure plan $\mathcal{H}(\xi^{t+j}), s(\xi^{t+j})$, which generates corresponding stochastic income stream $X_k(\xi^{t+j}) = X(\mathcal{H}_k(\xi^{t+j-1}), \mathcal{H}_k(\xi^{t+j}), s_k(\xi^{t+j}); \mathbf{W}_t))$. Given this stream, a household solves the inner consumption problem:

$$\max_{\{C_k(\xi^{t+j})\}} \sum_{j=0}^{\infty} \tilde{\beta}^j \int_{\xi^{t+j}\in\Xi^{t+j}} \pi(\xi^{t+j}) u(C_k(\xi^{t+j})) \quad \text{s.t.}$$
$$\sum_{j=0}^{\infty} \int_{\xi^{t+j}\in\Xi^{t+j}} p(\xi^{t+j}) C_k(\xi^{t+j}) \leq A_{k,t-1} - \sum_{j=0}^{\infty} \int_{\xi^{t+j}\in\Xi^{t+j}} p(\xi^{t+j}) X_k(\xi^{t+j}).$$

The first order conditions with respect to consumption are:

$$\tilde{\beta}^j \pi(\xi^{t+j}) u'(C_k(\xi^{t+j})) = \varphi_k p(\xi^{t+j}),$$

where φ_k is the Lagrange multiplier on household $k's$ budget constraint.

We assume the Arrow-Debreu prices take the form $p(\xi^{t+j}) = \pi(\xi^{t+j})\beta_{t,t+j}$. Substitute for $p(\xi^{t+j})$ in the first order condition:

$$u'(C_k(\xi^{t+j})) = \varphi_k \tilde{\beta}^{-j}\beta_{t,t+j} \equiv u'(C_{k,t+j}),$$

i.e. individual k's marginal utility of consumption must be constant across states at any date. We can therefore rewrite the household's inner problem as a choice over deterministic consumption:

$$\tilde{V}^C(A_{k,t-1} - V^X_{k,t}(\{\mathcal{H}_k(\xi^{t+j}), s_k(\xi^{t+j}\}))) = \max_{\{C_{k,t+j}\}} \sum_{j=0}^{\infty} \tilde{\beta}^j u(C_{k,t+j}) \text{ s.t. } \sum_{j=0}^{\infty} \beta_{t,t+j} C_{k,t+j} = A_{k,t-1} - V^X_{k,t},$$

$$\text{where: } V^X_{k,t}(\{\mathcal{H}_k(\xi^{t+j}), s_k(\xi^{t+j}\})) = \sum_{j=0}^{\infty} \beta_{t,t+j}\mathbb{E}[X(\mathcal{H}_k(\xi^{t+j-1}), \mathcal{H}_k(\xi^{t+j}), s_k(\xi^{t+j}); \mathbf{W}_t))]$$

denotes the expected present value of spending on shelter.

We can then write the household's outer tenure choice problem as

$$\max_{\{\mathcal{H}_k(\xi^{t+j}), s_k(\xi^{t+j})\}} \tilde{V}^C(A_{k,t-1} - V^X_{k,t}(\{\mathcal{H}_k(\xi^{t+j}), s_k(\xi^{t+j}\}))) + \underbrace{\sum_{j=0}^{\infty} \tilde{\beta}^j \mathbb{E}\left[v_{t+j}(\tilde{\theta}_k(\Theta_{k,t+j}))\mathcal{H}_k(\xi^{t+j})\right]}_{\tilde{V}^{\theta}_{k,t}(\{\mathcal{H}_k(\xi^{t+j}), s_k(\xi^{t+j}\})} \text{ s.t.}$$
$$(\mathcal{H}_k(\xi^{t+j-1}), s_k(\xi^{t+j-1}), \mathcal{H}_k(\xi^{t+j}), s_k(\xi^{t+j})) \in \Gamma(\Theta_{k,t+j}).$$

Now let $\{\mathcal{H}^*_k(\xi^{t+j})\}$, $\{s^*(\xi^{t+j})\}$, $\{C^*_{k,t+j}\}$ mutually satisfy the fixed point

$$\max_{\mathcal{H}_k(\xi^{t+j}), s_k(\xi^{t+j})} - V^X_{k,t}(\{\mathcal{H}_k(\xi^{t+j}), s_k(\xi^{t+j}\}) + \frac{\tilde{V}^{\theta}_{k,t}(\{\mathcal{H}_k(\xi^{t+j}), s_k(\xi^{t+j}\})}{u'(C^*_{k,t})} \text{ s.t.}$$
$$(\mathcal{H}_k(\xi^{t+j-1}), s_k(\xi^{t+j-1}), (\mathcal{H}_k(\xi^{t+j}), s_k(\xi^{t+j})) \in \Gamma(\Theta_{k,t+j}),$$

and $\{C^*_{k,t+j}\}$ solves the household's inner consumption problem given

$$V^{X^*}_{k,t} = V^X_{k,t}(\{\mathcal{H}^*_k(\xi^{t+j}), s^*_k(\xi^{t+j}\}).$$

We claim that $\{\mathcal{H}^*_k(\xi^{t+j})\}$, $\{s^*(\xi^{t+j})\}$, $\{C^*_{k,t+j}\}$ solve the full joint optimization problem. To prove this define

$$\tilde{V}^{\theta^*}_{k,t} = \tilde{V}^{\theta}_{k,t}(\{\mathcal{H}^*_k(\xi^{t+j}), s^*_k(\xi^{t+j}\}).$$

We now need to show that for any other tenure path $\mathcal{H}_k(\xi^{t+j})$ and $s(\xi^{t+j})$ and corresponding $V^X_{k,t}$, $\tilde{V}^{\theta}_{k,t}$ that

$$\tilde{V}^C(A_{t-1} - V^{X^*}_{k,t}) + \tilde{V}^{\theta^*}_{k,t} \geq \tilde{V}^C(A_{t-1} - V^X_{k,t}) + \tilde{V}^{\theta}_{k,t}.$$

To that end, let $\mathcal{H}_k(\xi^{t+j})$ and $s(\xi^{t+j})$ be an arbitrary tenure path. We know from the definition of $\mathcal{H}^*_k(\xi^{t+j})$ and $s^*(\xi^{t+j})$, that

$$-u'(C^*_{k,t})V^{X^*}_{k,t} + \tilde{V}^{\theta^*}_{k,t} \geq -u'(C^*_{k,t})V^X_{k,t} + \tilde{V}^{\theta}_{k,t} \implies \tilde{V}^{\theta^*}_{k,t} - \tilde{V}^{\theta}_{k,t} \geq u'(C^*_{k,t})(V^{X^*}_{k,t} - V^X_{k,t}).$$

We also know that u is concave, which implies that V^C is also concave, which implies

$$\tilde{V}^C(A_{k,t-1} - V^X_{k,t}) \leq \tilde{V}^C(A_{k,t-1} - V^{X^*}_{k,t}) + \frac{d\tilde{V}^C}{dA}(A_{k,t-1} - V^{X^*}_{k,t})(V^{X^*}_{k,t} - V^X_{k,t}).$$

By the envelope theorem, we know that

$$\frac{d\tilde{V}^C}{dA}(A_{k,t-1} - V_{k,t}^{X^*}) = u'(C_{k,t}^*),$$

which implies that

$$u'(C_{k,t}^*)(V_{k,t}^{X^*} - V_{k,t}^X) \geq \tilde{V}^C(A_{k,t-1} - V_{k,t}^X) - \tilde{V}^C(A_{k,t-1} - V_{k,t}^{X^*})$$

So, overall, we have that

$$\tilde{V}_{k,t}^{\theta^*} - \tilde{V}_{k,t}^{\theta} \geq \tilde{V}^C(A_{k,t-1} - V_{k,t}^X) - \tilde{V}^C(A_{k,t-1} - V_{k,t}^{X^*}) \implies \tilde{V}_{k,t}^{\theta^*} + \tilde{V}^C(A_{k,t-1} - V_{k,t}^{X^*}) \geq \tilde{V}_{k,t}^{\theta} + \tilde{V}^C(A_{k,t-1} - V_{k,t}^X),$$

as required.

B.3.3

Because all of the θ_{t+j} processes are Markov, so too are all of the ξ_{t+j} processes. Moreover, by the Euler equation we know that

$$u'(C_{k,t}^*) = \frac{\tilde{\beta}^j}{\beta_{t,t+j}} u'(C_{k,t+j}^*).$$

We can thus represent the tenure choice maximization problem recursively. Define $\mathcal{H}_{-1}, s_{-1}$ as last period's tenure and duration and ξ^{+1} next period's ξ. The problem of choosing new tenure and duration $\mathcal{H}, s$ for date t takes the form:

$$\begin{aligned} V_{k,t}(\xi, \mathcal{H}_{-1}, s_{-1}) = \max_{\mathcal{H},s} & -X(\mathcal{H}_{-1}, \mathcal{H}, s; \mathbf{W}_t) + \frac{v_t}{u'(C_{k,t}^*)}(\tilde{\theta}_k(\Theta_{k,t}))\mathcal{H} + \beta_{t,t+1}\mathbb{E}\left[V_{k,t+1}(\xi^{+1}, \mathcal{H}, s)\middle|\, \xi\right] \text{ s.t.} \\ & (\mathcal{H}_{-1}, s_{-1}, \mathcal{H}, s) \in \Gamma(\Theta_{k,t}). \end{aligned}$$

Note here that the expectation is taken over the physical distribution of ξ, π, which is entirely exogenous. Because the expectation is entirely exogenous, we can construct a solution where the choices of $\mathcal{H}$ and s depend only on the previous endogenous states, $\mathcal{H}$ and s, and the current exogenous state, $\Theta_{k,t}$. Thus, in the sequence version of the problem, we can say that

$$\mathcal{H}_k^*(\xi^{t+j}) = \mathcal{H}_k^*(\Theta_k^{t+j}), \quad s_k^*(\xi^{t+j}) = s_k^*(\Theta_k^{t+j}).$$

B.3.4

We can now justify equations (14) to (17). As in the main text, we collect a household's initial state at t as $\Omega_t = (A_{t-1}, \mathcal{H}_{t-1}, s_{t-1}, \Theta_t)$, where we omit the k subscript since every household with the same Ω_t will make the same choices. Then given $\beta_{t,t+j}$ and the the Arrow-Debreu prices, the solution to the household maximization problem is a joint choice of deterministic consumption $C_{t+j}(\Omega_t, \mathbf{W}_t)$ that depends on initial wealth and the exogenous idiosyncratic states and tenure plans that condition only on the household's own idiosyncratic states $\mathcal{H}(\Theta^{t+j})$, $s(\Theta^{t+j})$ such that given the tenure choices, $\{\mathcal{H}_{t+j}(\Omega_t, \mathbf{W}_t), s_{t+j}(\Omega_t, \mathbf{W}_t)\}$, consumption solves:

$$\tilde{V^C}\left(A_{t-1}(\Omega_t) - \underbrace{\sum_{j=0}^{\infty} \beta_{t,t+j}\mathbb{E}_t\left[X(\mathcal{H}_{t+j-1}(\Omega_t, \mathbf{W}_t), \mathcal{H}_{t+j}(\Omega_t, \mathbf{W}_t), s_{t+j}(\Omega_t, \mathbf{W}_t); \mathbf{W}_t)|\Omega_t\right]}_{V_t^X(\Omega_t)}\right) =$$

$$\max_{C_{t+j}(\Omega_t, \mathbf{W}_t)} \sum_{j=0}^{\infty} \tilde{\beta}^j u(C_{t+j}(\Omega_t, \mathbf{W}_t)) \text{ s.t. } \sum_{j=0}^{\infty} \beta_{t,t+j} C_{t+j}(\Omega_t, \mathbf{W}_t) = A_{t-1}(\Omega_t) - V_t^X(\Omega_t, \mathbf{W}_t)$$

and given the consumption choices, $\{C_{t+j}(\Omega_t, \mathbf{W}_t)\}$, the tenure choices solve:

$$\begin{aligned}\max_{\mathcal{H}(\Theta^{t+j}), s(\Theta^{t+j})} &\sum_{j=0}^{\infty} \left(\frac{\tilde{\beta}^j}{u'(C_t(\Omega_t, \mathbf{W}_t))}\mathbb{E}_t\left[v_{t+j}(\tilde{\theta}_{t+j})\mathcal{H}(\Theta^{t+j})|\Omega_t\right]\right) \\ &- \sum_{j=0}^{\infty}\left(\beta_{t,t+j}\mathbb{E}_t\left[X(\mathcal{H}(\Theta^{t+j-1}), \mathcal{H}_{t+j}(\Theta^{t+j}), s(\Theta^{t+j}); \mathbf{W}_t)|\Omega_t\right]\right) \quad \text{s.t.} \\ &(\mathcal{H}(\Theta^{t+j-1}), s(\Theta^{t+j-1}), \mathcal{H}(\Theta^{t+j}), s(\Theta^{t+j})) \in \Gamma(\Theta_{t+j}).\end{aligned}$$

Realized household welfare will then be

$$\tilde{V}(\Omega_t) = \tilde{V^C}\left(A_{t-1}(\Omega_t) - V_t^X(\Omega_t)\right) + \underbrace{\sum_{j=0}^{\infty} \tilde{\beta}^j \mathbb{E}_t\left[v_{t+j}(\tilde{\theta}_{t+j})\mathcal{H}_{t+j}(\Omega_t, \mathbf{W}_t)|\Omega_t\right]}_{\tilde{V}^\theta(\Omega_t)}.$$

B.3.5

We now close the output market and endogenize the form of Arrow-Debreu prices assumed thus far. A representative outside agent receives all rents, mortgage payments, and moving costs as income. This state-contingent aggregate shelter income is:

$$X(\xi^{t+j}) = \int_k X(\mathcal{H}_k(\xi^{t+j-1}), \mathcal{H}_k(\xi^{t+j}), s_k(\xi^{t+j}); \mathbf{W}_t).$$

Note that when one household buys a house and another sells, these transactions net out in the computation of $X(\xi^{t+j})$ except for the transaction costs. If the home ownership rate is not constant, the income of the outside agent additionally changes by the value of the homes transacted. The outside agent has identical preferences over the non-shelter good but does not consume shelter. They enter the market with their own Arrow-Debreu claims to future income in state ξ^{t+j} worth A^r_{t-1}. The representative outside agent solves:

$$\begin{aligned}\max_{\{C^r(\xi^{t+j})\}} &\sum_{j=0}^{\infty} \tilde{\beta}^j \int_{\xi^{t+j}\in\Xi^{t+j}} \pi(\xi^{t+j}) u(C^r(\xi^{t+j})) \text{ s.t.} \\ &\sum_{j=0}^{\infty} \int_{\xi^{t+j}\in\Xi^{t+j}} p(\xi^{t+j}) C^r(\xi^{t+j}) \le A^r_{t-1} + \sum_{j=0}^{\infty} \int_{\xi^{t+j}\in\Xi^{t+j}} p(\xi^{t+j}) X(\xi^{t+j}).\end{aligned}$$

The outside agent's first order condition with respect to consumption is:

$$\tilde{\beta}^j \pi(\xi^{t+j}) u'(C^r(\xi^{t+j})) = \varphi_r p(\xi^{t+j}),$$

where φ^r is the multiplier on the representative outside agent's budget constraint. Taking ratios with any household k, we obtain the risk sharing-condition that marginal utilities are proportional across all individuals in every state:

$$\frac{u'(C_k(\xi^{t+j}))}{u'(C^r(\xi^{t+j}))} = \frac{\varphi_k}{\varphi_r} \implies C_k(\xi^{t+j}) = (u')^{-1}\left(\frac{\varphi_k}{\varphi_r} u'(C^r(\xi^{t+j}))\right).$$

Let Y_{t+j} be the deterministic output endowment for the economy. The Arrow-Debreu equilibrium given information set $\mathbf{W}_t$ is defined as the set of prices $\{p(\xi^{t+j})\}_{\xi^{t+j} \in \Xi^{t+j}}$ such that households optimize and markets clear in all states of the world:

$$C^r(\xi^{t+j}) + \int_k C_k(\xi^{t+j}) = Y_{t+j} \ \forall \xi^{t+j} \in \Xi^{t+j}.$$

Market clearing then implicitly pins down $C^r(\xi^{t+j})$:

$$C^r(\xi^{t+j}) + \int_k (u')^{-1}\left(\frac{\varphi_k}{\varphi_r} u'(C^r(\xi^{t+j}))\right) = Y_{t+j} \ \forall \xi^{t+j} \in \Xi^{t+j}.$$

In particular, since Y_{t+j} on the right hand side is deterministic, so is $C^r(\xi^{t+j}) = C^r_{t+j}$ and thus also $C_k(\xi^{t+j}) = C_{k,t+j}$.

B.3.6

The price of a risk-free bond is the value of a set of securities that guarantees one unit of income at any state at date $t+j$:

$$\beta_{t,t+j} = \sum_{\xi^{t+j} \in \Xi^{t+j}} p(\xi^{t+j}).$$

Sum over every state in the household first order conditions to yield the Euler equation:

$$\beta_{t,t+j} = \tilde{\beta}^j \frac{u'(C_{k,t+j})}{u'(C_{k,t})},$$

where we use that $\varphi_k = u'(C_{k,t})$. Plug this back into the first order condition:

$$p(\xi^{t+j}) = \pi(\xi^{t+j}) \beta_{t,t+j}.$$

Thus, this functional form for the Arrow-Debreu prices arises endogenously from deterministic output growth and the outside agent. It also means that solving for the equilibrium amounts to solving for the risk free bond prices.

B.3.7

We also know that because household shelter choices depend only on their own histories, Θ^k_{t+j}, and the distribution over idiosyncratic states is deterministic, that aggregate shelter expenditure will be deterministic:

$$X_{t+j} = \int_{dG_t(\Omega_t)} \mathbb{E}_t \left[X(\mathcal{H}_{t+j-1}, \mathcal{H}_{t+j}, s_{t+j}; \mathbf{W}_t) | \Omega_t \right].$$

Then the outside agent solves:

$$\max_{C^r_{t+j}} \sum_{j=0}^{\infty} \tilde{\beta}^j u(C^r_{t+j}) \text{ s.t. } \sum_{j=0}^{\infty} \beta_{t,t+j} C^r_{t+j} = A^r_{t-1} + \sum_{j=0}^{\infty} \beta_{t,t+j} X_{t+j}.$$

The equilibrium $\beta_{t,t+j}$ will be such that given the solution to these problems, markets clear at every date:

$$C^r_{t+j} + \underbrace{\int_{dG_t(\Omega_t)} C_{t+j}(\Omega_t)}_{C_{t+j}} = Y_{t+j} \ \forall j.$$

Such a path for $\beta_{t,t+j}$ generically exists.

We now specialize utility to $u(C) = \frac{C^{1-\gamma}}{1-\gamma}$. The risk-sharing condition then requires that all households have the same consumption growth, equal to $1 + \mu$ by market clearing. The Euler equation then requires $\beta_{t,t+j} = \beta^j$, where $\beta \equiv (1 + \mu)^{-\gamma} \tilde{\beta}$. In particular, suppose that there is some change $d\mathbf{W}_t$ from a reference $\mathbf{W_t}$. This will result in an equilibrium shift in aggregate housing expenditure dX_{t+j}. If the risk free bond price does not change, both the households and representative outside agent will exactly adjust their consumption in equal and opposite directions such that markets continue to clear. This result holds because given the form for u, consumption at each date is the same linear function of the present value of income for both households and the outside agent (with time varying slope). So, the equilibrium risk free bond price and full set of Arrow-Debreu security prices will not respond to the housing price shocks $d\mathbf{W}_t$.

Finally, assume $v_t(\tilde{\theta}) = \bar{R}_t^{1-\gamma} \tilde{v}(\theta)$ and that $R_t = \bar{R}_t$, $P^H_t / \bar{R}_t$ is constant, and i_t is constant. Then, $X(\mathcal{H}_{t+j-1}, \mathcal{H}_{t+j}, s_{t+j}; \mathbf{W}_t)$ will always be proportional to $\bar{R}_t$. Define $x = \frac{X}{\bar{R}_t}$. We can then write the recursive form of the tenure choice problem in the following form

$$V_t(\Theta, \mathcal{H}_{-1}, s_{-1}) = \max_{\mathcal{H}, s} -x(\mathcal{H}_{-1}, s_{-1}, \mathcal{H}) \bar{R}_t + \frac{\bar{R}_t^{1-\gamma} v(\tilde{\theta})}{C_t(\Omega_t, \mathbf{W}_t)^{-\gamma}} \mathcal{H} + \beta \mathbb{E}[V_{t+1}(\Theta_{+1}, \mathcal{H}, s) | \Theta], \quad \text{s.t.}$$
$$(\mathcal{H}_{-1}, s_{-1}, \mathcal{H}, s) \in \Gamma(\Theta_t)$$

Now, note that $\bar{R}_t / C_t(\Omega_t, \mathbf{W}_t)$ is constant, which implies that $\theta \equiv \left(\frac{\bar{R}_t}{C_t(\Omega_t, \mathbf{W}_t)} \right)^{-\gamma} v(\tilde{\theta})$ is constant. Then, if we define $V = \frac{V_t}{\bar{R}_t}$, we have

$$V(\Theta, \mathcal{H}_{-1}, s_{-1}) = \max_{\mathcal{H}, s} -x(\mathcal{H}_{-1}, s_{-1}, \mathcal{H}) + \theta \mathcal{H} + \beta(1 + \mu) \mathbb{E}[V(\Theta_{+1}, \mathcal{H}, s) | \Theta], \quad \text{s.t.}$$
$$(\mathcal{H}_{-1}, s_{-1}, \mathcal{H}, s) \in \Gamma(\Theta_t),$$

which is a stationary dynamic program. As long as $\beta(1 + \mu) < 1$ and the exogenous process for Θ has standard regularity conditions, then a solution to the Bellman equation will exist with corresponding time-invariant policy functions. Moreover, the joint distribution of $\mathcal{H}$, s, and Θ will converge to a stationary distribution and thus so too will x.

B.4 Proof of Proposition 4

The application of the definition of dY to equations (13) and (14) gives:

$$d\tilde{V}_t\left(\Omega_t, d\mathbf{W}_t\right) = d\tilde{V}_t^{\theta}\left(\Omega_t, d\mathbf{W}_t\right) - \left(\frac{\partial \tilde{V}_t^C\left(A_{t-1} - V_t^X\left(\Omega_t\right)\right)}{\partial A_{t-1}}\right) dV_t^X\left(\Omega_t, d\mathbf{W}_t\right).$$

Dividing this equation through by the marginal utility of a dollar $\partial \tilde{V}_t^C\left(.\right)/\partial A_{t-1}$ gives equation (18) in the main text. To arrive at equation (19), we use from the consumption-savings problem the envelope condition $\partial \tilde{V}_t^C\left(A_{t-1} - V_t^X\left(\Omega_t\right)\right)/\partial A_{t-1} = u'\left(C_t\left(\Omega_t, \mathbf{W}_t\right)\right)$ and the Euler equation $u'\left(C_t\left(\Omega_t, \mathbf{W}_t\right)\right) = \tilde{\beta}^j \beta_{t,t+j}^{-1} u'\left(C_{t+j}\left(\Omega_t, \mathbf{W}_t\right)\right)$, which together give:

$$\frac{\tilde{\beta}^j v_{t+j}\left(\tilde{\theta}_{t+j}\right)}{\partial \tilde{V}_t^C\left(.\right)/\partial A_{t-1}} = \frac{\beta_{t,t+j} v_{t+j}\left(\tilde{\theta}_{t+j}\right)}{u'\left(C_{t+j}\left(\Omega_t, \mathbf{W}_t\right)\right)}.$$

Using this condition and the definition of $\tilde{V}_t^{\theta}\left(\Omega_t\right)$ in equation (16) gives equation (19).

B.5 Proof of Proposition 5

Equation (22) follows from equations (19) to (21). For equation (23), note that $dV_t^X\left(\Omega_t, d\mathbf{W}_t\right) = V_t^X\left(\Omega_t\right) - \mathbb{E}_{t-1}\left[V_t^X\left(\Omega_t\right)\right]$. Furthermore, the measure $G_t\left(\Omega_t\right)$ over initial states at date t is known as of date $t-1$. Therefore, the aggregate revision to shelter expenditure from date t forward is:

$$\mathbb{E}_{\Omega_t}\left[V_t^X\left(\Omega_t\right)\right] - \mathbb{E}_{t-1}\left[\mathbb{E}_{\Omega_t}\left[V_t^X\left(\Omega_t\right)\right]\right] = \mathbb{E}_{\Omega_t}\left[dV_t^X\left(\Omega_t, d\mathbf{W}_t\right)\right].$$

Using this result and aggregating equation (22) yields equation (23).

B.6 Proof of Proposition 6

Equation (26) follows directly from iterating forward the definition $dP_{t|0}$ and using the telescoping property for the non-pecuniary term:

$$\begin{aligned}
&\mathbb{E}_{\Omega_{t-j+1}}\mathbb{E}_{t-j}\mathbb{E}_{t-j+1}\left[\mathcal{H}_t\left(\Omega_{t-j+1}, \mathbf{W}_{t-j+1}\right)\theta_t|\Omega_{t-j+1}\right] = \mathbb{E}_{t-j}\mathbb{E}_{\Omega_{t-j+1}}\left[\mathcal{H}_t\left(\Omega_{t-j+1}, \mathbf{W}_{t-j}\right)\theta_t\right] \\
&= \mathbb{E}_{t-j}\mathbb{E}_{\Omega_{t-j}}\left[\mathcal{H}_t\left(\Omega_{t-j}, \mathbf{W}_{t-j}\right)\theta_t\right] = \mathbb{E}_{\Omega_{t-j}}\mathbb{E}_{t-j}\left[\mathcal{H}_t\left(\Omega_{t-j}, \mathbf{W}_{t-j}\right)\theta_t|\Omega_{t-j}\right]
\end{aligned}$$

where the first and third equalities use the fact that we can reverse the order of $\mathbb{E}_{t-j}$ and $\mathbb{E}_{\Omega_{t-j+1}}$ because Ω_{t-j+1} is in the time $t-j$ information set along with the law of iterated expectations. The second equality uses the fact that by the exact Law of Large Numbers, both $\mathbb{E}_{t-j}\mathbb{E}_{\Omega_{t-j}}\left[\mathcal{H}_t\left(\Omega_{t-j}, \mathbf{W}_{t-j}\right)\theta_t\right]$ and $\mathbb{E}_{t-j}\mathbb{E}_{\Omega_{t-j+1}}\left[\mathcal{H}_t\left(\Omega_{t-j+1}, \mathbf{W}_{t-j}\right)\theta_t\right]$ equal the anticipated cross sectional mean (taken over the measure of individual households) of $\mathcal{H}\theta$ at time t from the perspective of time $t-j$.

Next, by shifting j indices, we also have:

$$\begin{aligned}
dP_{t-1} = &\sum_{j=1}^{t} \mathbb{E}_{\Omega_{t-j}}\left[m_{j-1} dV_{t-j}^X\left(\Omega_{t-j}, d\mathbf{W}_{t-j}\right)\right] \\
&- \left(\mathbb{E}_{\Omega_{t-1}}[\mathcal{H}_{t-1}\left(\Omega_{t-1}, \mathbf{W}_{t-1}\right)\theta_{t-1}] - \mathbb{E}_{-1}\mathbb{E}_{\Omega_{t-1}}[\mathcal{H}_{t-1}\left(\Omega_{t-1}, \mathbf{W}_{t-1}\right)\theta_{t-1}]\right)\bar{R}_{t-1}.
\end{aligned}$$

Equation (27) follows from imposing the definition $m_j = (1-\beta(1+\mu))(1+\mu)^j$. Specifically, the de-trended change can be written:

$$\frac{P_t}{\bar{R}_t} - \frac{P_{t-1}}{\bar{R}_{t-1}} = \frac{dP_t}{\bar{R}_t} - \frac{dP_{t-1}}{\bar{R}_{t-1}} = \frac{m_0}{\bar{R}_t}\mathbb{E}_{\Omega_t}\left[dV_t^X(\Omega_t, d\mathbf{W}_t)\right]$$
$$+\sum_{j=1}^{t}\left(\frac{m_j}{\bar{R}_t} - \frac{m_{j-1}}{\bar{R}_{t-1}}\right)\mathbb{E}_{\Omega_{t-j}}\left[dV_{t-j}^X(\Omega_{t-j}, d\mathbf{W}_{t-j})\right] - \left(\mathbb{E}_{\Omega_t}[\mathcal{H}_t(\Omega_t, \mathbf{W}_t)\theta_t] - \mathbb{E}_{\Omega_{t-1}}[\mathcal{H}_{t-1}(\Omega_{t-1}, \mathbf{W}_{t-1})\theta_{t-1}]\right)$$
$$= (1-\beta(1+\mu))\mathbb{E}_{\Omega_t}\left[dV_t^X(\Omega_t, d\mathbf{W}_t)\right]/\bar{R}_t - \left(\mathbb{E}_{\Omega_t}[\mathcal{H}_t(\Omega_t, \mathbf{W}_t)\theta_t] - \mathbb{E}_{\Omega_{t-1}}[\mathcal{H}_{t-1}(\Omega_{t-1}, \mathbf{W}_{t-1})\theta_{t-1}]\right)$$

The penultimate equality uses the fact that at date -1 households expect a balanced growth path and hence the level and distribution of homeownership to be the same at $t-1$ and t. The last equality uses $m_j/\bar{R}_t = m_{j-1}/\bar{R}_{t-1} = (1-\beta(1+\mu))(1+\mu)^{j-t}/\bar{R}_0$. Thus, the date t (de-trended) change in the pecuniary term of the price index depends only on news realized in period t about current and future shelter expenditure. This Markov property does not hold for a fully general IMPC profile, in which case the change in dP requires tracking the history of shocks.

C Price Index with Incomplete Markets

This Appendix extends the framework of Section 3 to a setting with incomplete markets. Importantly, we continue to assume that changes to shelter prices do not feedback into changes in the state-contingent marginal utility of nondurable consumption. That is, we consider small changes to shelter prices or the limit where shelter is a small part of the overall budget.

C.1 Setup

As in the main text, let $\Omega_t = (A_{t-1}, \mathcal{H}_{t-1}, s_{t-1}, \Theta_t)$ denote the state vector consisting of non-housing wealth A_{t-1}, previous tenure $\mathcal{H}_{t-1}$ of duration s_{t-1}, and exogenous type Θ_t. We also incorporate (uncertain) income y that we include in Θ. The incomplete markets household optimization problem is

$$\tilde{V}_t(\Omega_t) \equiv \tilde{V}(\Omega_t, \mathbf{W}_t) = \max_{\{C(\Theta^{t+j}), \mathcal{H}(\Theta^{t+j}), s(\Theta^{t+j})\}_{j=0}^{\infty}} \sum_{j=0}^{\infty}\tilde{\beta}^j\mathbb{E}_t\left[u\left(C\left(\Theta^{t+j}\right)\right) + \mathcal{H}\left(\Theta^{t+j}\right)v_{t+j}(\tilde{\theta}_{t+j})|\Omega_t\right],$$

$$\text{s.t.}\;\; C\left(\Theta^{t+j}\right) + X(\mathcal{H}\left(\Theta^{t+j-1}\right), \mathcal{H}\left(\Theta^{t+j}\right), s\left(\Theta^{t+j}\right); \mathbf{W}_{t+j}) + A\left(\Theta^{t+j}\right) \leq \frac{A\left(\Theta^{t+j-1}\right)}{\beta_{t+j-1,t+j}} + y(\Theta_{t+j})\;\forall\Theta^{t+j},$$
$$\left(\mathcal{H}\left(\Theta^{t+j-1}\right), s\left(\Theta^{t+j-1}\right), \mathcal{H}\left(\Theta^{t+j}\right), s\left(\Theta^{t+j}\right)\right) \in \Gamma\left(\Theta_{t+j}\right)\;\forall\Theta^{t+j}.$$

A solution to this problem yields a full set of Θ history-contingent allocations $C_{\Theta^{t+j}}(\Omega_t, \mathbf{W}_t)$, $X_{\Theta^{t+j}}(\Omega_t, \mathbf{W}_t)$, $\mathcal{H}_{\Theta^{t+j}}(\Omega_t, \mathbf{W}_t)$ of consumption, shelter expenditure, and tenure choice at each date and state history. These allocations obey a set of Euler equations:

$$u'\left(C_{\Theta^{t+j}}(\Omega_t, \mathbf{W}_t)\right) = \tilde{\beta}\beta_{t+j,t+j+1}^{-1}\mathbb{E}\left[u'\left(C_{\Theta^{t+j+1}}(\Omega_t, \mathbf{W}_t)\right)|\Theta^{t+j}\right]\;\forall\Theta^{t+j}, \Theta^{t+j+1}.$$

Substitute into the value function:

$$\tilde{V}_t(\Omega_t) = \mathbb{E}_t\left[\sum_{j=0}^{\infty}\tilde{\beta}^j\left(u\left(C_{\Theta^{t+j}}(\Omega_t, \mathbf{W}_t)\right) + \mathcal{H}_{\Theta^{t+j}}(\Omega_t, \mathbf{W}_t)v\left(\tilde{\theta}_{t+j}\right)\right)|\Omega_t\right].$$

Let $\Lambda_{t,\Theta^{t+j}}(\Omega_t) \equiv \tilde{\beta}^j u'(C_{\Theta^{t+j}}(\Omega_t, \mathbf{W}_t)) / u'(C_t(\Omega_t, \mathbf{W}_t))$ denote the household's stochastic discount factor relating marginal utility in state-date Θ^{t+j} to marginal utility at date t.

C.2 Changes in Welfare

Consider a change $d\mathbf{W}_t$ that affects current and/or future shelter costs along some paths, keeping the idiosyncratic components of the problem fixed. Also assume the risk free bond price, $\beta_{t,t+j}$, remains unchanged. Define $dY_{\Theta^{t+j}}$ as the difference in a variable Y in state-date Θ^{t+j} across the old and new allocations. Using $du(C_{\Theta^{t+j}}) = u'(C_{\Theta^{t+j}})\, dC_{\Theta^{t+j}}$, we have:

$$dV_t(\Omega_t, d\mathbf{W}_t) \equiv \frac{d\tilde{V}_t(\Omega_t, d\mathbf{W}_t)}{u'(C_t(\Omega_t, \mathbf{W}_t))}$$
$$= \mathbb{E}_t\left[\sum_{j=0}^{\infty} \Lambda_{t,\Theta^{t+j}} \left(dC_{\Theta^{t+j}}(\Omega_t, d\mathbf{W}_t) + d\mathcal{H}_{\Theta^{t+j}}(\Omega_t, d\mathbf{W}_t) \frac{v\left(\tilde{\theta}_{t+j}\right)}{u'(C_{\Theta^{t+j}}(\Omega_t, \mathbf{W}_t))} \right) | \Omega_t \right]. \tag{C.1}$$

The non-shelter consumption changes must obey

$$dC_{\Theta^{t+j}}(\Omega_t, d\mathbf{W}_t) + dX_{\Theta^{t+j}}(\Omega_t, d\mathbf{W}_t) + dA_{\Theta^{t+j}}(\Omega_t, d\mathbf{W}_t) = \frac{dA_{\Theta^{t+j-1}}(\Omega_t, d\mathbf{W}_t)}{\beta_{t+j-1,t+j}}.$$

Thus, we still have the result that the present value of changes in consumption expenditure discounted at the risk-free rate equals the present value of changes in spending on shelter along any given path of idiosyncratic states. However, the path of nondurable consumption changes required to restore utility discounts with the agent's stochastic discount factor, $\Lambda_{t,\Theta^{t+j}}$, rather than the financial discount rate, $\beta_{t,t+j}$, as in Farhi, Olivi and Werning (2022). For example, a shelter cost increase in a state of the world where the household has lower permanent income causes a larger welfare decline than the same shelter cost increase in a state of the world with higher permanent income.

We next rewrite the right hand side of equation (C.1) in terms of certainty-equivalent consumption and θ. To that end, define $dC^{\Lambda}_{t+j}(\Omega_t, d\mathbf{W}_t)$ as the certainty equivalent change in consumption given shelter cost changes at date t, i.e.:

$$\beta_{t,t+j} dC^{\Lambda}_{t+j}(\Omega_t, d\mathbf{W}_t) = \mathbb{E}_t\left[\Lambda_{t,\Theta^{t+j}} dC_{\Theta^{t+j}}(\Omega_t, d\mathbf{W}_t)\right].$$

Define $\theta \bar{R}_{t+j} \equiv v\left(\tilde{\theta}_{t+j}\right) / \mathbb{E}_t\left[u'(C_{\Theta^{t+j}}(\Omega_t, \mathbf{W}_t))\right]$. Then using the Euler equations and the definition of the stochastic discount factor, we get

$$dV_t(\Omega_t, d\mathbf{W}_t) = \sum_{j=0}^{\infty} \beta_{t,t+j} \left(dC^{\Lambda}_{t+j}(\Omega_t, d\mathbf{W}_t) + d\mathbb{E}_t\left[\mathcal{H}_{\Theta^{t+j}}(\Omega_t, \mathbf{W}_t)\, \theta_{t+j} | \Omega_t\right] \bar{R}_{t+j} \right). \tag{C.2}$$

We use the formulation in equation (C.2) to define the per-period price index.

C.3 Price Index Impulse Response

We define the price index response to news at date t using the certainty-equivalent for consumption:

$$dP_{t+j}(\Omega_t, d\mathbf{W}_t) = -dC^{\Lambda}_{t+j}(\Omega_t, d\mathbf{W}_t) - d\mathbb{E}_t\left[\mathcal{H}_{\Theta^{t+j}}(\Omega_t, \mathbf{W}_t)\, \theta_{t+j} | \Omega_t\right] \bar{R}_{t+j}. \tag{C.3}$$

By construction, the present value of price deviations discounted using the risk-free rate equals the value function deviation:

$$\sum_{j=0}^{\infty} \beta_{t,t+j} dP_{t+j} \left(\Omega_t, d\mathbf{W}_t\right) = -dV_t \left(\Omega_t, d\mathbf{W}_t\right).$$

Averaging over types:

$$dP_{t+j} \left(d\mathbf{W}_t\right) = -\mathbb{E}_{\Omega_t} \left[dC^{\Lambda}_{t+j} \left(\Omega_t, d\mathbf{W}_t\right) + d\mathbb{E}_t \left[\mathcal{H}_{\Theta^{t+j}} \left(\Omega_t, \mathbf{W}_t\right) \theta_{t+j} | \Omega_t\right] \bar{R}_{t+j}\right]. \tag{C.4}$$

C.4 Historical Price Index

Now consider a sequence of news. Define $dY_{t+j|t}$ as the change in a variable Y at date $t+j$ in response to news at date t. At date 0, the set of transfers is:

$$dP_{t|0} = -\mathbb{E}_{\Omega_0} \left[dC^{\Lambda}_{t|0} \left(\Omega_0, d\mathbf{W}_0\right) + \left(\mathbb{E}_0 - \mathbb{E}_{-1}\right) \left[\mathcal{H}_{\Theta^t} \left(\Omega_0, \mathbf{W}_0\right) \theta_t | \Omega_0\right] \bar{R}_t\right].$$

At date 1:

$$dP_{t|1} = dP_{t|0} - \mathbb{E}_{\Omega_1} \left[dC^{\Lambda}_{t|1} \left(\Omega_1, d\mathbf{W}_1\right) + \left(\mathbb{E}_1 - \mathbb{E}_0\right) \left[\mathcal{H}_{\Theta^t} \left(\Omega_1, \mathbf{W}_1\right) \theta_t | \Omega_1\right] \bar{R}_t\right].$$

The realized transfer at date t equals the sum of all past transfers:

$$dP_t = dP_{t|t} = -\sum_{j=0}^{t} \mathbb{E}_{\Omega_{t-j}} \left[dC^{\Lambda}_{t|t-j} \left(\Omega_{t-j}, d\mathbf{W}_{t-j}\right)\right] \tag{C.5}$$

$$- \left(\mathbb{E}_{\Omega_t} \left[\mathcal{H}_{\Theta^t} \left(\Omega_t, \mathbf{W}_t\right) \theta_t\right] - \mathbb{E}_{\Omega_0} \left[\mathbb{E}_{-1} \left[\mathcal{H}_{\Theta^t} \left(\Omega_0, \mathbf{W}_0\right) \theta_t | \Omega_0\right]\right]\right) \bar{R}_t. \tag{C.6}$$

Equation (C.6) mirrors equation (26) in the main text, except that with uncertainty and incomplete markets the price tracks revisions to the certainty equivalent value of consumption.

D Additional Survey Material

D.1 Demographic and Financial Benchmarking

Table D.1 compares demographic characteristics of our sample to the population as reported in the CPS. Table D.4 compares the distribution of rent and owners' equivalent rent in our sample to the population as reported in the CEX.

Table D.1: Demographic Characteristics Comparison to Current Population Survey

	Percent of household heads or spouses		
Sample:	CPS	Full survey	Baseline sample
18-24 years old	3.6	8.6	6.3
25-34 years old	15.7	17.2	15.9
35-44 years old	18.8	18.0	19.7
45-54 years old	17.2	17.8	19.0
55-64 years old	17.9	24.6	25.0
65+ years old	26.7	13.9	14.0
Female	52.1	50.8	51.6
Married	61.4	52.2	53.8
No children	60.4	67.4	69.0
1 child	17.0	15.6	15.5
2 children	14.5	12.3	11.7
3+ children	8.2	4.6	3.9
No college	32.5	9.5	9.7
Some college	25.2	27.9	28.6
BA	25.8	41.1	41.5
Graduate or professional	16.5	21.4	20.0

Notes: the table compares demographics in our survey to reference persons and their partners in the December 2024 Current Population Survey.

Table D.2: Demographic Characteristics Comparison to SIPP

	Percent of household heads or spouses								
	Pooled			Owners			Renters		
Sample:	SIPP	Full survey	Baseline sample	SIPP	Full survey	Baseline sample	SIPP	Full survey	Baseline sample
Owner	68.4	63.9	66.0						
18-24 years old	2.8	8.6	6.3	1.1	4.7	4.3	6.4	15.6	10.1
25-34 years old	14.4	17.2	15.9	9.4	12.4	11.5	25.3	25.6	24.4
35-44 years old	18.5	18.0	19.7	17.3	18.4	20.6	21.3	17.2	18.1
45-54 years old	17.5	17.8	19.0	18.1	18.8	19.5	16.1	15.8	18.1
55-64 years old	19.1	24.6	25.0	21.4	28.4	27.5	13.9	17.8	20.2
65+ years old	27.7	13.9	14.0	32.7	17.3	16.5	16.9	8.1	9.2
Female	52.5	50.8	51.6	53.0	50.9	52.8	54.4	50.4	49.2
Married	60.2	52.2	53.8	69.0	64.5	65.9	36.5	30.3	30.3
No children	61.6	67.4	69.0	60.4	64.1	65.1	64.2	73.3	76.5
1 child	17.0	15.6	15.5	17.8	15.9	16.3	15.3	15.3	13.9
2 children	13.9	12.3	11.7	14.9	14.3	13.4	11.9	8.9	8.4
3+ children	7.4	4.6	3.9	6.8	5.8	5.2	8.6	2.5	1.3
No college	31.0	9.5	9.7	27.2	8.6	8.7	39.2	11.1	11.8
Some college	25.8	27.9	28.6	25.8	26.7	29.3	25.6	30.0	27.3
BA	25.3	41.1	41.5	26.8	41.0	41.0	22.3	41.4	42.4
Graduate or professional	17.9	21.4	20.0	20.2	23.5	20.8	12.9	17.5	18.5

Notes: the table compares demographics in our survey to reference persons and their partners in the 2023 SIPP.

Table D.3: Homeownership by Age Comparison to SIPP

	Homeownership rate		
Sample:	SIPP	Full survey	Baseline sample
18-24 years old	27.6	34.9	45.5
25-34 years old	44.4	46.2	47.7
35-44 years old	63.6	65.4	68.8
45-54 years old	70.8	67.8	67.7
55-64 years old	76.9	73.9	72.6
65+ years old	80.7	79.1	77.6
25+ years old	69.5	66.6	67.3

Table D.4: Shelter Cost Comparison to Consumer Expenditure Survey

	Statistic				
Statistic:	P10	P25	P50	P75	P90
Owner equivalent rent					
CEX	1000	1500	2100	3000	3803
Full survey	800	1250	2000	3000	4000
Baseline sample	800	1300	2000	2800	3500
Rent					
CEX	400	853	1594	2433	4100
Full survey	562.5	910	1400	1900	2750
Baseline sample	675	960	1400	1900	2800

D.2 Reasons for Moving

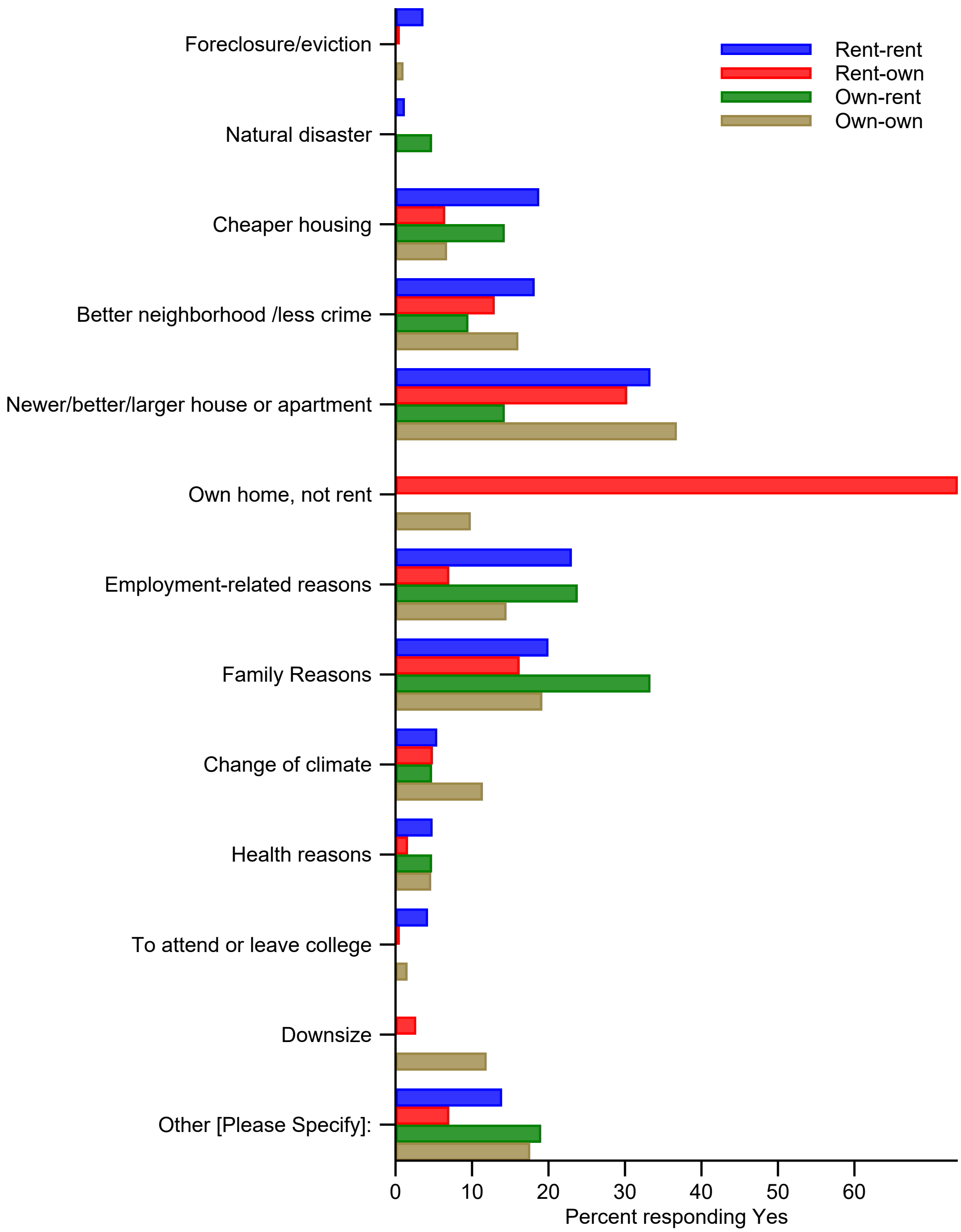
This appendix presents evidence on reasons for moving from our survey and from the SIPP, American Housing Survey (AHS), and Current Population Survey Annual Social and Economic Supplements (CPS ASEC).

Figure D.2 presents results from the SIPP question "What was the main reason you moved to this address?" (`EEHC_WHY`). The sample for this analysis coincides with Appendix E. Respondents can choose one answer.

Figure D.3 presents results from a similar question asked of recent (last two years) movers in the AHS (`RM*`). The sample for this is the AHS waves in 2015, 2017, and 2019. Unlike the SIPP, the AHS prefaces a series of questions with "People choose to move for a variety of reasons, either voluntary or non-voluntary" and respondents can choose multiple reasons.

Figure D.4 presents results from a similar question asked of movers (in the previous year) in the CPS ASEC: "What was your main reason for moving?" (`NXTRES`). The sample for this is the 2015-2018 ASECs. Like the SIPP, respondents may choose only one answer. Unlike the SIPP and

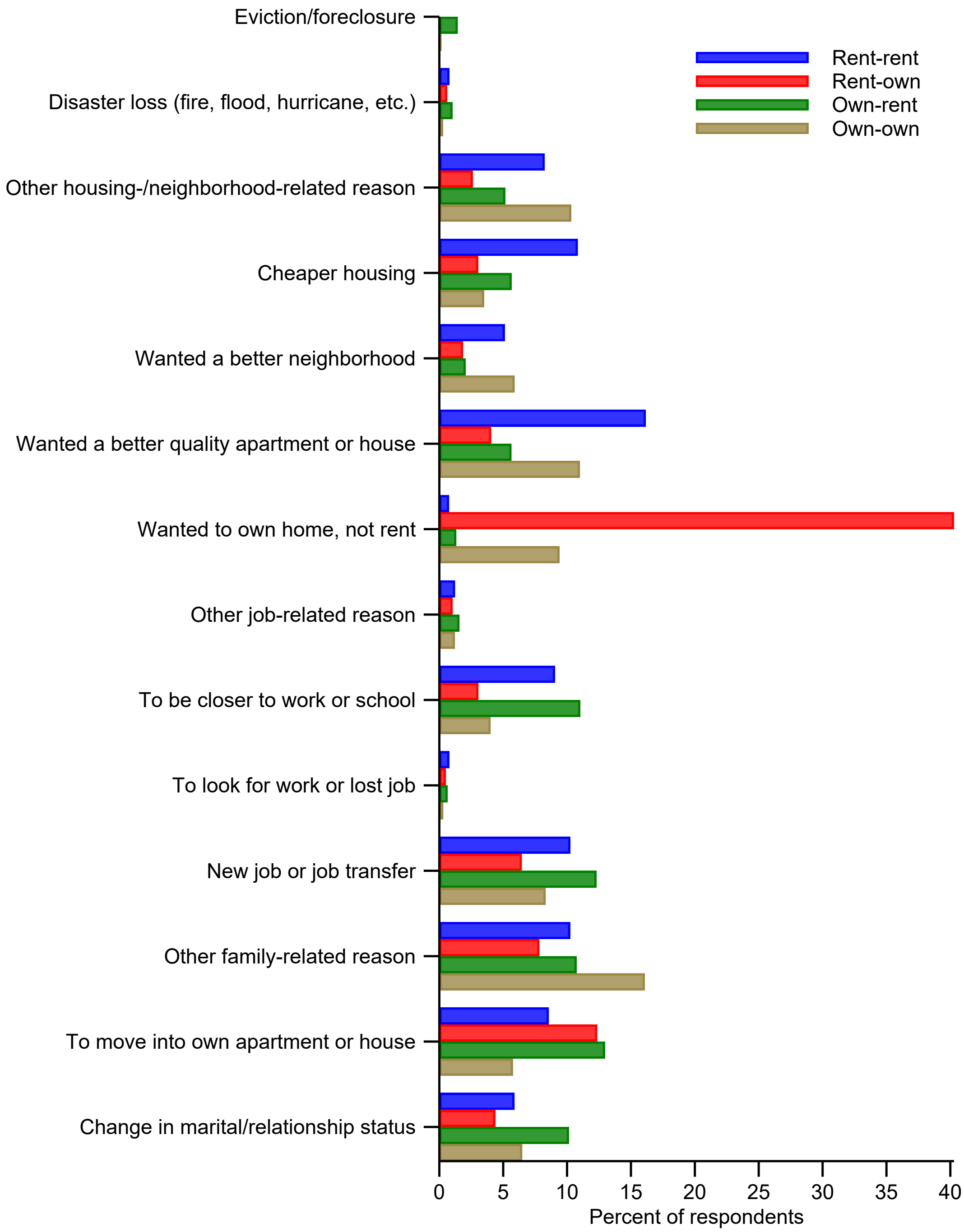
Figure D.1: Reason for Moving: Our Survey



Notes: Due to a survey module error, we did not offer current renters the option to select "downsize".

AHS, we cannot split respondents by whether they change tenure status as the CPS does not ask about the tenure of the previous residence.

Figure D.2: Reason for Moving: SIPP



Notes:

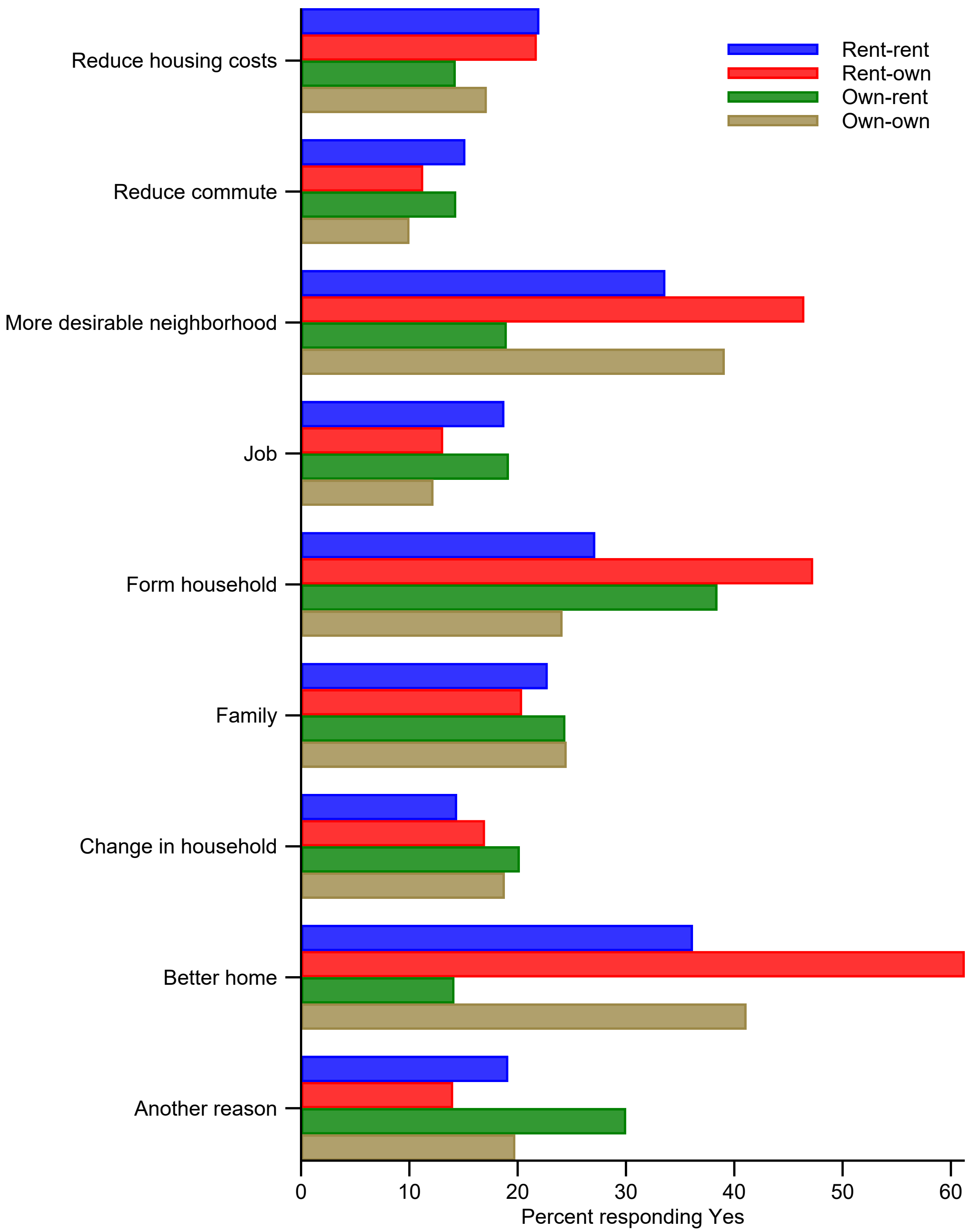
D.3 Willingness-to-pay Questions

Imagine the following scenario: When you bought your home, you also considered renting. Let's compare the outcome of your choice to buy a home with a hypothetical alternative where you chose to rent instead.

The Decision Point

When you bought your home, you faced a choice about where to

Figure D.3: Reason for Moving: AHS



Notes:

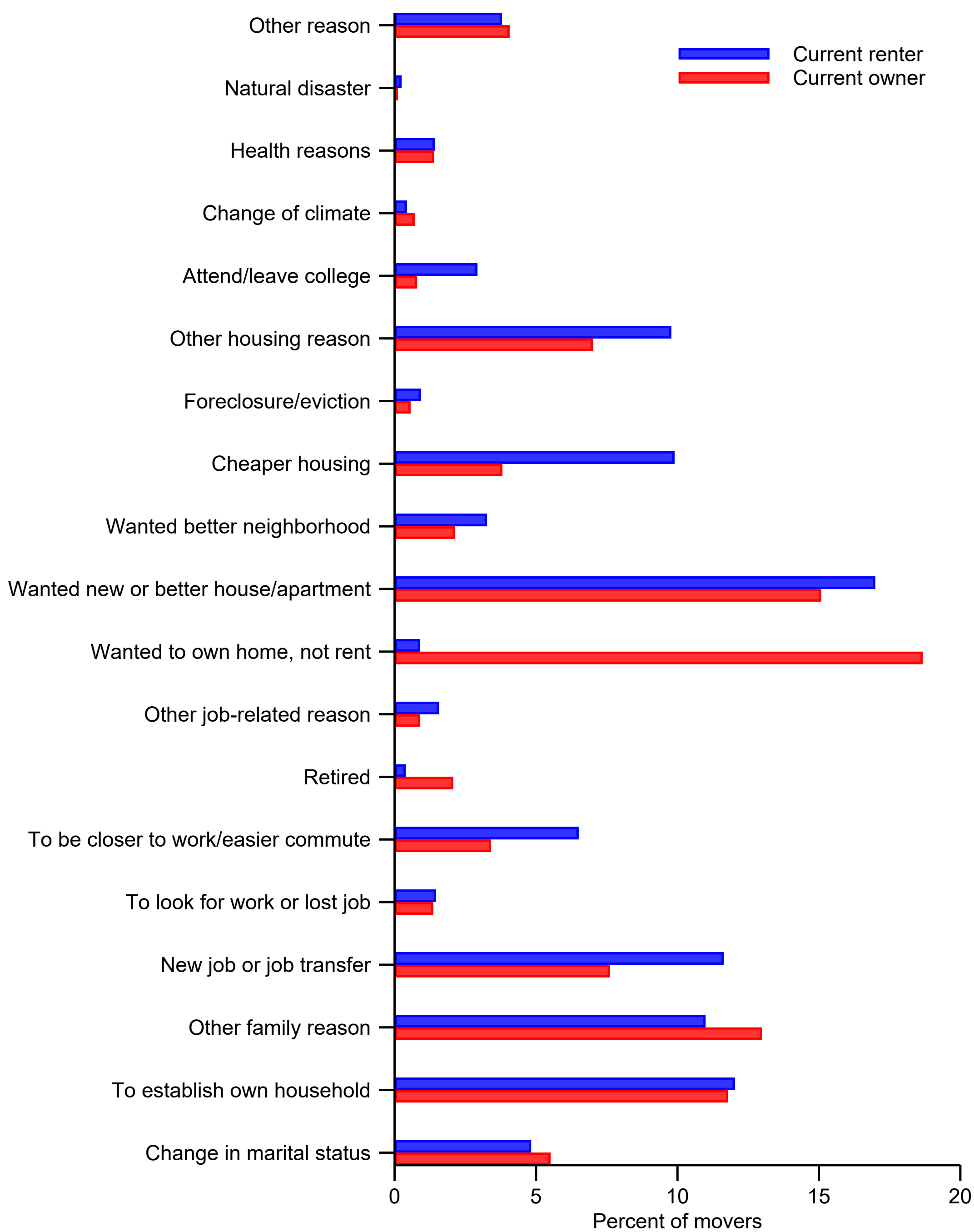
Imagine this hypothetical scenario: You've just inherited $25,000 from a distant relative. This amount is enough to cover a down payment on a home you might like to buy. You now face a significant financial decision.

The Decision Point

With this unexpected inheritance, you have two options:

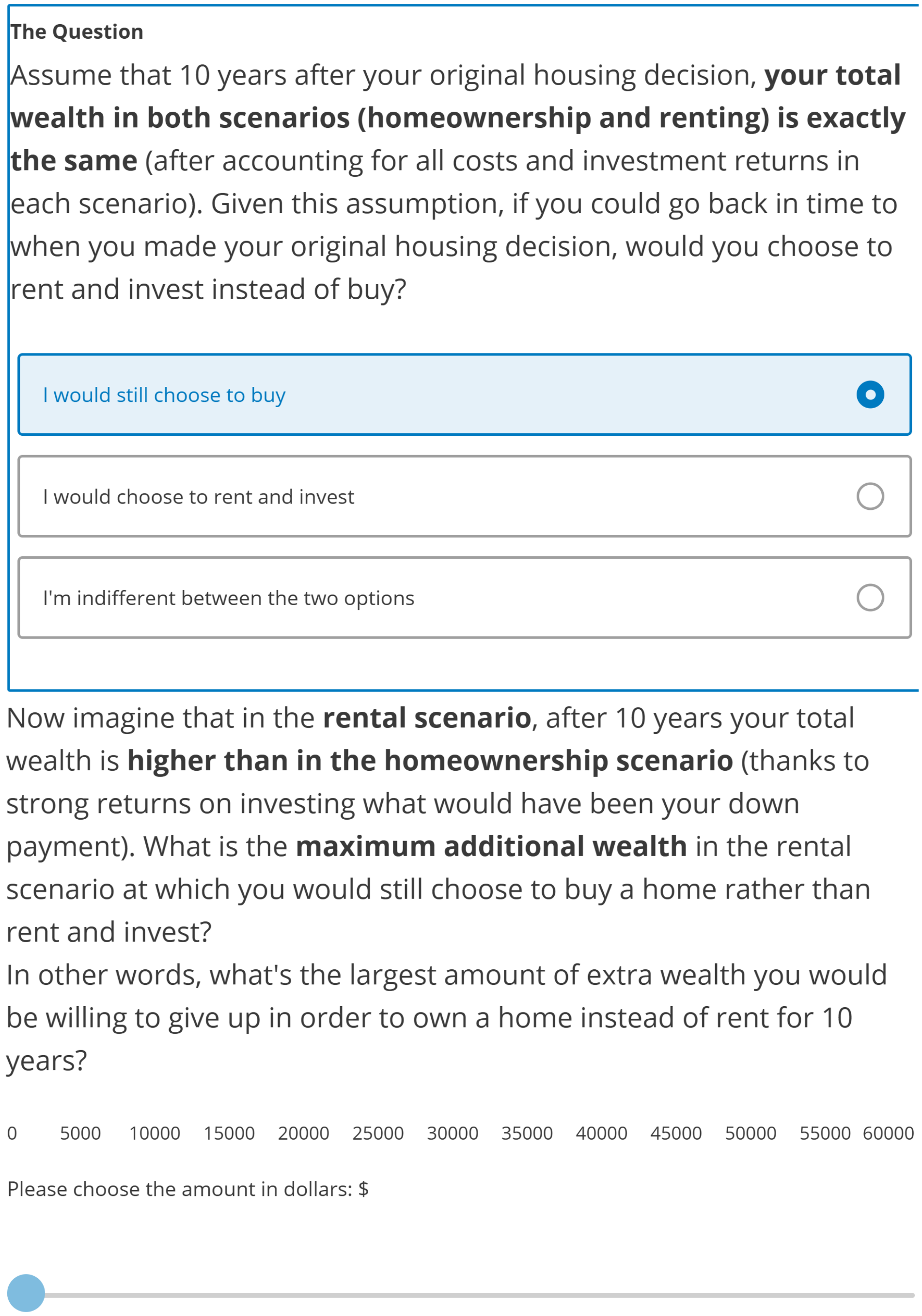
1. **Buy a Home:** Use the inheritance as a down payment to

Figure D.4: Reason for Moving: CPS ASEC



Notes:

Homeownership (Your Actual Choice)	Rental Scenario (Hypothetical)
Living Situation: You lived in a home you owned for 10 years, paying off part of your mortgage	**Living Situation:** You would have been continuously living in a rented home for 10 years



The Question

Assume that 10 years after your original housing decision, **your total wealth in both scenarios (homeownership and renting) is exactly the same** (after accounting for all costs and investment returns in each scenario). Given this assumption, if you could go back in time to when you made your original housing decision, would you choose to rent and invest instead of buy?

- I would still choose to buy
- I would choose to rent and invest
- I'm indifferent between the two options

Now imagine that in the **rental scenario**, after 10 years your total wealth is **higher than in the homeownership scenario** (thanks to strong returns on investing what would have been your down payment). What is the **maximum additional wealth** in the rental scenario at which you would still choose to buy a home rather than rent and invest?

In other words, what's the largest amount of extra wealth you would be willing to give up in order to own a home instead of rent for 10 years?

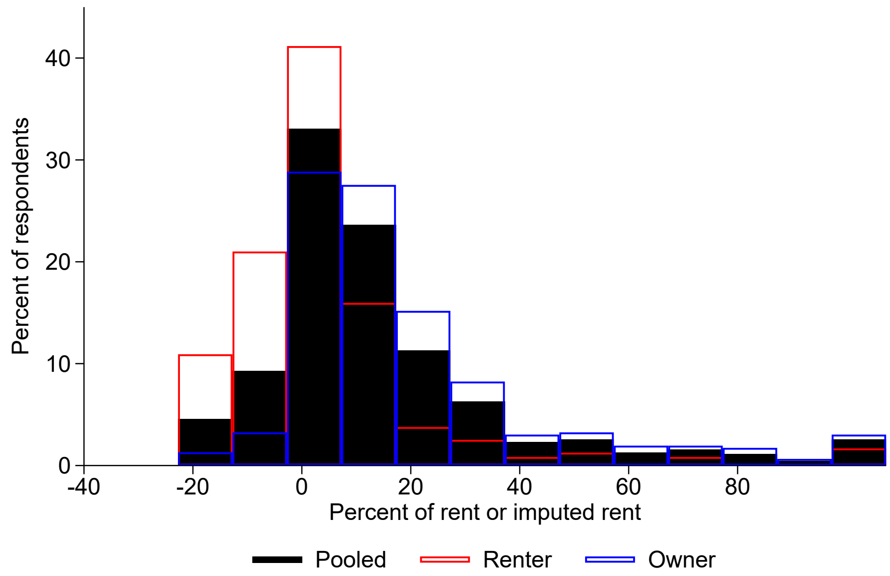
0 5000 10000 15000 20000 25000 30000 35000 40000 45000 50000 55000 60000

Please choose the amount in dollars: $

D.4 Results With WTP Scaled by Own Rent

Table D.5 reports regressions of WTP scaled by actual or equivalent rent on homeownership.

Figure D.5: WTP Distribution



Notes: The figure reports the histogram of willingness-to-pay as a share of the respondent's own rent or imputed rent. We winsorize the top and bottom 2.5% of observations.

D.5 Mis-reporting and Results From Follow-up Survey

D.5.1 Follow-up Survey

We launched an approximately 15 minute follow-up survey five weeks after the main survey.[3] We made the follow-up survey available to a randomly-selected 300 respondents of the main survey, excluding respondents who reported their WTP did not reflect their true valuation (whom we exclude from our baseline sample) and 89 respondents newly ineligible to participate in Prolific surveys because they are not U.S. nationals. We received 230 responses, for an overall response rate of 77%. We exclude one respondent who finished the survey in less than one minute (the next shortest response time is 00:03:40) and six respondents who did not complete the WTP portion, leaving 223 responses, or 74% of the potential sample.

The selected respondents were not told this survey was related to our earlier survey. To mask any connection, the follow-up survey asked a series of questions about different trade-offs around living arrangements. For example, homeowners were asked in order: (i) their typical commute time; (ii) open-ended question about their decision to live with that commute; (iii) a WTP for a 10 minute reduction in commute time; (iv) an explanation of that amount; (v) the WTP to own question shown below including related open-ended questions; (vi) to select and explain household tasks done by a paid employee versus self; (vii) hobbies; (viii) outdoor space; (ix) number of bedrooms; a trade-off between indoor and outdoor space.

To assess whether interviewer bias might contaminate the follow-up, we asked respondents about what they thought was the purpose of the survey and whether any questions stood out as especially important. No respondent mentioned a connection to the earlier survey. Several men-

[3]Specifically, we collected the main survey on January 9, 2025, the short follow-up to obtain numeric values for those who chose the slider or loop maximum over January 16-22, 2025, and launched the main follow-up on February 21, 2025.

Table D.5: Willingness-to-pay to Own and Homeownership

Dep. var.:	WTP to own/Own rent (%)							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Owner	15.0**	14.3**	16.7**	16.9**	16.7**	15.9**	17.9**	12.0**
	(1.9)	(1.7)	(1.8)	(1.9)	(2.6)	(1.7)	(2.0)	(1.1)
Identical house	-1.2	-1.4	-1.7	-1.6	-3.5	-2.4	-1.7	-0.9
	(2.0)	(1.8)	(2.0)	(2.0)	(2.7)	(2.0)	(2.3)	(1.3)
Loop	0.4	2.2	0.7	1.0	2.0	-0.8	0.2	0.1
	(2.2)	(2.2)	(2.2)	(2.3)	(3.3)	(2.0)	(2.5)	(1.2)
Constant	2.7^{+}	4.1**	3.4*	3.4*	7.5**	5.0**	3.5*	4.4**
	(1.6)	(1.4)	(1.5)	(1.6)	(2.1)	(1.4)	(1.7)	(1.0)
WTP$<25k$	✓							
Winsorized 2.5/97.5		✓	✓	✓	✓	✓	✓	
Winsorized 10/90								✓
Baseline sample			✓	✓		✓	✓	✓
No 18-24 year-olds				✓				
Confidence weighted					✓			
No age reweight						✓		
Addl. attention check							✓	
Observations	978	993	699	655	958	699	548	699

Notes: The dependent variable is the willingness-to-pay (WTP) to own scaled by the respondent's rent or self-reported owner's equivalent rent. Column (1) excludes respondents who reported a WTP greater than \$25,000 per year. Columns (2)-(7) winsorize the dependent variable at the 2.5 and 97.5 quantiles. Column (8) winsorizes the dependent variable at the 10 and 90 percentiles. Baseline sample excludes respondents who failed the first attention check or reported No (confused) or No (misclicked) to the question on valuation accuracy. Confidence weighted weights by self-reported confidence in the answer. No age reweight does not reweight the sample to match the SIPP age distribution. The additional attention check excludes respondents who failed the second attention check. The variable Identical house is an indicator for the hypothetical specifying an identical property in terms of location, size, quality, and features. Loop is an indicator for answering the WTP question using a loop instead of a slider. Heteroskedastic-robust standard errors in parentheses.

tioned that they found thinking through the various trade-offs as interesting and novel, suggesting they did not have explicit recall of the survey from five weeks earlier.

The WTP to own question was similar to but simpler than the version shown on the original survey. Figure D.6 shows the question for owners. We followed this question with a slider from \$0 to \$100,000 for the additional wealth required to induce the respondent to switch tenure.

The correlation coefficient between the WTP in the original survey (in dollars) and in the follow-up is 0.50. Restricting the sample to respondents who did not answer the short survey in the interim results in a correlation coefficient of 0.48. Thus, we find a meaningful correlation of responses across surveys.

D.5.2 Interpretation

To interpret the differences across the original and follow-up surveys, we provide the following cognitive uncertainty framework. An individual with a true value $\theta_i \sim N\left(\mu_\theta, \sigma_\theta^2\right)$ receives a signal of her true preference of $\theta_i + e_i$, with $e_i \sim N\left(0, \sigma_e^2\right)$ drawn independent of θ_i. The signal-to-noise

Figure D.6: Survey Follow-up WTP Text

*Think back to when you bought your home. Imagine that at the time, you ha
options:

1. **Buy a Home:**
    - Make down payment
    - Take out a mortgage
    - *Live there for 10 years, then sell*
2. **Keep Renting:**
    - Invest the down payment in a diversified portfolio
    - *Rent for 10 years*

Suppose after 10 years, **your total wealth would be exactly the same in scenarios** (accounting for all costs, home sale proceeds, and investment returns).
Which would you choose?

○ Buy a home

○ Keep renting and invest

○ I would be indifferent

ratio is:

$$b = \frac{\sigma_\theta^2}{\sigma_\theta^2 + \sigma_e^2}.$$

We consider two cases.

Case 1: naive. Individuals who do not recognize their cognitive uncertainty simply report $\hat{\theta}_i = \theta_i + e_i$. Then:

1. A regression of $\hat{\theta}$ on homeownership yields an unbiased coefficient of the true relationship. This result follows because e_i adds classical left hand side measurement error.

2. The cross-sectional variance is $Var\left(\hat{\theta}_i\right) = \sigma_\theta^2 + \sigma_e^2 = \sigma_\theta^2/b$. Thus, measurement error causes the cross-sectional variance to be inflated by a factor $1/b$.

3. If we elicit two values $\hat{\theta}_i^1$ and $\hat{\theta}_i^2$ for each individual with independent measurement error, then $Corr\left(\hat{\theta}_i^1, \hat{\theta}_i^2\right) = b$.

Case 2: sophisticate. An individual aware of her cognitive uncertainty shrinks her signal toward the mean and reports $\hat{\theta}_i = \mu_\theta + b\left(\theta_i + e_i - \mu_\theta\right)$. Then:

1. A regression of $\hat{\theta}$ on homeownership yields a coefficient attenuated by a factor b.

2. The cross-sectional variance is $Var\left(\hat{\theta}_i\right) = b^2\left(\sigma_\theta^2 + \sigma_e^2\right) = b\sigma_\theta^2$. Thus, measurement error causes the cross-sectional variance to be attenuated by a factor b.

3. If we elicit two values $\hat{\theta}_i^1$ and $\hat{\theta}_i^2$ for each individual with independent measurement error, then $Corr\left(\hat{\theta}_i^1, \hat{\theta}_i^2\right) = b$.

Comparing across both cases, we have the following conclusions:

1. A regression of $\hat{\theta}$ on homeownership yields a weakly attenuated coefficient.

2. The cross-sectional variance $Var\left(\hat{\theta}_i\right)$ maybe larger or smaller than the true variance but is bounded (in the case of uncorrelated measurement error) by b and $1/b$.

3. $Corr\left(\hat{\theta}_i^1, \hat{\theta}_i^2\right) = b$. Using our survey, we thus have $b \approx 0.5$.

E SIPP Mover Analysis

This appendix describes our analysis of the SIPP. Unlike most government surveys (including the CPS, ACS, and AHS), the SIPP follows individuals who move from the originally-sampled address.

We use the 2014-2021 panels, which cover the years 2013-2020. We use 2020 only to compute moving rates for the last few months of 2019.

We define a move as a change in residence (variable `ERESIDENCEID`). The SIPP contains its own edited mover variable (`TMOVER`). In nearly all cases, `TMOVER` coincides with a change in residence. U.S. Census Bureau (2021, p. 64) explains the discrepancies: "However, in a small number of cases a change in `ERESIDENCEID` from one month to another may not be reflected on `TMOVER` and

Table E.1: Moving Rates

	Population share			Hazard rate		
	1 month	3 month	12 month	1 month	3 month	12 month
Rent stayer	33.80	32.43	26.41	98.47	95.28	81.48
Rent-to-rent	0.40	1.21	4.45	1.16	3.56	13.75
Rent-to-own	0.13	0.39	1.54	0.37	1.16	4.77
Own stayer	65.41	65.16	64.74	99.60	98.78	95.78
Own-to-rent	0.10	0.30	0.98	0.15	0.46	1.45
Own-to-own	0.16	0.50	1.87	0.25	0.76	2.77

Notes: the table shows the population share and hazard rates for 1-month, 3-month, and 12-month moves. The sample consists of household reference persons in the SIPP panels covering 2013-2019. For households with multiple residences and reference persons in a reference year, we keep only the original reference person. We construct population shares and hazard rates by month, take averages for each of the 12 calendar months, and finally take averages over the calendar months to account for uneven sample sizes and seasonality.

`TRESDUR`. In these instances, a respondent has changed residences from one month to another but reports always living at the residence he or she has moved to on the reason for move variable (`EEHC_WHY`). Because respondents' own definitions of what constitutes a move may differ from how the SIPP survey identifies a move, we have chosen to leave these apparent inconsistencies in the data." We use changes in residence directly in order to compute moving rates across horizons greater than 1 month. The variable `EEHC_TEN` determines whether a residence is owned or rented.

To focus on moves likely to involve a change in title or lease contract at the original residence, we restrict the sample to reference persons (`ERELRPE`=1,2), which U.S. Census Bureau (2021, p. 161) defines as "an owner or renter of record." If a household splits into multiple residences (for example, a child moves into her own apartment), we keep only the reference person in the original unit. We further restrict the sample to residences defined as houses or apartments (`TPRVLVQRT`=1). We compute statistics weighted by the monthly sample weight (`WPFINWGT`).

The size of the SIPP sample varies over time. There also is seasonality in moving hazards. To address these issues, we compute population shares and moving hazards by month, take averages for each of the 12 calendar months, and finally take averages over the calendar months.

Table E.1 reports population shares and moving hazards by whether the move involves a change in tenure.

F Mortgage Rate, House Price, and Rent Forecasts

We obtain expectations of the nominal mortgage rate i_t^C from rolling 10 year projections of the Freddie Mac 30 year mortgage interest rate (FRED code MORTGAGE30US) on Treasury forward rates up to 15 years out, using the updated Gürkaynak, Sack and Wright (2007) data set available from Board of Governors of the Federal Reserve System (2026). Since these Treasury forward rates go out to 30 years, this procedure gives expectations of nominal mortgage rates out 15 years (i.e. $\mathbb{E}_t i_{t+15}^C$ applies the coefficients out 15 years to the forward rates for years $t+16$ through $t+30$). We assume expectations remain unchanged after year 15.

We obtain forecasts of house price and rent growth using a Bayesian vector autoregression (BVAR). House price expectations are notoriously unruly (Shiller and Thompson, 2022; Kuchler,

Table E.2: Moving Rates Age 25-34

	Population share			Hazard rate		
	1 month	3 month	12 month	1 month	3 month	12 month
Rent stayer	60.33	57.07	42.66	97.73	92.96	71.56
Rent-to-rent	1.07	3.32	12.72	1.74	5.39	21.30
Rent-to-own	0.33	1.01	4.26	0.53	1.65	7.14
Own stayer	37.88	37.39	36.05	98.98	96.84	89.29
Own-to-rent	0.22	0.64	1.89	0.58	1.67	4.71
Own-to-own	0.19	0.58	2.42	0.50	1.51	6.00

Notes: the table shows the population share and hazard rates for 1-month and 3-month moves. The sample consists of household reference persons in the SIPP panels covering 2013-2019. For households with multiple residences and reference persons in a reference year, we keep only the original reference person. We construct population shares and hazard rates by month, take averages for each of the 12 calendar months, and finally take averages over the calendar months to account for uneven sample sizes and seasonality.

Table E.3: Moving Rates Age 35-44

	Population share			Hazard rate		
	1 month	3 month	12 month	1 month	3 month	12 month
Rent stayer	41.04	39.38	32.02	98.37	95.05	80.17
Rent-to-rent	0.51	1.53	5.67	1.23	3.70	14.23
Rent-to-own	0.17	0.52	2.24	0.40	1.25	5.60
Own stayer	57.99	57.71	56.82	99.51	98.52	94.58
Own-to-rent	0.12	0.33	1.10	0.20	0.57	1.84
Own-to-own	0.19	0.54	2.16	0.32	0.92	3.59

Notes: the table shows the population share and hazard rates for 1-month and 3-month moves. The sample consists of household reference persons in the SIPP panels covering 2013-2019. For households with multiple residences and reference persons in a reference year, we keep only the original reference person. We construct population shares and hazard rates by month, take averages for each of the 12 calendar months, and finally take averages over the calendar months to account for uneven sample sizes and seasonality.

Table E.4: Moving Rates Age 45-54

	Population share			Hazard rate		
	1 month	3 month	12 month	1 month	3 month	12 month
Rent stayer	31.33	30.35	26.03	98.74	96.20	84.89
Rent-to-rent	0.30	0.89	3.45	0.96	2.83	11.33
Rent-to-own	0.11	0.31	1.16	0.34	0.98	3.78
Own stayer	68.05	67.79	66.98	99.68	99.02	96.56
Own-to-rent	0.10	0.26	0.82	0.15	0.38	1.18
Own-to-own	0.14	0.41	1.56	0.20	0.60	2.26

Notes: the table shows the population share and hazard rates for 1-month and 3-month moves. The sample consists of household reference persons in the SIPP panels covering 2013-2019. For households with multiple residences and reference persons in a reference year, we keep only the original reference person. We construct population shares and hazard rates by month, take averages for each of the 12 calendar months, and finally take averages over the calendar months to account for uneven sample sizes and seasonality.

Table E.5: Moving Rates Age 55-64

	Population share			Hazard rate		
	1 month	3 month	12 month	1 month	3 month	12 month
Rent stayer	24.83	24.19	21.33	99.00	96.86	86.86
Rent-to-rent	0.19	0.57	2.35	0.74	2.31	9.63
Rent-to-own	0.08	0.21	0.86	0.32	0.83	3.51
Own stayer	74.69	74.31	72.78	99.69	99.05	96.45
Own-to-rent	0.08	0.23	0.84	0.11	0.31	1.11
Own-to-own	0.17	0.49	1.84	0.22	0.65	2.44

Notes: the table shows the population share and hazard rates for 1-month and 3-month moves. The sample consists of household reference persons in the SIPP panels covering 2013-2019. For households with multiple residences and reference persons in a reference year, we keep only the original reference person. We construct population shares and hazard rates by month, take averages for each of the 12 calendar months, and finally take averages over the calendar months to account for uneven sample sizes and seasonality.

Table E.6: Moving Rates Age 65-79

	Population share			Hazard rate		
	1 month	3 month	12 month	1 month	3 month	12 month
Rent stayer	19.57	19.21	17.76	99.24	97.54	90.54
Rent-to-rent	0.12	0.36	1.41	0.59	1.85	7.26
Rent-to-own	0.05	0.12	0.43	0.24	0.63	2.19
Own stayer	80.07	79.61	78.15	99.73	99.13	97.19
Own-to-rent	0.06	0.17	0.61	0.07	0.21	0.76
Own-to-own	0.17	0.53	1.65	0.21	0.66	2.06

Notes: the table shows the population share and hazard rates for 1-month and 3-month moves. The sample consists of household reference persons in the SIPP panels covering 2013-2019. For households with multiple residences and reference persons in a reference year, we keep only the original reference person. We construct population shares and hazard rates by month, take averages for each of the 12 calendar months, and finally take averages over the calendar months to account for uneven sample sizes and seasonality.

Piazzesi and Stroebel, 2023). Our objective is not to resolve this debate using a BVAR. Rather, the purpose is to obtain a set of plausible forecasts, at each forecast horizon and for a long time series, that can be fed into our model to obtain a historical price index. Future work may improve on our statistical method or incorporate survey evidence.

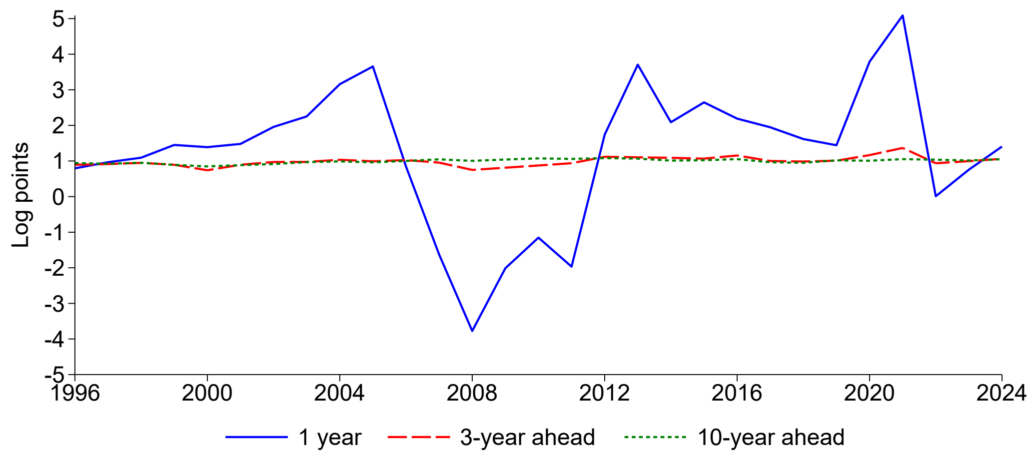
We construct a monthly data set that spans 1988-2025. Let $Y_t = \left(\log P_t^H, \log R_t, i_t\right)'$, where P_t^H is the real house price, R_t is real rent, and i_t is the real mortgage interest rate. We measure $\log P_t^H$ as the log of the Case-Shiller national house price index (FRED code CSUSHPISA) less the log of the non-shelter CPI (FRED code CUSR0000SA0L2) and $\log R_t$ as the log BLS primary rent index (FRED code CUSR0000SEHA) less non-shelter CPI. We measure i_t for the VAR by combining the nominal Freddie Mac mortgage rate with expected inflation over the expected life of the mortgage. To obtain the latter, let S_{t+j} denote the share of mortgages originated at date t that remain in force at date $t + j$ (i.e. the borrower has not refinanced or moved). Consistent with our steady state calibration, we assume 4.2% of owners sell and a fraction $\xi = 23.4\%$ of borrowers with a contract rate above the current mortgage rate refinance. We then have the law of motion $S_{t+j} = (1 - 0.042)\left(1 - \mathbb{P}_t\left\{i_{t+j} < i_t\right\} \times \xi\right) S_{t+j-1}$. We incorporate uncertainty into the mortgage rate forecast by assuming $i_{t+j} \sim N\left(\mathbb{E}_t\left[i_{t+j}\right], 0.015^2\right)$, where the forecast error standard deviation of 1.5p.p. is based on the time series of forecast errors. This gives a sample median expected mortgage duration of 9 years, with values as low as 5 years in years where the expected future mortgage rate is less than the current rate and values as high as 15 years when the expected mortgage rate is above the current rate. Given an expected mortgage duration of τ, we define the real mortgage interest rate as $1 + i_t = (1 + i_t^C)/(1 + \mathbb{E}_t\pi_{t,\tau})$, where $\mathbb{E}_t\pi_{t,\tau}$ denotes expected inflation between t and $t + \tau$ from Federal Reserve Bank of Cleveland (2026). Effectively, we assume that mortgage interest rates are par yields and obtain the real mortgage rate as the par yield if there were no underlying inflation. Allowing for deviations from the par yield assumption does not meaningfully change the real mortgage rate series.

We assume that the data are first-difference stationary with trend growth of house prices and rents of 1%, as in our model's steady state. Thus, let $\tilde{\Delta} Y_t = Y_t - Y_{t-1} - \begin{pmatrix}0.01 & 0.01 & 0\end{pmatrix}'/12$ denote the first difference of Y_t less the trend. For each month T starting with January 1996, we estimate the BVAR $\tilde{\Delta} Y_t = \sum_{\ell=1}^{12} B_\ell \tilde{\Delta} Y_{t-\ell} + e_t$ for a sample with all $t \le T$ and a standard Minnesota-style prior. (Note that this specification does not include a constant term, as we already removed trend growth.) Specifically, the slope coefficients $\{B_\ell\}$ have a multivariate normal prior with zero mean (implying a random walk with trend in levels) and block-diagonal covariance matrix with entries $(\lambda_1/\ell^{\lambda_3})^2$ on the main diagonal and $(\hat{\sigma}_i^2/\hat{\sigma}_j^2) \times (\lambda_1\lambda_2/\ell^{\lambda_3})^2$ for variables $i \neq j$ off the main-diagonal but with the same lag, where $\hat{\sigma}_i^2$ denotes the single variable empirical error variance. We set $\lambda_1 = 0.05, \lambda_2 = 0.5, \lambda_3 = 1$. The residuals e_t have an inverse-Wishart prior.

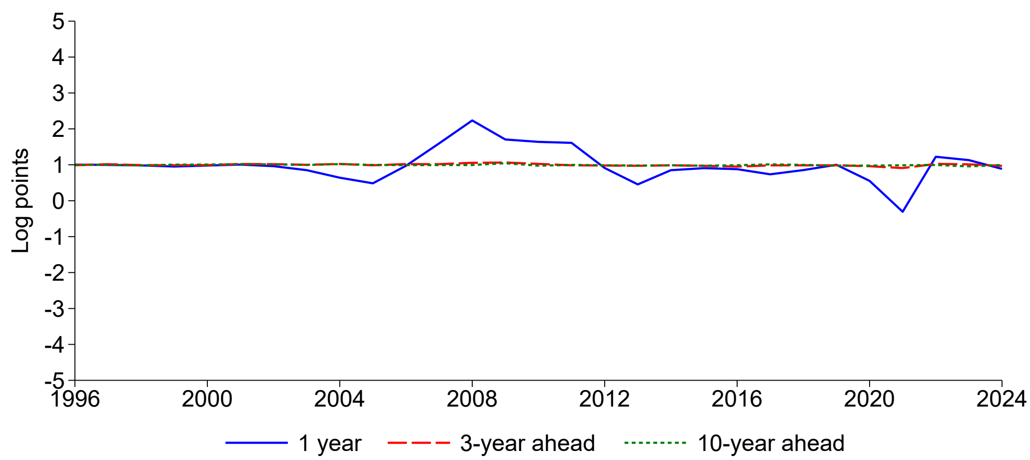
We define the dynamic forecast for growth at horizon h, $\mathbb{E}_T \tilde{\Delta} Y_{T+h}$, as the median of the posterior distribution of dynamic forecasts at horizon h. Summing these growth forecasts and adding back the trend gives the cumulative expected log change $\mathbb{E}_T\left[Y_{T+j} - Y_T\right] = \sum_{h=1}^{j} \mathbb{E}_T \tilde{\Delta} Y_{T+h} + \begin{pmatrix}0.01 & 0.01 & 0\end{pmatrix}' \times j/12$. We keep the $12, 24, 36, \ldots, 180$ month-ahead forecasts. We average these forecasts across months in the calendar year to obtain forecasts at annual frequency. Figure F.2 displays the forecasts for one-year house price and rent growth over the next year, three years ahead, and ten years ahead. Notably, short-run house price expectations are much more volatile than rent expectations but dissipate quite rapidly. The one-year forecasts reflect BVAR expectations of short-run momentum in house prices, with higher expected growth near the peak of the early 2000s housing boom in 2004-06, the start of the housing rebound in 2013-14, and the COVID boom in 2021, and expectations of negative growth during the 2007-12 housing bust.

Figure F.1: House Price and Rent BVAR Forecasts

(a) House Prices



(b) Rents



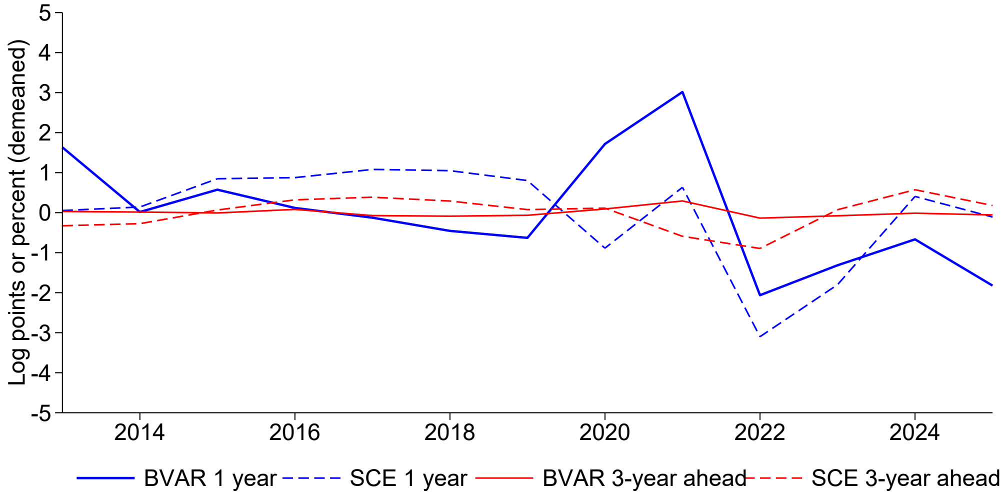
Notes: the figure shows the BVAR forecasts of log point changes in real house prices and rents at the horizons indicated, inclusive of trend growth.

Panel (a) of Figure F.2 compares the BVAR forecasts of log point changes in real house prices over the next year and three years ahead to forecasts at the same horizons in the Federal Reserve Bank of New York Survey of Consumer Expectations (SCE).[4] For expositional clarity, we demean each series over the overlapping sample of 2013-2025. Three main features stand out. First, in both the BVAR and the SCE, the three-year ahead forecast is substantially attenuated relative to the one-year forecast. The Bayesian shrinkage of the VAR coefficients is crucial to achieving this attenuation; in fact, without the Bayesian shrinkage in a few months T the VAR coefficients would not satisfy the stability criterion and hence imply wild long-run forecasts. Second, the BVAR and SCE 1-year forecasts have similar time series patterns. Both of these features provide some external validation to the BVAR. The main exception to the time series overlap is 2020, when the BVAR forecast rises and the SCE forecast falls. Given the complicated within-year timing in 2020 and the fact that the BVAR does not know about COVID, we find this miss excusable.

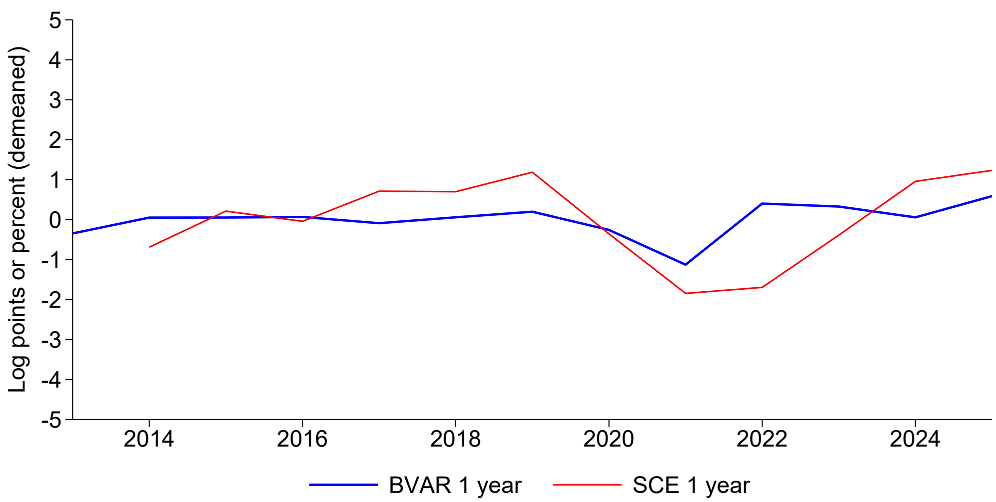
[4]The SCE forecast lines are the median of the SCE main module house price point forecasts at each horizon less the median of the SCE inflation forecast at the same horizon, averaged across calendar months in the year.

Figure F.2: BVAR Forecasts Versus SCE

(a) House Prices



(b) Rents



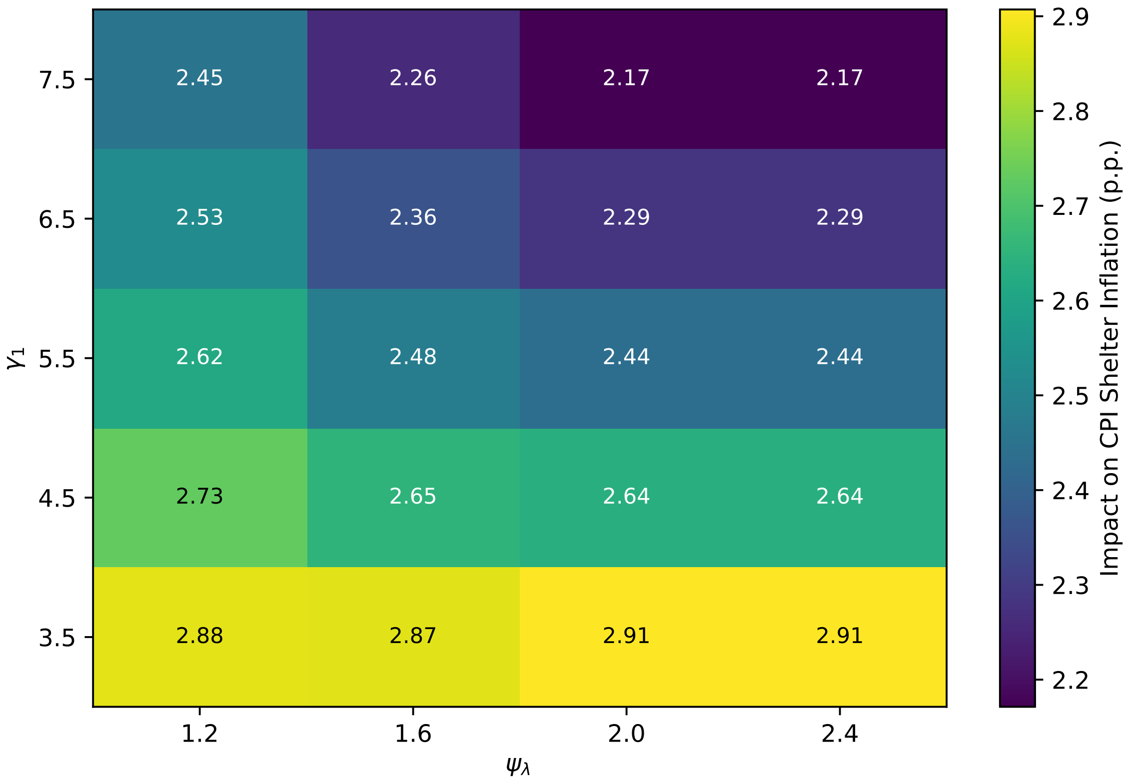
Notes: panel (a) compares the BVAR forecasts of log point changes in real house prices at the one and three-year horizons (not cumulative) to forecasts at the same horizons in the Federal Reserve Bank of New York Survey of Consumer Expectations. Panel (b) compares the forecasts of one year changes in real rent (the SCE does not contain rent forecasts at the three-year horizon.

Third, the one-year forecasts have different means over the overlapping sample period, with the sample average forecast from the BVAR above the one-year forecast from the SCE. This difference could reflect different non-housing price deflators (non-shelter CPI in the BVAR, unspecified in the SCE), the tendency of households to over-estimate general price inflation and hence under-estimate real house price growth, or some other factor. Panel (b) repeats the exercise for rents.[5].

We make two final comments. First, the rolling estimation implies that the forecasts use only data available in real-time (with the caveat that we use the published versions of the data as

[5]The SCE housing module obtains rent forecasts at the one and five year horizons. Since the overall inflation forecasts pertain only to the one and three year horizons, Panel (b) only reports one year horizon forecasts

Figure G.1: Sensitivity of Horizon 0 of IRF to 2p.p. Mortgage Rate Shock

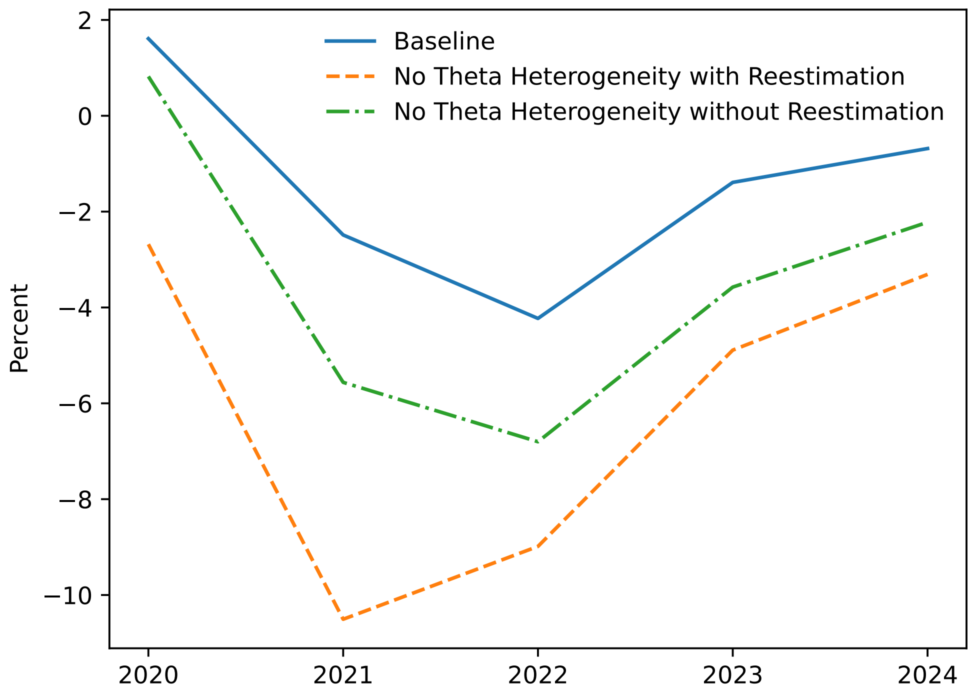


Notes: The figure shows the horizon 0 price index change under alternative parameterizations of the cost of not moving given a nudge, ψ_λ, and the slope of the supply curve, γ_1. The value for $\psi_\lambda = 1.2, \gamma_1 = 5.5$ reproduces the baseline price index change shown in Figure 9.

of August 2025 and not the real-time releases). Second, the estimation in first differences does not constrain the levels of house prices, rents, and mortgage rates to obey any cointegrating relationships. Given the large swings in the price-rent ratio during our sample and the ongoing debate over its origins, we view this flexibility as a virtue.

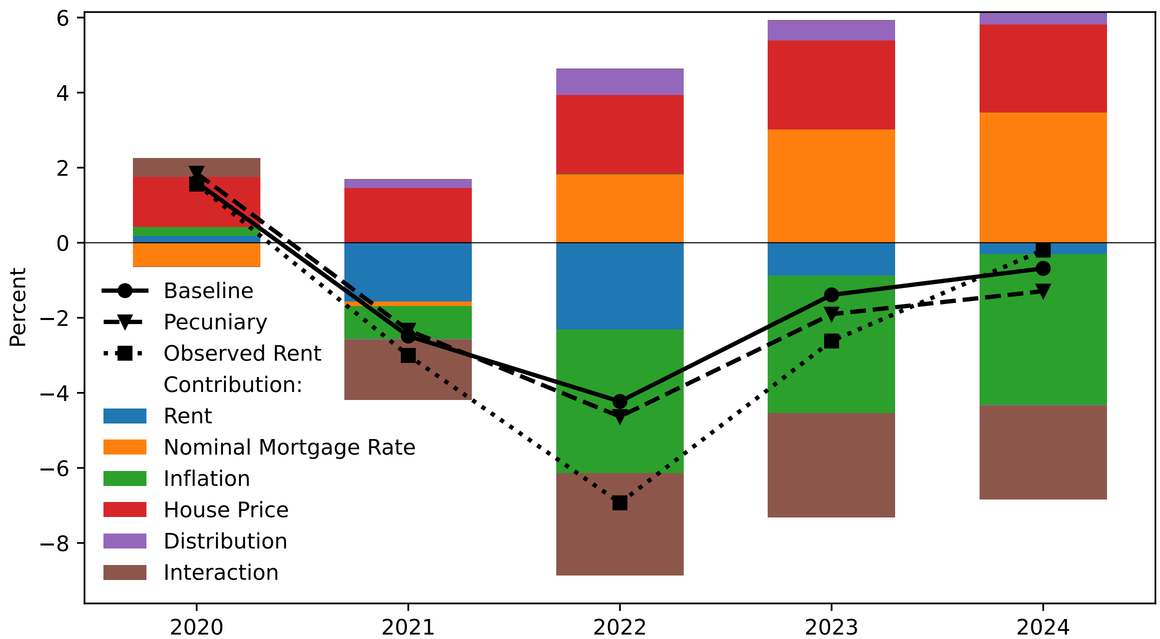
G Additional Results

Figure G.2: Historical Price Index without Variation in θ



Notes: The figure shows the baseline welfare price index, the index when θ has a degenerate distribution and other parameters remain at their baseline values, and the index when θ has a degenerate distribution and the other parameters are re-estimated to match all targeted moments except $\mathbb{E}_\Theta[\theta|\mathcal{H} = 1] - \mathbb{E}_\Theta[\theta|\mathcal{H} = 0]$ in Table 3. The indexes are plotted relative to non-shelter CPI and de-trended by real rent growth of 1% per year.

Figure G.3: Historical Shelter Inflation and its Components



Notes: The figure shows the overall welfare price index, BLS rent, and contributions to the overall price index. The indexes and each component are plotted relative to non-shelter CPI and de-trended by real rent growth of 1% per year. The contributions labeled House Price, Nominal Mortgage Rate, Rent, and Inflation display the price index with only the realized and expected deviations of each variable one-at-a-time. The contribution labeled Distribution shows the effect on welfare at date t that arises because the $t-1$ distribution of owners and renters differs due to the residual demand shocks. The contribution labeled Interaction arises due to non-linear interactions.