Long- and Short-run Effects of Interest Rates on Builders and the Housing Market*

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Abstract

This paper analyzes the effects of real interest rates on homebuilders and the housing market under fixed-rate mortgages (FRM), both in long-run equilibrium and during transitional dynamics, and finds that the endogenous supply-side response to interest rate increases mitigates short-run housing price declines. I develop a heterogeneous agent model incorporating different mortgage structures, liquid assets, lumpy housing adjustment, and a construction sector with time-to-build constraints to decompose the effects of interest rates on housing prices. The findings demonstrate that in a long-run stationary equilibrium, heterogeneous household policy functions and the corresponding stationary distribution influence housing demand, while increased interest rates consistently suppress construction activity. The calibrated model demonstrates that when the interest rate temporarily increases from 0.618% to 6%, it results in short-run housing prices exceeding those in a counterfactual without endogenous supply by 5 to 7 percentage points of the stationary price. Adjustable-rate mortgages reduce short-run housing prices by 1 percentage point of the stationary price relative to fixed-rate mortgages. The builder's financial constraint has limited impact on housing prices since a temporary increase in interest rates lowers optimal construction levels, resulting in a looser financial constraint.

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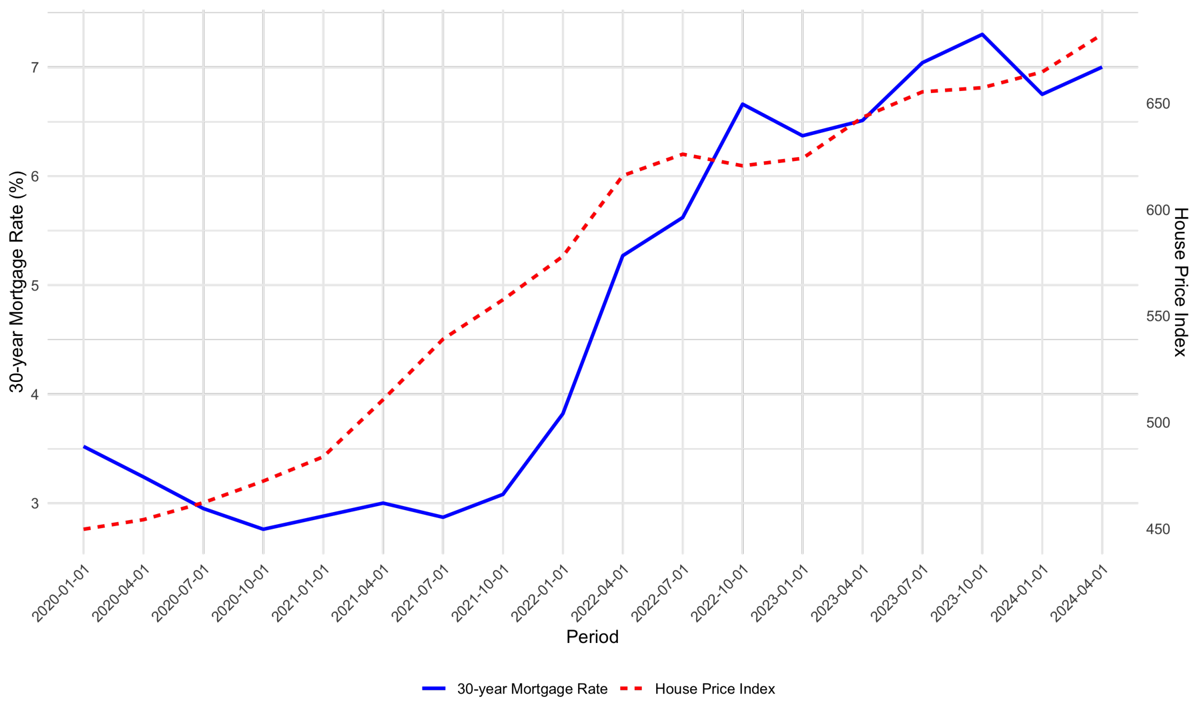
1 Introduction

After 2022, we have witnessed a surge in both housing prices and mortgage rates. Figure 1 depicts a sharp increase in 30-year mortgage rates alongside steadily rising house prices. This raises an important policy question about the effects of interest rates on housing prices. Surprisingly, existing literature struggles to provide an explanation for this co-movement, particularly as theoretical frameworks often predict a negative relationship between interest rates and house prices due to declining demand caused by rising mortgage costs. This puzzling pattern motivates a deeper exploration of the housing market dynamics and the channels through which real interest rates affect housing prices.



Note: This figure displays the time series of the average 30-year fixed mortgage rate with the blue real line (left y-axis) and the all-transaction house price index with the red dash line (right y-axis) from Q1 2020 to Q2 2024 in the U.S. Source: FRED.

Figure 1: 30-year Mortgage Rate and Housing Price Index (Q1 2020-Q2 2024)

How do real interest rate changes impact the housing market and real house prices in both the short run and long run? This paper addresses this central research question with a particular emphasis on the supply side–builders, a sector often underexplored in the literature. Figure 2 shows that the housing permits and the housing starts growth rates are negatively correlated with the real interest rate during the past 2 decades, with correlation coefficients -0.457 and -0.421 respectively . This implies that new construction investment from builders is very interest rate sensitive. In addition, a weak correlation between housing completion and the real interest rate is displayed in figure E1, implying that construction takes time to build (TtB). The evidence motivates me to consider the builder channel subject to time to build in a rich model of the incomplete market and heterogeneous households to investigate the effects of interest rates on housing prices and the housing market.

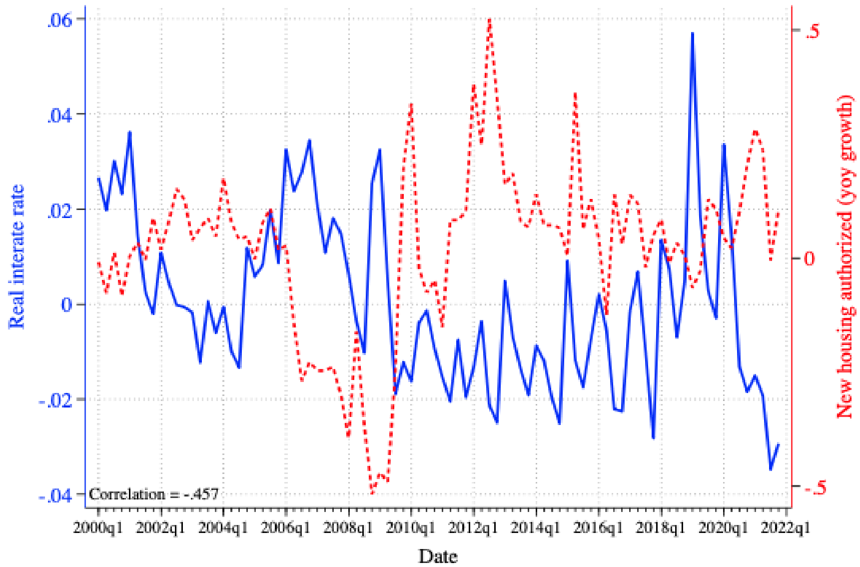
Recent discussions emphasize the lock-in effect as the primary channel of higher housing prices. Lock-in effect refers to the fact that when interest rates increase, homeowners with low mortgage rates are disincentivized to sell or move under a fixed-rate mortgage (FRM) structure.[1] This argument suggests that the lock-in effect reduces the quantity of existing home supply, leading to rising housing prices. However, this channel primarily affects housing quantity rather than price.

Why does the lock-in effect not adequately explain higher housing prices? In the housing market, there are three key agents: new buyers, homeowners, and builders. The total housing supply consists of listed existing houses from homeowners and new construction from builders. The total housing demand consists of demand from new home buyers and existing homeowners. The lock-in effect suggests that higher prices arise when the housing supply from existing homeowners decreases. That is, there is an inward shift in supply. However, this reasoning overlooks the fact that existing homeowners are not only suppliers of used houses but also demanders of houses. When homeowners do not list their houses, there is a simultaneous reduction in housing demand. Therefore, there is an inward shift in demand. The resulting pattern is clear: the quantity of houses decreases, while the price response remains minimal.

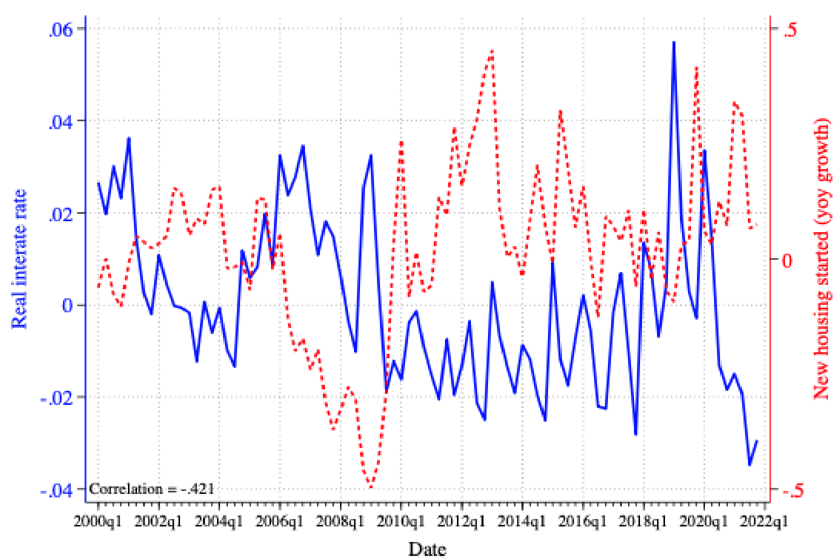
The main contribution of this paper is to develop a more general model that incorporates builders subject to time-to-build constraints and a detailed mortgage structure. Simultaneously, the model preserves key features such as household heterogeneity and incomplete markets. Subsequently, I calibrate the model and quantitatively decompose the channels through which the economy responds to changes in interest rates.

This model features overlapping-generation builders subject to time to build, financial constraint of construction loans against partial value of construction projects, and equity-issuance costs. Builders decide construction loans, dividends, construction inputs, and the amount of new construction. I show that the interest rate deters the new construction due to time-to-build constraints. Thus, a higher interest rate always decreases new housing supply. The model also incorporates heterogeneous households facing idiosyncratic income shocks and choosing consumption and housing subject to financial constraints and adjustment costs. The financial constraints take the form of mortgage borrowing limits, which

[1]Another mortgage structure is the adjustable-rate mortgage (ARM). The mortgage payments vary with the current interest rate.



(a) Housing Permits and Real Interest Rate



(b) Housing Starts and Real Interest Rate

Note: This figure displays the quarterly time series of 1-year real interest rate with the blue solid line (left y-axis) and builder's construction investment growth rate with the red dashed line (right y-axis) from Q1 2000 to Q1 2022 in the U.S. Specifically, the red dashed line in the top panel reports the new housing permits year-over-year growth rate. The red dashed line in the bottom panel reports the new housing starts year-over-year growth rate. The correlation coefficient of real interest rates and housing permits year-over-year growth rate is -0.457. The correlation coefficient of real interest rates and housing starts year-over-year growth rate is -0.421.

Figure 2: Real Interest Rate and Housing Permit and Starts Growth (Q1 2000-Q1 2022)

are pledged against the residual future value of housing. I demonstrate that interest rate changes not only discourage housing purchases through the mortgage cost channel but can also increase housing demand from high-saving households. Furthermore, beyond influencing heterogeneous housing choices, interest rates affect the distribution of households, which determines the dominant type of household response. There are overlapping-generation rental companies that pin down the rental rate by Jorgenson user cost formula. In equilibrium, the housing price clears the housing market while taking an exogenous interest rate.

After calibrating the model to match key moments in the U.S. economy, I conduct a quantitative analysis of a temporary interest-rate increase and decompose effects through various channels in the short run. First, homebuilders' response to rising interest rates causes housing prices to either decrease by a smaller magnitude or increase compared to the counterfactual with fixed housing supply in the short run, primarily due to time-to-build constraints. Second, the decomposition reveals that rising interest rates (from 0.618% to 6%) contribute a $5-7\%$ of the initial price level increase to housing prices compared to those in the counterfactual with fixed housing supply in the short run. Third, the mortgage structure plays a significant role: compared to fixed-rate mortgages (FRMs), adjustable-rate mortgages (ARMs) reduce housing prices by approximately 1% of the initial price level while simultaneously decreasing the proportion of homeowners who maintain ownership (stayers) and reducing the overall homeownership rate in the short run. Finally, financial constraints on builders have limited effects on housing prices during periods of rising interest rates, as builders respond by optimally decreasing construction levels, which in turn relaxes their financial constraints.

The rest of the paper is organized as follows. Section 2 discusses the related literature. Section 3 describes a model that features builders, heterogeneous households, and rental companies to illustrate interest rate mechanisms in the housing market. Section 4 calibrates the model and analyzes mechanisms in the stationary equilibrium. Section 5 analyzes the transitional dynamics in economies with builders, without builders, with ARM structure, and with builder's financial constraint respectively. Section 6 is the conclusion.

2 Related Literature

This paper mainly contributes to two branches of literature. First, this paper contributes to literature investigating the interest rate driver of housing prices. The other is related to literature on housing supply and builder behavior.

Drivers of house prices. A large literature studies the effects of aggregate interest rate shocks and interest rate changes on housing prices (Kiyotaki et al., 2011; Sommer et al., 2013; Hacamo, 2021; Greenwald, 2018; Del Negro and Otrok, 2007; Favilukis et al., 2017). This literature emphasizes the effects on the household side. These studies mainly predict a higher interest rate leading to a lower housing price because housing demand is suppressed from a higher mortgage cost and a higher alternative investment rate of return. In addition, they do not consider the effects on the supply side, specifically builders. Besides interest rate shocks, studies suggest that the housing price is affected by expectation shocks (Garriga et al., 2019; Kaplan et al., 2020), credit supply (Justiniano et al., 2019), and collateral constraints (Landvoigt et al., 2015; Garriga and Hedlund, 2020). This paper contributes to this strand of literature by investigating interest rate effects in the long run and in the short run under ARMs and FRMs with the new construction margin.

Housing supply and builders. There is a strand of literature discussing housing supply and builders' behavior. Some literature measures the elasticity of housing supply (Saiz, 2010; Aastveit et al., 2023; Baum-Snow and Han, 2024; Green et al., 2005). With respect to builders' decisions, Murphy (2018) estimates the price function and the cost structure of builders and determines the dynamic discrete choice of builders to build or delay construction on a lot. Van Straelen (2024) shows that public homebuilders cut prices for a fire sale in one market when they face a negative price shock in other markets. Oh and Yoon (2020) shows that the uncertainty during construction would delay the timing of an incomplete house when it takes time to build. However, the rich household side is abstracted in this literature. This paper contributes to the literature on housing supply and builders by considering builders' time-to-build constraints and shows how this friction affects builders' response to changes in interest rates with a sophisticated household side. That is, this paper provides a more general framework with rich properties of the household side and the builder side to decompose the effects of interest rates on the housing market.

3 Model

I now describe a model of household housing decisions subject to distinct terms for savings and mortgages and builders' construction investment subject to time-to-build constraints. The model provides a generalized framework to analyze the effects of interest-rate changes on the housing market, explicitly considering builders' decisions while preserving rich features of household behavior. The key feature of this model is the interaction between mortgage structures and interest rates and their effects on housing price dynamics. Specifically, higher interest rates act as a disincentive for new construction, which is the main driver of short-term fluctuations in housing prices.

The economy is populated by a measure-one continuum of long-lived heterogeneous households, overlapping-generation builders, and rental companies. Households face idiosyncratic income shocks and consume non-durable goods. They gain housing service flow either from buying houses subject to a mortgage borrowing constraint or from renting. Homeowners may either stay in their current houses by making minimum mortgage repayments or sell their properties while incurring adjustment costs. Households also have access to liquid savings, which, alongside mortgages, feature distinct terms but share the same exogenously determined interest rate. Overlapping-generation builders invest in new construction subject to time-to-build constraints and financial constraints of external and internal funds. Builders are the sole providers of new housing stock. Overlapping-generation rental companies purchase housing units and lease them to households. The housing price is endogenously determined through the housing-market clearing condition, while rental prices are set according to the Jorgensonian user cost.

This paper builds upon the foundational framework established by Kaplan et al. (2020). Similar to Kaplan et al. (2020), this model is composed of three main sectors: households, builders, and rental companies. These sectors collectively enable the model to capture the interplay between housing supply and demand under varying interest rates. However, unlike Kaplan et al. (2020), this model is simplified by abstracting from financial intermediaries, from aggregate shocks, and from explicit default options, and it focuses on steady-state behaviors rather than life-cycle patterns.

This model differs from Kaplan et al. (2020) in several aspects. First, it incorporates a fixed-rate mortgage (FRM) structure, allowing households to lock in their existing mortgage rates and mitigate exposure to fluctuating interest rates. Second, a continuous renting choice enables households to choose an arbitrary size of their rental units, beyond certain discrete choices. Third, the model explicitly examines builders' responses to interest-rate changes, emphasizing the impact of the time-to-build property on construction decisions. These innovations enhance the model's ability to capture the nuanced interactions between builders' investment strategies, household behavior, and interest rate policies, which generates subtle housing price dynamics. By integrating these features, the model provides a more comprehensive framework for analyzing the broader implications of interest-rate policy on the housing market.

3.1 Environment

Time is discrete with an infinite horizon. There are long-lived households, overlapping-generation builders, and overlapping-generation rental companies in the economy. The gross interest rate $R = 1 + r$ is exogenous. It applies to the mortgage rate, the liquid saving rate, and the builders' discount factor. For simplicity, there is no unsecured borrowing and no default option. I assume that there are zero-profit foreign banks taking deposits and lending to households and builders under the exogenous interest rate.[2] In a stationary equilibrium, the interest rate is constant. However, during transitional dynamics, the interest rate changes with an MIT-shock flavor; i.e., before any change is realized, sectors in the economy do not have any prior information and will perceive the new interest-rate path immediately when the change is realized. In this section, I consider the stationary equilibrium of a stochastic overlapping generations model of builders with time-to-build constraints. All price variables are constant.

3.2 Builders

I now describe the builder's problem. In each period, a measure $\rho \in (0, 1]$ continuum of overlapping-generation builders are born, and a measure ρ of existing builders exit the economy after completing and selling houses. Builders are risk neutral, and their objective is to maximize the net present value of dividends.

Technology. Each builder adopts a construction technology $h_s = \min\{\ell, f(x)\}$, where $f' > 0, f'' < 0, \lim_{x\to 0} f(x) = \infty, \lim_{x\to\infty} f(x) = 0$. Builders build houses h_s with land ℓ and factor x.[3] Houses take time to build–builders buy inputs in the current period to build and sell h_s in the next period.[4] The land price p_ℓ and the factor price p_x are exogenous.

Financial Frictions. New builders are endowed with an initial net worth w. Builders can finance with short-term construction loans b, which are external funds, at an exogenous interest rate R. Due to limited enforcement for lenders to continue an incomplete project, builders pledge up to a fraction $\theta_b \in (0, 1)$ of their future home sales to finance through construction loans. Builders can also raise internal funds subject to a convex equity issuance cost $\phi(-d)$, for $d < 0$, and zero otherwise, where d is builders' dividends.[5] A negative dividend implies equity issuance with cost $\phi(-d)$.[6]

Builders' problem. Given initial net worth w, builders maximize the present value of their dividends deducting equity issuance costs by choosing dividends d, construction loan

[2]This assumption avoids a banking problem or the credit market clearing condition. It treats the financial intermediary as a shadow sector.

[3]Unlike Cobb-Douglas housing production function in the literature, e.g., Kaplan et al. (2020), the Leontief production function aims to highlight the specialty of land in housing production. It is simple to decompose the housing value into land value and others.

[4]Note that houses take time to build. If we bring the time index back, the new construction is $h_s(t+1) = \min\{\ell(t), f(x(t))\}$ and is sold under future price $p_h(t+1)$.

[5]Convex equity issuance cost means $\phi_d > 0$ and $\phi_{dd} > 0$.

[6]This equity issuance cost follows the setting in Lanteri and Rampini (2023a).

b, land input ℓ, factor x, and new construction h_s to solve

$$V_s(w) = \max_{\{d,\ell,x,h_s,b,w'\}} d - \phi(-d) + R^{-1}\{\rho w' + (1-\rho)V_s(w')\} \tag{1}$$

subject to current budget constraint

$$d + p_\ell \ell + p_x x \leq w + b, \tag{2}$$

net worth evolution

$$w' = p_h h_s - Rb, \tag{3}$$

the financial constraint

$$Rb \leq \theta_b p_h h_s \tag{4}$$

and the construction technology

$$h_s = \min\{\ell, f(x)\}. \tag{5}$$

At the optimum, builders choose land and the amount of factor such that $\ell = f(x)$. We can substitute h_s and ℓ with $f(x)$ to solve the problem. For tractability, I assume $\rho = 1$, which implies that builders exist for 2 periods and will exit after selling their houses.[7] The complete optimality conditions of builders are characterized in Appendix A.

The time-to-build flavor is represented in (2) and (3); i.e., the production cost is incurred in the current period, while the sales revenue is collected as an element of future net worth. A key property of time-to-build is that revenue is always discounted, regardless of whether the builder is constrained or unconstrained. Using $R^{-1}\lambda'$ as the multiplier of the financial constraint, the optimality condition of the new construction for unconstrained builders is

$$p_h = R\left(p_\ell + \frac{p_x}{f'(x)}\right). \tag{6}$$

Because of time-to-build, the price is the future value of the marginal cost. For an unconstrained builder, $\lambda' = 0$ implies that the borrowing constraint is slack, and equity is never issued. The interest rate affects the optimal construction investment through the

[7]With this assumption, it is easy to extend to heterogeneous builders. We can assume that the initial wealth follows an exogenous distribution $G(w)$. Tracking evolution of the endogenous net worth distribution is not necessary since only the exogenous distribution $G(w)$ matters.

time-to-build property instead of the financing cost. Given the housing price, the first-best construction investment is fixed for all builders. This implies that builders are indifferent between issuing current dividends and saving for future net worth once they achieve the optimal construction investment level. The optimality condition of the new construction for a constrained builder is

$$p_h = R\left(p_\ell + \frac{p_x}{f'(x)}\right)\frac{1+\lambda'}{1+\theta_b\lambda'}. \tag{7}$$

Note that $\lambda' = \phi_d$ in equilibrium. That is, a constrained builder always issues equity, while an unconstrained builder relies solely on construction loans or issues dividends.

3.3 Households

There are long-lived heterogeneous households with a continuum of measure 1 in the economy. They gain utility from consuming non-durable goods and housing services. For housing choices, they can choose to move, stay, or rent. They can borrow through long-term mortgage borrowing and save in liquid assets. There is no unsecured borrowing and no default option by households.

Preference. Households maximize lifetime utility from consumption c and housing service flow h_f. The per-period utility is $U(c, h_f)$, where $U_c > 0$, $U_h > 0$, $U_{cc} < 0$, $U_{hh} < 0$ and $U_{ch} > 0$. The homeowner enjoys owner-occupied housing service flow, while the renter receives reduced utility from the rental unit by factor $\xi \in (0, 1)$. Specifically, a household with h_o units of owner-occupied houses implies $h_f = h_o$, while a household with h_r units of rental houses implies $h_f = \xi h_r$. Future utility is discounted at rate $\beta \in (0, 1)$.

Income. Households receive exogenous idiosyncratic income y_i every period. This is the only uncertainty in the economy. It follows a first-order Markov process, which is modeled as an AR(1) process with persistence ρ_y and volatility σ_y:

$$\log(y_i') = \rho_y \log(y_i) + \sigma_y \epsilon_i', \tag{8}$$

where ϵ_i is drawn from a standard normal distribution. Income good is the numeraire.

Liquid Asset. Households can save in liquid assets, a, with rate of return r. The liquid asset is a one-period asset. Saving in one unit of the liquid asset will earn the saver R units of goods in the next period. We do not allow for negative a, which means that unsecured borrowing is unavailable.

Housing. Households gain housing service flow via owning or renting houses. Similar to Kaplan et al. (2020), homeowners select an owner-occupied housing unit from a finite set

$\mathrm{H} = \{h^1, h^2, h^3, ..., h^N\}$, where $h^1 < h^2 < ... < h^N$. When a household moves to a new house, they move to housing unit $h' \in \mathrm{H}$. However, renters can rent an arbitrary size of rental units $h_{rent} > 0$.[8] That is, a household deciding to be a homeowner chooses $h' > 0$ and $h_{rent} = 0$, while a household deciding to be a renter chooses $h' = 0$ and $h_{rent} > 0$. There is no friction in purchasing and renting houses. The housing price is denoted as p_h, and the rental rate is denoted as r_h. Households can purchase or rent houses at competitive prices without any time lag.

If a homeowner currently owns h units of houses, these houses depreciate with rate $\delta_h \in (0, 1)$ every period. Let i_h denote the subjective change in housing units if the homeowner moves. A housing transaction costs the existing home seller a proportional adjustment cost $FC_h(p_h h) = \kappa_h(1 - \delta_h)p_h h$ if $i_h \neq 0$. Therefore, the owner-occupied house evolves as

$$h' = (1 - \delta_h)h + i_h. \tag{9}$$

The household pays the adjustment costs and the value gap between existing and new houses $p_h(\kappa_h(1 - \delta_h)h + i_h)$ when moving to a new house.[9]

Mortgage. A homeowner can borrow long-term mortgages with a D-period maturity by pledging up to $\theta_h \in (0, 1)$ of their future undepreciated housing value. The collateral constraint is

$$Rm' \leq \theta_h(1 - \delta_h)p_h h'. \tag{10}$$

This collateral constraint only needs to be satisfied at origination since the mortgage is long-term.[10] Note that p_h in (10) refers to the housing price in the future. It equals the current housing price because we focus on the stationary equilibrium. After origination, the household with mortgage balance m is required to repay the minimum amount $r_m = \frac{r}{1-(1+r)^{-D}}$ based on amortization. If the homeowner does not move, they need to repay the minimum required payment. The mortgage balance evolves as

$$m' \leq (R - r_m)m. \tag{11}$$

The household is free to repay more to decrease the amount of rolling-over principal. If the household chooses to move, they must pay off the entire mortgage balance and can borrow

[8] In Kaplan et al. (2020), renters can only rent from a finite set of rental units.

[9] I assume that $i_h \neq 0$ implies moving to another house. The household has to pay off the mortgage attached to the old house.

[10] The literature often assumes a positive spread between the mortgage rate and the risk-free rate, such as Kaplan et al. (2020) and Fonseca et al. (2024). Here we do not have any micro-foundation of default option or other origination costs, so we have the same mortgage rate and saving rate.

a new mortgage contract with the new house. There is no default on mortgage payments in this economy.

Household's problem. I now describe the household problem for movers, stayers, and renters. A homeowner can choose to move to a new house, stay in the existing house, or sell the existing house to rent. A renter can choose to keep renting or become a homeowner. Since a household can rent an arbitrary rental unit ($h_{rent} \geq 0$, renting is always an option for households.[11]

The state variables at the beginning of each period are $s = (m, h, a, y)$, where m is mortgage, h is housing position, a is liquid asset, and y is income. A household solves

$$V(m,h,a,y;r) = \max\{V^m(m,h,a,y;r), V^{stay}(m,h,a,y;r), V^r(m,h,a,y;r)\}, \tag{12}$$

where V^m, V^{stay} and V^r are value functions for movers, stayers and renters respectively.

The problem for movers is

$$V^m(m,h,a,y;r) = \max_{\{c,h',a',m'\}} U(c,h') + \beta \mathbb{E} V(m',h',a',y';r),$$

s.t.

$$\begin{aligned} & c + p_h[h' - (1-\delta_h)h] + FC_h(p_h h) + a' + Rm \leq y + Ra + m', \\ & Rm' \leq \theta_h (1-\delta_h) p_h h'. \end{aligned}$$

When a household moves, it needs to pay off all mortgages and choose the new housing position. Since the terms of assets and mortgages are different, it is not sufficient to track net saving solely. The reason is that if one saves and borrows 1 unit at the same time, one earns R from saving and is required to repay r_m. The difference $R - r_m$ can provide liquidity premium if one is constrained in some future states. Therefore, we need to separate the mortgage and the liquid asset as two state variables.

The problem for stayers is

$$V^{stay}(m,h,a,y;r) = \max_{\{c,a',m'\}} U(c,(1-\delta_h)h) + \beta \mathbb{E} V(m',(1-\delta_h)h,a',y';r),$$

[11] Optimally, households never choose zero housing service flow because of standard properties of the utility function. Then $h_{rent} \geq 0$ implies that a household is always able to rent when they have positive wealth.

s.t.

$$c + a' + Rm \leq y + Ra + m',$$
$$m' \leq (R - r_m)m.$$

Stayers are not involved with housing transactions. They keep their existing houses and consume the undepreciated housing service flow $(1 - \delta_h)h$, which is also the future housing state.

The problem for renters is

$$V^r(m, h, a, y; r) = \max_{\{c,a'\}} U(c, \xi h_{rent}) + \beta \mathbb{E} V(0, 0, a', y'; r),$$

s.t.

$$c + a' + Rm + FC_h(p_h h) + r_h h_{rent} \leq y + Ra + p_h(1 - \delta_h)h,$$

where $\xi \in (0, 1)$ denotes the disutility of renting. Renters do not own any houses, so their future housing and mortgage states are zeros by definition. Since the only uncertainty is the idiosyncratic shock on y, the random variable of the future value function is y', and the expectation is taken over the future income state y' conditional on current income state y.

3.4 Rental Companies

Overlapping-generation rental companies are risk-neutral. They buy houses and rent to renters in the current period, sell the undepreciated houses in the next period, and exit the economy. The discount factor for future resale value is R. Following Jorgenson (1963), the rental rate is determined by Jorgenson user-cost:

$$p_h = r_h + R^{-1}(1 - \delta_h)p'_h. \tag{13}$$

The left-hand side (LHS) refers to the cost of purchasing a house, and the right-hand side (RHS) refers to the benefits, which include rental revenue r_h and the resale value $(1 - \delta_h)p'_h$. The resale value is discounted by the interest rate. In a stationary equilibrium, housing prices are constant. We have

$$r_h = \frac{r + \delta_h}{1 + r} p_h. \tag{14}$$

3.5 Equilibrium

In equilibrium, the housing price p_h clears the housing market. Note that F is the stationary distribution over states s. The housing price p_h depends on this distribution F. The distribution evolves as

$$F_{t+1}(s_{t+1}) = \Gamma(F_t(s_t)), \tag{15}$$

where Γ is the law of motion of state variables. In a fixed housing supply economy with exogenous housing quantity $\bar{H}$, the market clearing condition is

$$\int (h'(s) + h_{rent}(s)) dF(s) = \bar{H}. \tag{16}$$

In an economy with builders, the market clearing condition is

$$\delta_h \int (h'(s) + h_{rent}(s)) dF(s) = h_s(w). \tag{17}$$

The housing demand contains owner-occupied and rental houses. In a fixed supply economy, the depreciation of houses is automatically rebuilt, while in an economy with builders, builders inject new housing flow to refill the depreciation in a stationary equilibrium.[12]

Definition 1 *A recursive competitive equilibrium of the economy with builders is a set of prices* $\{p_h, r_h\}$*, a set of value functions* $\{V, V^m, V^{stay}, V^r, V_s\}$*, a set of policy functions* $\{c, a', m', h', h_{rent}, h_s, b, d, \ell, x\}$*, a time-invariant distribution* F*, a distribution law of motion* Γ*, given the exogenous interest rate* r*, Markov process of the income, and initial net worth of builders* w*,*

1. V˙V^m, V^{stay}, V^r *satisfy household's Bellman equations, and* V_s *satisfies builder's Bellman equation.*

2. *Functions* $c(s), a'(s), m'(s), h'(s), h_{rent}(s)$ *are optimal policy functions for households given* p_h *and* r_h*.*

3. *Functions* $h_s(w), b(w), d(w), \ell(w), x(w)$ *are optimal policy functions for builders given* p_h*.*

4. p_h *and* r_h *satisfy rental companies' zero-profit conditions.*

5. p_h *clears the housing market clearing condition.*

[12]The market clearing condition for a economy with heterogeneous builders will be $\int h_s(w) dG(w)$ if builder's initial net worth is drawn from distribution $G(w)$.

6. *The law of motion Γ defines the evolution of time-invariant distribution of households' state variables, which is $F = \Gamma(F)$, according to households' policy functions and the Markov transition process of the income.*

Solving this model is computationally challenging. The main challenge is the number of state-space dimensions and the differing terms for mortgages and liquid assets. In Appendix D.1, I describe the process of the numerical solution and the methods to resolve challenges mentioned above.

I then characterize the properties of builders' problem in stationary equilibrium.

Proposition 1 *Characterization of builders' optimal strategy: Given a housing price,*

1. *there exists a net worth threshold $\bar{w}$ such that a builder is constrained if and only if $w < \bar{w}$, and a builder is unconstrained if and only if $w \geq \bar{w}$.*

2. *a higher interest rate qualitatively decreases the new construction level $h_s(w)$ for constrained and unconstrained builders.*

3. *given an interest rate, unconstrained builders build more than the construction level of constrained builders. Specifically, $h_s(w)$ is a non-decreasing function.*

Higher interest rates deter unconstrained builders' construction through a smaller present value of discounted future revenue with concave $f(x)$. Constrained builders borrow to the limit to build. A positive λ' implies a positive liquidity premium of the financial constraint relaxation. A higher interest rate directly tightens constrained builders' borrowing constraint, leading to a lower construction investment level due to fewer construction loans.

In a stationary equilibrium, the rental rate endogenously determined by the Jorgenson user cost simultaneously with an exogenous interest rate and an endogenous housing price is higher under a higher housing price p_h, a higher depreciation rate δ_h, and a higher interest rate r. The required return r_h for rental companies is higher under a higher purchasing cost p_h, a higher lost value of houses from δ_h, and a higher alternative rate of return r. This user-cost formula (13) captures the fact that the rental rate comoves with the housing price. These properties match observations in Kiyotaki et al. (2024).

4 Calibration and Quantitative Analysis

This section describes the choice of parameter values and analysis of the stationary equilibrium. Some parameters are determined based on external evidence, while others are internally calibrated to fit with key cross-sectional moments of the U.S. economy in 2022.

This was the year when the Fed raised interest rates to fight inflation.[13] The datasets I use to generate moments are mainly from the Survey of Consumer Finances (SCF) and the American Community Survey (ACS).[14] After calibrating the baseline model, I provide a quantitative analysis of the stationary equilibrium under different interest-rate regimes.

4.1 Calibration

All variables are normalized by the mean family income in SCF 2022, which is \$141.39 thousand. Table 1 reports parameter values of the model. Internal parameters are jointly calibrated to match targeted moments in the data. Targeted and non-targeted moments are shown in Table 2. A period in this model represents one year, which coincides with the length of data used to generate moments.

Preferences. The household utility function is $U(c, h_f) = \frac{\left[c^{1-\alpha}h_f^{\alpha}\right]^{1-\gamma}-1}{1-\gamma}$. I set $\gamma = 2$, which implies that elasticity of intertemporal substitution is 0.5. I internally calibrate the discount factor $\beta = 0.936$, the share of housing service in total consumption $\alpha = 0.16$, and disutility of renting $\xi = 0.85$ to normalize aggregate housing stock to 1 and match the share of owner-occupied housing 64.8% and the share of homeowners with mortgages 61.5%.

Income. The idiosyncratic income shock follows an AR(1) process in logs. I set the persistence parameter $\rho_y = 0.97$ and the standard deviation $\sigma_y = 0.2$ following Kaplan et al. (2020). In the quantitative analysis, I discretize it to a two-state Markov chain and normalize the mean of income to 1.

Interest rate. The real interest rate data are sourced from FRED and is set at 0.618%, which is calculated as the average quarterly 10-year real interest rate over the period from 2013 to 2019. This time frame spans the years between the aftermath of the Great Recession and the onset of the COVID-19 pandemic, during which the interest rate remained relatively stable.

Housing and Mortgage. The housing depreciation $\delta_h = 0.0364$ is motivated by Internal Revenue Service (IRS) Publication 946 (2023)[15], which illustrates the property depreciation method. It suggests a depreciation rate of 0.0364 for a residential rental property in table A6. The variable adjustment cost of selling houses is $FC_h(p_h h) = \kappa_h(1-\delta_h)p_h h$. Following Boar et al. (2022), I set the housing adjustment cost $\kappa_h = 0.06$, which is a common estimate of the housing transaction cost.

Based on Fonseca et al. (2024), the 95th percentiles of the mortgage loan-to-value ratio in Home Mortgage Disclosure Act is 0.9, and the spread between 30-year mortgage rate

[13]The Fed raised interest rates 11 times between March 2022 and July 2023.
[14]ACS data is from "2022: ACS 5-Year Estimates Data Profiles, DP04 Selected Housing Characteristics."
[15]Source: `https://www.irs.gov/publications/p946#en_US_2023_publink1000270861`

and Treasury yield is 2.5%. Hence, I set the loan-to-value ratio of the mortgage borrowing constraint at $\theta_h = 0.9$ and mortgage maturity at $D = 20$. This implies that the periodic payment for a 20-year mortgage with zero mortgage spread is equivalent to the periodic payment for a 30-year mortgage with 2.5% mortgage spread when the interest rate is 0.618%.

Builder. The production factor x is assumed to be labor, so the cost of labor is set at the mean income, which is normalized to $p_x = 1$. Sourced from updated land value dataset from Davis et al. (2021), the standardized $\frac{1}{4}$ acre land value is $215,700$.[16] The land price is normalized to $p_\ell = 1.5256$. Following Kaplan et al. (2020), I set the return to scale of the construction labor at $\alpha_h = 0.6$. The TFP of builders $A_h = 0.2563$ is calibrated to match the housing price. The equity-issuance cost and the builder's loan-to-value ratio θ_b are not reported here. I focus on the unconstrained builder for the baseline analysis, so the equity-issuance cost and builders' loan-to-value ratio do not provide any information on matching moments.[17] The effect of the financial constraint is discussed in section 5.4.

Table 1: Baseline Parameter Values

Parameter	Description	Value	Target/Source
	External		
γ	Risk aversion	2	Kaplan et al. (2020)
δ_h	Depreciation rate of house	0.036	IRS
κ_h	Housing variable adjustment cost	0.06	Boar et al. (2022)
θ_h	Mortgage loan-to-value ratio	0.9	HMDA (Fonseca et al., 2024)
D	Mortgage maturity	20	30-y 2.5% mortgage spread
ρ_y	Autocorrelation of endowment	0.97	Kaplan et al. (2020)
σ_y	Standard deviation of endowment shock	0.2	Kaplan et al. (2020)
r	Real interest rate	0.618%	Avg 10-year real rate
α_h	RTS of construction labor	0.6	Kaplan et al. (2020)
p_ℓ	Land price	1.526	FHFA
p_x	Cost of labor	1	Normalized
	Internal		
β	Discount factor	0.936	
α	Share of housing service in total consumption	0.164	
ξ	Disutility of renting	0.85	
A_h	TFP of builders	0.256	

Note: The table reports the externally and internally calibrated parameter values used in the quantitative analysis.

In table 2, the model matches the targeted moments well. The model-implied and data-generated new construction sales shares are not consistent. This discrepancy can be addressed by introducing moving shocks to create existing-home sales (Fonseca and Liu, 2024). Since the transactions of existing homes are not the primary drivers of housing price dynamics, I focus on the effects of interest-rate changes and abstract from the moving shock.

[16]Source of the dataset: `https://www.fhfa.gov/research/papers/wp1901`.

[17]This can be achieved by assuming an extremely large initial net worth, such as $w = 10^{100}$.

Table 2: Targeted and Non-targeted Moment

Targeted Moment	Data	Model
Avg house price/Avg income (SCF)	3.332	3.332
Share of owner-occupied housing (ACS)	64.8%	64.8%
Share of owners with mortgages (ACS)	61.5%	61.5%
Avg residential housing stock (Normalized)	1	1.01
Non-targeted Moment		
Avg wealth for homeowners to renters (SCF)	9.94	10.997
Avg housing debt for homeowners (SCF)	3.57	3.81
Avg income for homeowners to renters (SCF)	2.47	3.43
Avg wealth (SCF)	7.49	4.64
New construction sales share (AEI-Zillow)	12.9%	31.4%

Note: The table reports the targeted moments used in calibration and non-targeted moments for model validation.

4.2 Long-run Stationary Equilibrium Analysis

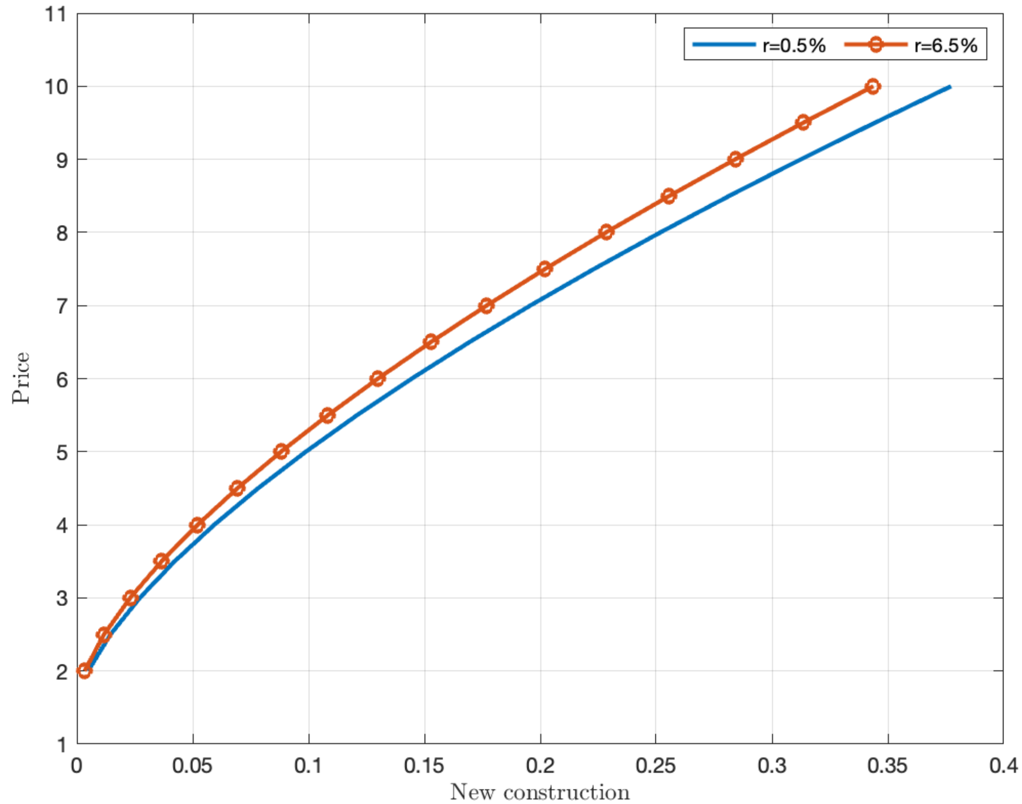
This subsection elaborates the effects of interest rate on the housing demand and supply in a stationary equilibrium and shows the numerical results given the calibration in the previous section. In the literature, declining interest rates fuel the housing demand and housing prices via a looser mortgage constraint (Kiyotaki et al., 2011; Sommer et al., 2013; Geng, 2018). The mortgage effect governs how households respond to the interest-rate change. With respect to the housing supply, interest rates do not affect construction strategies since builders are solving a static problem (Kaplan et al., 2020). Unlike the literature, interest rates have richer effects on the housing demand side and affect builders' construction investment because of time to build in this model. All these effects jointly pin down how interest rates affect the stationary equilibrium.[18]

Housing Supply. Figure 3 shows the new construction level for unconstrained builders. The effect of interest rates on construction operates through the time-to-build channel, as builders are unconstrained. Lower interest rates lead to higher new housing stock injection. Without time-to-build frictions, unconstrained builders' optimal construction investment remains constant across interest rates. Time-to-build frictions create a key distinction: with these frictions, future housing prices determine current construction decisions, while without them, current prices drive construction strategy. While this distinction affects transitional dynamics, it becomes irrelevant in the stationary equilibrium where housing prices are constant.

While the magnitude of new construction appears modest, its economic impact is more

[18] Appendix B shows that homogeneous households cannot obtain rich housing demand properties described above. This is a reason for modeling household heterogeneity.

substantial when considering net housing transactions (excluding offsetting sales and purchases by existing homeowners). Moreover, new construction accumulates into the housing stock over time, extending beyond the current period. The immediate response of builders to interest rate changes makes new construction particularly important for short-run housing market dynamics following interest rate shocks.



Note: This figure shows the new housing supply curves across interest rate regimes. Specifically, the blue solid line depicts builder's construction level under different housing prices when $r = 0.5\%$. The orange line with circle depicts builder's construction level under different housing prices when $r = 6.5\%$.

Figure 3: New Housing Supply Curve

Housing Demand. Figure 4 presents the aggregate housing demand across different prices and interest rates. Counter to existing literature, I find that higher interest rates do not uniformly decrease housing demand. This result stems from two forces: heterogeneous household responses and the distribution effect. The heterogeneous response reflects varying interest rate impacts across households with different mortgage-asset portfolios. High-saving households increase housing demand due to positive wealth effects from higher rates, while mortgage-dependent households reduce demand due to higher borrowing costs. This extends beyond the standard mortgage channel in the literature by incorporating positive wealth effects for high-saving households. Additionally, the distribution effect captures the changing composition of households across interest rate regimes, with a larger share of high-saving households in high-rate environments.

Figure 4 reveals that the distribution effect strengthens at higher housing prices. When housing prices are high, households find it more advantageous to accumulate wealth through liquid assets under higher interest rates, leading to greater average wealth and housing demand. Conversely, at lower housing prices, households prefer mortgage-financed home purchases, causing the mortgage effect to dominate and housing demand to rise with lower interest rates.

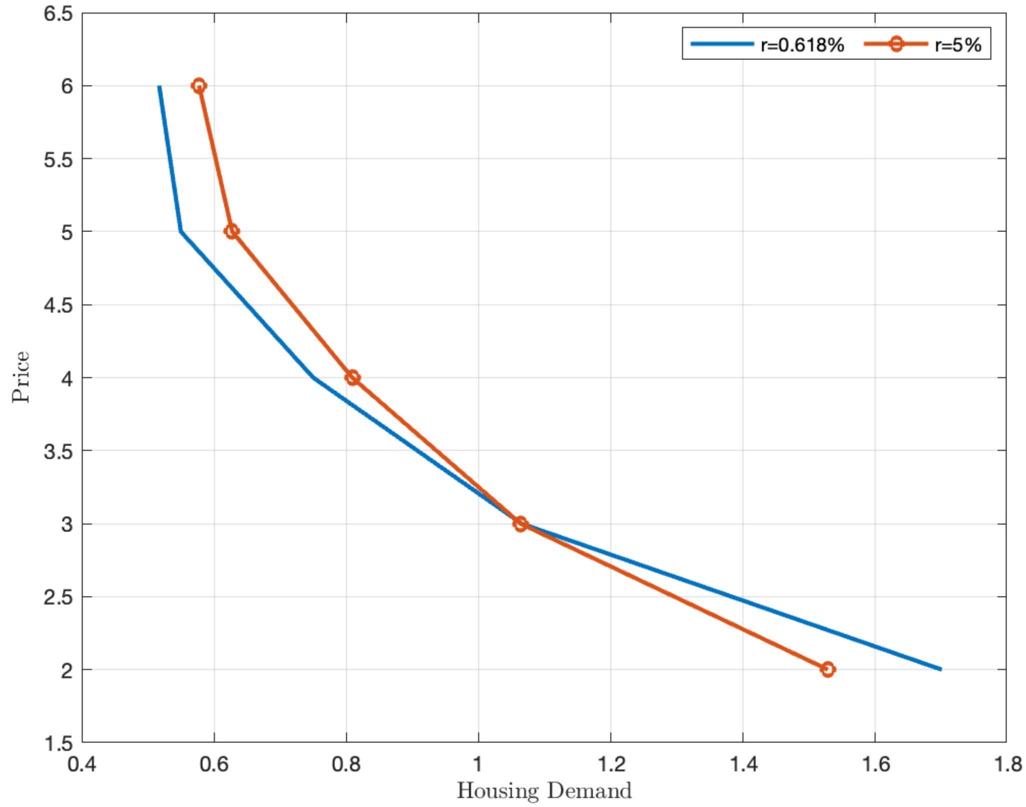
At a fixed housing price of $p_h = 3$, the equilibrium net savings differ substantially between low-rate (0.6%) and high-rate (5%) regimes, at -0.135 and 8.282 respectively, reflecting markedly different stationary distributions. Non-housing consumption also diverges, with 0.8464 in the low-rate economy versus 1.2921 in the high-rate economy. Households in the low-rate environment rely on mortgage financing and maintain lower consumption, while those in the high-rate environment accumulate savings for housing purchases and consumption. Despite similar aggregate housing stocks, household behavior and portfolio composition differ significantly between regimes.

Figure E2 and E3 decompose total housing demand into owner-occupied and rental units. From these two figures, the impact of interest rates on aggregate housing demand primarily operates through owner-occupied housing. Given a housing price, a higher interest rate decreases renters' rental housing demand for a higher rental rate implied in (13). However, interest rates also affect the renter-owner composition through the distribution effect, making the net impact on aggregate rental housing ambiguous.

Figure 5 shows the simulation of a household for 1000 periods at housing price $p_h = 3$ in a low-rate ($r = 0.618\%$) regime. The five panels of the figures are Markov chain simulation of idiosyncratic income shocks, owner-occupied housing, rental housing, liquid assets, and non-housing consumption. The results show that households purchase homes during high-income periods and downsize when hit with negative income shocks. Extended low-income periods lead to a transition to renting.

5 Transitional Dynamics–the Effects of Interest Rate Shocks

This section analyzes housing price dynamics following a temporary interest rate increase. At $t = 1$, the economy begins at the stationary equilibrium. At $t = 2$, the interest rate



Note: This figure displays household aggregate housing demand curve. Specifically, the blue solid line depicts housing demand under different housing prices when $r = 0.618\%$. The orange line with circle depicts housing demand under different housing prices when $r = 5\%$.

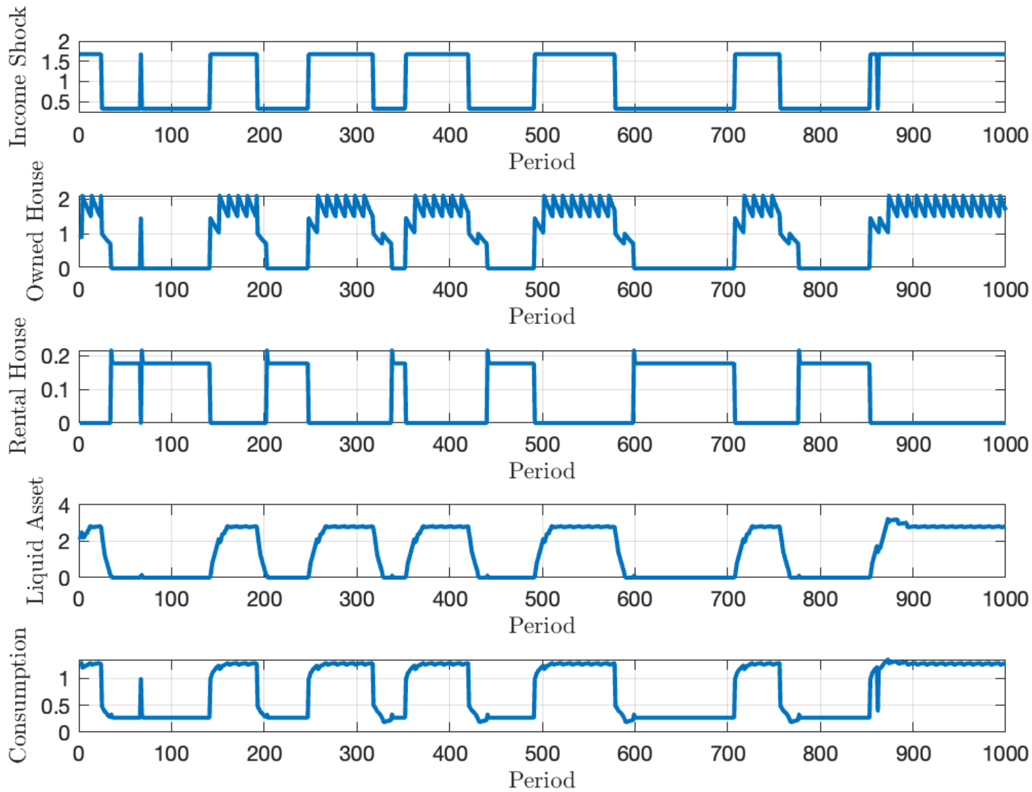
Figure 4: Aggregate Housing Demand Curve

is assumed to temporarily increase to 6% for 4 periods before returning to the baseline of 0.618%. That is, the interest rate path after $t = 2$ is

$$r_t = \begin{cases} 6\%, & \text{if} \quad 2 \leq t \leq 5 \\ 0.618\%, & \text{if} \quad \quad t \geq 6 \end{cases} .$$

This change is an MIT shock, unanticipated until $t = 2$ but fully known to all agents thereafter.[19] To be clear, the interest rate r_t at time t is the rate of return of the saving at t. The saver will receive $1+r_t$ at $t+1$. I first examine the baseline case—an FRM economy with builders—then compare it to three variants: an FRM economy without builders, an ARM economy with builders, and an FRM economy with financially constrained builders. These

[19]We can also interpret the "realization" as an expectation. Then at least the solution at the date of the realization is correct. That is, this model can replicate solution for arbitrary combination of interest-rate expectations and realizations.



Note: This figure displays simulation of an individual household for 1000 periods given housing price $p_h = 3$ and interest rate $r = 0.618\%$. The first panel plots a simulation of the idiosyncratic income shock. The second panel plots the owner-occupied housing choice h'_o. The third panel plots the rental housing choice h_{rent}. The fourth panel plots the liquid asset choice a'. The fifth panel plots the non-housing consumption choice.

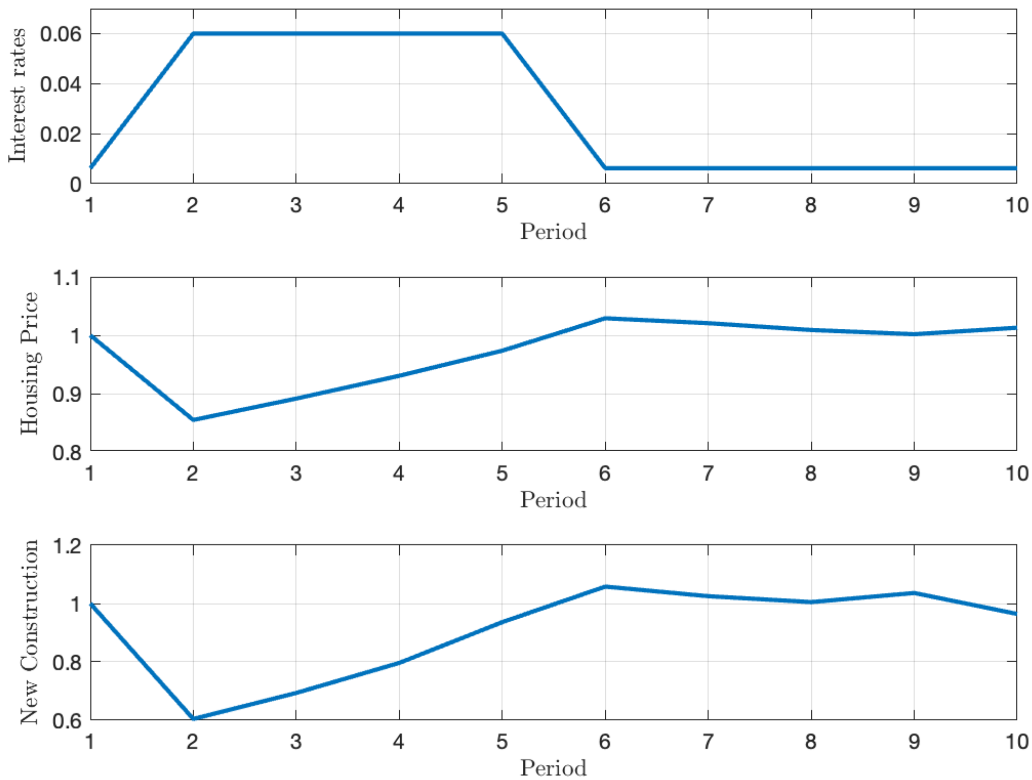
Figure 5: Individual Household Simulation under $p_h = 3$ and $r = 0.618\%$

comparisons highlight the effect of builders, mortgage structures, and builders' financial constraints, respectively. The steps of transitional dynamics computation is specified in Appendix D.2.

5.1 Interest Rate Shocks in Baseline: FRM with Builders

Figure 6 illustrates housing price dynamics following a temporary interest rate increase in an economy with FRM and builders, with prices normalized to the stationary equilibrium level. The housing price significantly drops by 14.52% at $t = 2$, driven by two key mechanisms. First, the new construction is determined at $t = 1$, which is based on the originally low interest rate level, so builders overbuild with the benefit of hindsight. Second, the distribution effect is almost impotent since households cannot immediately leverage the high interest rate to accumulate wealth–the initial distribution reflects the low-rate, high-leverage equilibrium.

Consequently, the heterogeneous housing response for high-leverage households dominates and decreases the housing demand. The combined responses from builders and households at $t = 2$ imply an excess supply at the stationary price, leading to a housing price slump.



Note: This figure illustrates the aggregate response of the economy with FRM and builders to a temporary increase in interest rates. The top panel plots the exogenous change in the interest rate. The middle panel plots the transition of housing prices normalized by the stationary price. The bottom panel plots the transition of the new construction normalized by the stationary new construction level from builders. All sectors and agents have perfect foresight of dynamic path of all variables after the unexpected interest shock is realized.

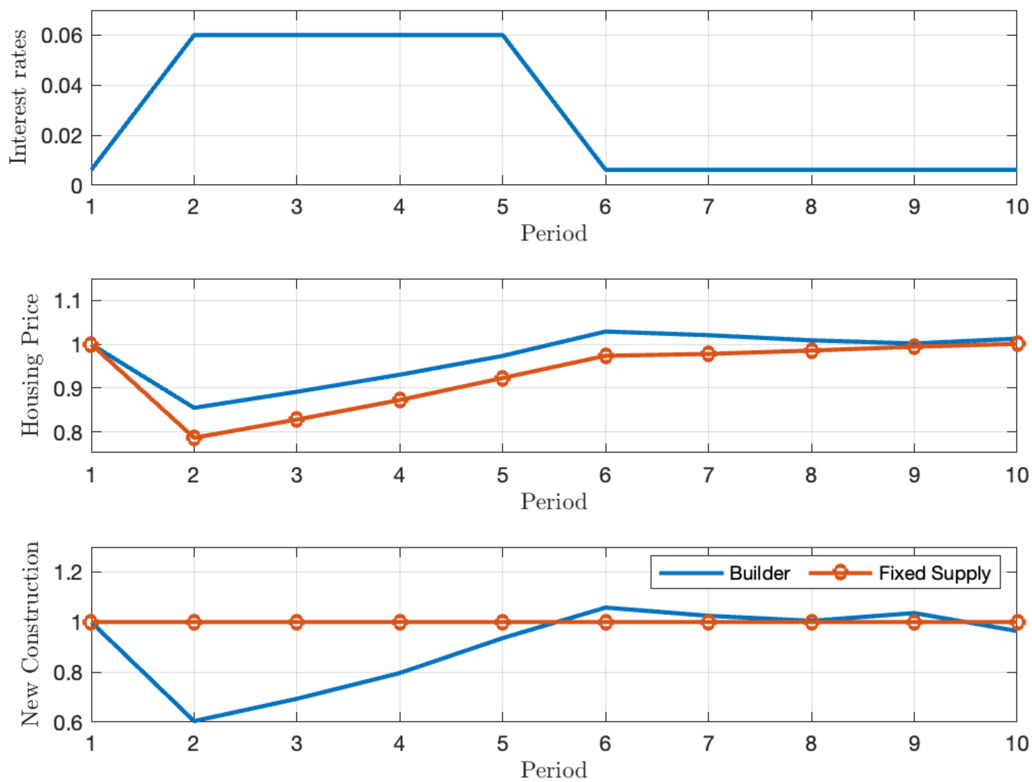
Figure 6: Transitional Path to Interest Rate Shock–Baseline with FRM and Builders

Housing prices rise during the high-rate period and decline after the interest rate returns to the baseline rate. The direction is consistent with builders' behavior characterized in Proposition 1.[20] Figure 6 also shows that housing prices and new construction follow similar patterns. Therefore, the effect of new construction dominates in the early stage of housing price dynamics.

[20]Note that the new construction at $t = 6$ depends on r_5, which is still at the high-rate level.

5.2 Counterfactual with Fixed Supply: the Role of Builders

This subsection compares housing price dynamics with and without builders. The results indicate that incorporating builder responses to interest rates dampens price declines or even generates price increases, contrasting with models that focus solely on housing demand.



Note: This figure illustrates the aggregate response of the economy under a fixed-rate mortgage (FRM) regime to a temporary increase in interest rates, comparing scenarios with builders and fixed housing supply. The top panel plots the exogenous change in the interest rate. The middle panel plots the transition of housing prices normalized by the stationary price in an economy with builders (blue solid line) and with fixed supply (orange dashed line). The bottom panel plots the transition of the new construction normalized by the stationary new construction level in an economy with builders (blue solid line) and with fixed supply (orange dashed line). All sectors and agents have perfect foresight of dynamic path of all variables after the unexpected interest shock is realized.

Figure 7: Transitional Path to Interest Rate Shock–Builders and Fixed Supply

Figure 7 compares housing price and construction dynamics in economies with and without builders. In a fixed supply economy, it is equivalent to treat new construction investment as constant. Prices fall more sharply initially, as new construction supply always automatically offsets depreciation. With endogenous construction, builders reduce supply in response to higher rates, moderating the initial price decline and leading to a 2.9% price increase above steady state at $t = 6$. The price paths show opposite direction after rates drop:

with endogenous supply, prices fall as construction adjusts, while under fixed supply, prices continue rising as lower rates stimulate demand.

Table 3 presents the decomposition of the contribution from households and builders to the housing price dynamics. I normalize all numbers by the stationary housing price. The total effect measures the price deviation from steady state in the economy with builders. The demand component captures household contributions through the price deviation in the fixed-supply economy, while the builder component reflects the price differential between economies with and without builders. During high-rate periods, builders' responses mitigate price declines by $5-7$ percentage points of the stationary price level compared to a counterfactual scenario with fixed housing supply in the short run. Even after the interest rate drops, builders' effects persist positively as cumulative construction remains below fixed-supply levels. This moderation of price declines stems from builders' negative supply response to higher rates and their role as the sole source of new housing stock.

Table 3: Housing Price Dynamics Decomposition

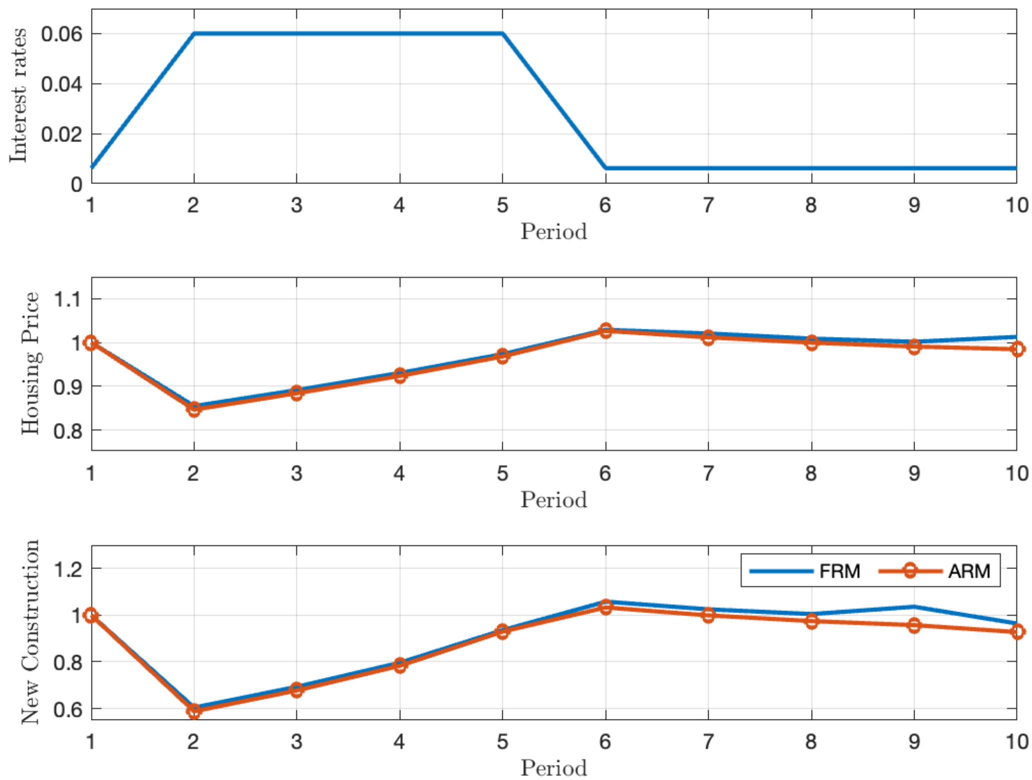
Period	2	3	4	5	6	7	8	9	10
Total	-0.1452	-0.1085	-0.0695	-0.0265	0.0290	0.0207	0.0090	0.0018	0.0129
Demand	-0.2135	-0.1719	-0.1273	-0.0770	-0.0264	-0.0221	-0.0143	-0.0057	0.0008
Builders	0.0684	0.0634	0.0579	0.0506	0.0554	0.0427	0.0233	0.0074	0.0121

Note: The table presents the effects of interest rate shocks on housing prices and decomposes these effects into demand-side and builder-side responses.

5.3 Counterfactual with ARM: the Role of Mortgage Structure

Figure 8 displays housing price dynamics under FRM and ARM with endogenous construction. The price paths track closely as higher rates discourage builder activity similarly in both regimes. The new construction paths of the two economies are also similar. The ARM structure exhibits lower housing price dynamics in the short run under a temporary increase in interest rates, with prices approximately 1 percentage of the stationary price below compared to a counterfactual FRM structure.

The key distinction between FRM and ARM economies lies in housing tenure dynamics. FRM provides insurance against rate increases. Homeowners can stay in their existing houses without suffering from higher mortgage costs. This generates the lock-in effect, as shown in Figure E4. The share of stayers initially rises and remains higher under FRM in the short run. Under an ARM structure, higher periodic mortgage payments force some homeowners to transition to renting, leading to lower homeownership rates in the short run. Figure E4 shows that the homeownership rate drops in both economies at the beginning of the transition



Note: This figure illustrates the aggregate response of the economy with builders under FRM and ARM respectively to a temporary increase in interest rates. The top panel plots the exogenous change in the interest rate. The middle panel plots the transition of housing prices normalized by the stationary price in an economy with FRM (blue solid line) and with ARM (orange dashed line). The bottom panel plots the transition of the new construction normalized by the stationary new construction level in an economy with FRM (blue solid line) and with ARM (orange dashed line). All sectors and agents have perfect foresight of dynamic path of all variables after the unexpected interest shock is realized.

Figure 8: Transitional Path to Interest Rate Shock–FRM and ARM

and becomes lower in the short run in an economy with ARM structure. Because of different housing tenure paths between FRM and ARM, the prices in the economy adopting ARM is smaller by 1 percentage of the stationary price than the prices in the economy with FRM in the short run. This gap reflects FRM's insurance effect on housing demand, as owner-occupied units typically exceed rental unit sizes. Thus, mortgage structure primarily affects housing tenure and have a smaller impact on price dynamics.

5.4 Counterfactual with Builder's Financial Constraint: the Role of Financial Friction

This subsection demonstrates that builders' financial constraints surprisingly have minimal impact on housing price dynamics under a temporary interest rate increase. A higher interest rate implies a higher construction loan rate and a tighter financial constraint (4) given the price and the amount of new construction. To implement the quantitative analysis, the equity-issuance cost and the builder's loan-to-value ratio need to be defined and parameterized. Following Lanteri and Rampini (2023b), I define the equity-issuance cost function as $\phi(-d) = \phi_0(-d)^{\phi_1}$ for $d < 0$, with parameter $\phi_0 = 0.3$ and $\phi_1 = 2$, and set the builder's loan-to-value ratio at $\theta_b = 0.5$. From Proposition 1, there exists a net worth threshold $\bar{w}$ separating constrained and unconstrained builders. Given the same set of parameters in Table 1, I set constrained builders' net worth at this threshold $w = \bar{w} = 0.0347$, calculated using calibrated parameters and the steady-state price. Higher interest rates would constrain previously unconstrained builders if they maintain their original construction plans, compelling them to adjust their building strategies.

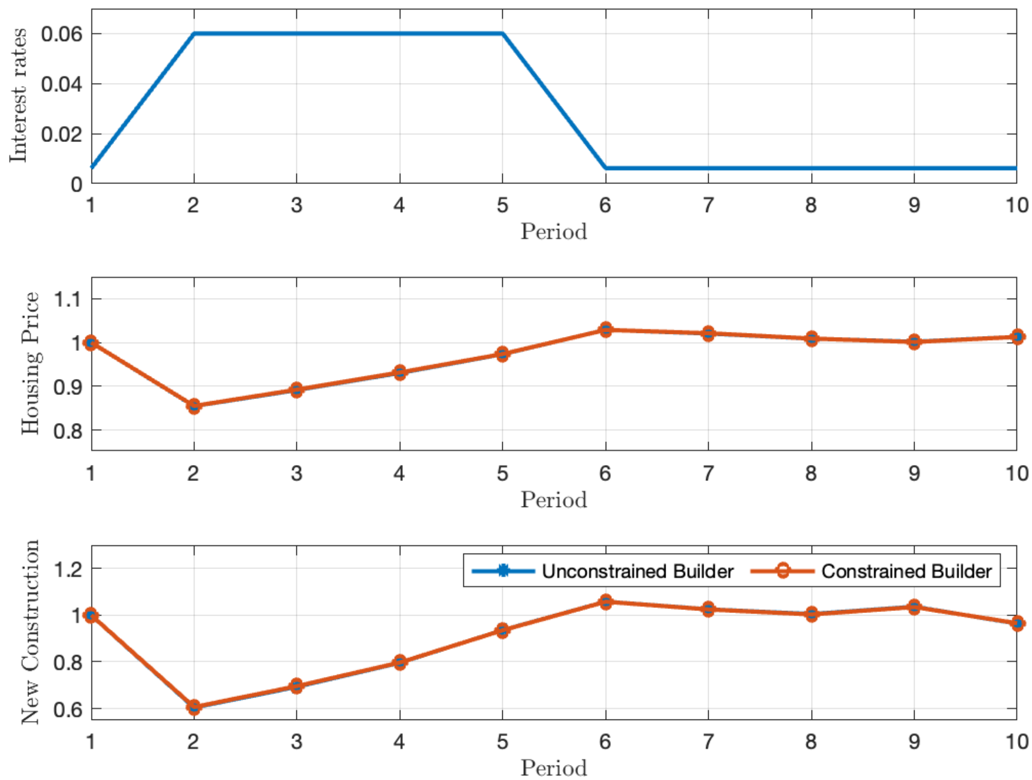
Figure 9 depicts the housing price paths of economies with and without financial constraint respectively. The two paths nearly overlap, indicating that the financial constraint has little impact on housing prices. Further examination of the tightness of the financial constraint, shown by the marginal cost of equity issuance ϕ_d in Figure E5, reveals that builders remain unconstrained in the short run ($t \leq 5$). Specifically, along the transitional path, the marginal value of net worth is never larger than 0.15% in the short run.

The key factor is the effect of interest rates on the optimal new construction level $h_{s,unc}$. In Appendix A, equation (23) shows that the optimal new construction level declines with higher interest rates, R. Given the stationary housing price and stationary new construction, an increase in the interest rate directly constrains the builder with $\bar{w}$. However, the decline in the optimal new construction level alleviates the financial constraint. A higher interest rate does not necessarily make the builder more constrained. On the contrary, the constraint might be slacker since builders can adjust to the new and smaller optimal level. Figure 9 displays that the optimal new construction levels in each period are similar in the two economies. That is, a temporary increase in interest rate mainly affects the optimal construction level and loosens the financial constraint.[21]

6 Conclusion

This paper provides a more general framework to evaluate the effect of interest rates on the housing price by incorporating endogenous construction. I develop a model of builders' new construction investment subject to time-to-build constraints while preserving rich demand-side properties. In the model, the builder responds negatively to a higher interest rate.

[21] The financial constraint might have a larger effect when the interest rate decreases, as the optimal construction level increases.



Note: This figure illustrates the aggregate response of the economy under FRM and builders with and without builder's financial constraint respectively to a temporary increase in interest rates. The top panel plots the exogenous change in the interest rate. The middle panel plots the transition of housing prices normalized by the stationary price in an economy without builder's financial constraint (blue solid line) and with builder's financial constraint (orange dashed line). The bottom panel plots the transition of the new construction normalized by the stationary new construction level in an economy without builder's financial constraint (blue solid line) and with builder's financial constraint (orange dashed line). All sectors and agents have perfect foresight of dynamic path of all variables after the unexpected interest shock is realized.

Figure 9: Transitional Path to Interest Rate Shock–with and without Builder's Financial Constraint

Higher interest rates reduce optimal construction, moderating price declines or even generating price increases in the short run.

The numerical decomposition demonstrates builders' significant impact on housing price dynamics. Comparing economies with and without builders shows that new construction responses moderate price declines by $5 - 7$ percentage points of the stationary price level compared to a counterfactual scenario with fixed housing supply in the short run. These findings highlight the importance of incorporating supply-side responses when analyzing interest rates' effects on housing markets.

In addition to the role of builders, the analysis also examines mortgage structure effects under a temporary increase in interest rates. While ARM and FRM yield similar price paths, they generate distinct tenure patterns. FRM enables mortgage rate lock-in, preserving homeownership, while ARM leads to lower homeownership rates and a lower share of stayers, as borrowers face higher mortgage payments.

Furthermore, the financial constraint on builders is counterintuitive in housing price dynamics when interest rates temporarily increase. Higher rates reduce optimal construction levels, which relaxes financial constraints, offsetting the direct tightening effect from higher construction loan costs.

The theoretical and quantitative analysis demonstrates builders' significant impact on housing price dynamics through their interest rate responses. As the sole providers of new housing stock, builders warrant explicit consideration in housing policy-related evaluations. While existing literature emphasizes demand-side effects, this paper develops a framework incorporating supply-side responses, establishing their importance for housing market analysis. For future research, it should be noted that builders may have a significant impact. This paper provides a general framework and develops a quantitative algorithm for housing market analysis.

References

Aastveit, K. A., Albuquerque, B., and Anundsen, A. K. (2023). Changing supply elasticities and regional housing booms. *Journal of Money, Credit and Banking*, 55(7):1749–1783.

Baum-Snow, N. and Han, L. (2024). The microgeography of housing supply. *Journal of Political Economy*, 132(6):1897–1946.

Berger, D. W., Milbradt, K., Tourre, F., and Vavra, J. S. (2024). Optimal mortgage refinancing with inattention. Technical report, National Bureau of Economic Research.

Boar, C., Gorea, D., and Midrigan, V. (2022). Liquidity constraints in the us housing market. *The Review of Economic Studies*, 89(3):1120–1154.

Davis, M. A., Larson, W. D., Oliner, S. D., and Shui, J. (2021). The price of residential land for counties, zip codes, and census tracts in the united states. *Journal of Monetary Economics*, 118:413–431.

Del Negro, M. and Otrok, C. (2007). 99 luftballons: Monetary policy and the house price boom across us states. *Journal of Monetary Economics*, 54(7):1962–1985.

Favilukis, J., Ludvigson, S. C., and Van Nieuwerburgh, S. (2017). The macroeconomic effects of housing wealth, housing finance, and limited risk sharing in general equilibrium. *Journal of Political Economy*, 125(1):140–223.

Fonseca, J. and Liu, L. (2024). Mortgage lock-in, mobility, and labor reallocation. *The Journal of Finance*, 79(6):3729–3772.

Fonseca, J., Liu, L., and Mabille, P. (2024). Unlocking mortgage lock-in: Evidence from a spatial housing ladder model. Technical report, Working paper.

Garriga, C. and Hedlund, A. (2020). Mortgage debt, consumption, and illiquid housing markets in the great recession. *American Economic Review*, 110(6):1603–1634.

Garriga, C., Manuelli, R., and Peralta-Alva, A. (2019). A macroeconomic model of price swings in the housing market. *American Economic Review*, 109(6):2036–2072.

Geng, M. N. (2018). *Fundamental drivers of house prices in advanced economies*. International Monetary Fund.

Green, R. K., Malpezzi, S., and Mayo, S. K. (2005). Metropolitan-specific estimates of the price elasticity of supply of housing, and their sources. *American Economic Review*, 95(2):334–339.

Greenwald, D. (2018). The mortgage credit channel of macroeconomic transmission.

Hacamo, I. (2021). Interest rates and the distribution of housing wealth. In *Interest Rates and the Distribution of Housing Wealth: Hacamo, Isaac*. [Sl]: SSRN.

Jorgenson, D. W. (1963). Capital theory and investment behavior. *The American economic review*, 53(2):247–259.

Justiniano, A., Primiceri, G. E., and Tambalotti, A. (2019). Credit supply and the housing boom. *Journal of political economy*, 127(3):1317–1350.

Kaplan, G., Mitman, K., and Violante, G. L. (2020). The housing boom and bust: Model meets evidence. *Journal of Political Economy*, 128(9):3285–3345.

Kiyotaki, N., Michaelides, A., and Nikolov, K. (2011). Winners and losers in housing markets. *Journal of Money, Credit and Banking*, 43(2-3):255–296.

Kiyotaki, N., Michaelides, A., and Nikolov, K. (2024). Housing, distribution, and welfare. *Journal of Money, Credit and Banking*, 56(5):981–1020.

Landvoigt, T., Piazzesi, M., and Schneider, M. (2015). The housing market (s) of san diego.

American Economic Review, 105(4):1371–1407.

Lanteri, A. and Rampini, A. A. (2023a). Constrained-efficient capital reallocation. *American Economic Review*, 113(2):354–395.

Lanteri, A. and Rampini, A. A. (2023b). Financing the adoption of clean technology. Technical report, Working Paper.

Murphy, A. (2018). A dynamic model of housing supply. *American economic journal: economic policy*, 10(4):243–267.

Oh, H. and Yoon, C. (2020). Time to build and the real-options channel of residential investment. *Journal of Financial Economics*, 135(1):255–269.

Saiz, A. (2010). The geographic determinants of housing supply. *The Quarterly Journal of Economics*, 125(3):1253–1296.

Sommer, K., Sullivan, P., and Verbrugge, R. (2013). The equilibrium effect of fundamentals on house prices and rents. *Journal of Monetary Economics*, 60(7):854–870.

Van Straelen, E. (2024). Desperate house sellers: Distress among developers. *The Review of Financial Studies*, 37(3):802–836.

Appendix

A Builder's Problem

The multipliers of current budget constraint, the net worth evolution and the financial constraint are μ, $R^{-1}\mu'$ and $R^{-1}\lambda'$ respectively. The first-order conditions are:

$$d: \quad 1+\phi_d = \mu, \tag{18}$$
$$w': \quad \mu' = 1, \tag{19}$$
$$b: \quad \mu = 1+\lambda', \tag{20}$$
$$x: \quad p_h - R\left(p_\ell + \frac{p_x}{f'(x)}\right) = \left\{R\left(p_\ell + \frac{p_x}{f'(x)}\right) - \theta_b p_h\right\}\lambda'. \tag{21}$$

With a functional form $\phi(-d) = \phi_0(-d)^{\phi_1}$ if $d<0$ and $f(x) = A_h x^{\alpha_h}$, given p_h and R, the equilibrium building strategy for unconstrained builders is:

$$p_h = R\left(p_\ell + \frac{p_x}{f'(x)}\right)$$
$$\Rightarrow x_{unc} = \left(A_h\alpha_h * \frac{p_h - Rp_\ell}{Rp_x}\right)^{\frac{1}{1-\alpha_h}} \tag{22}$$
$$h_{s,unc} = \ell_{unc} = f(x_{unc}) = A_h^{\frac{1}{1-\alpha_h}}\left(\alpha_h * \frac{p_h - Rp_\ell}{Rp_x}\right)^{\frac{\alpha_h}{1-\alpha_h}}. \tag{23}$$

We first observe $\lambda' = \phi_d$; i.e., a constrained builder always issues equity, and vice versa. Let $x = x_{unc}$, $d=0$, and $b = R^{-1}\theta_h p_h h_s$ in (2), we get a threshold $\bar{w}$ of constrained and unconstrained builders:

$$\begin{aligned}\bar{w} &= (p_\ell - R^{-1}\theta_b p_h)A_h^{\frac{1}{1-\alpha_h}}\left(\alpha_h * \frac{p_h - Rp_\ell}{Rp_x}\right)^{\frac{\alpha_h}{1-\alpha_h}} + p_x^{\frac{-\alpha_h}{1-\alpha_h}}\left(A_h\alpha_h * \frac{p_h - Rp_\ell}{R}\right)^{\frac{1}{1-\alpha_h}} \\ &= \left[p_\ell(1-\alpha_h) + R^{-1}p_h(\alpha_h - \theta_b)\right]A_h^{\frac{1}{1-\alpha_h}}\left(\alpha_h * \frac{p_h - Rp_\ell}{Rp_x}\right)^{\frac{\alpha_h}{1-\alpha_h}}\end{aligned}$$

From (21), a constrained builder with initial net worth $w < \bar{w}$ solve $x(w)$ and $h_s(w)$ satisfying

$$p_h = R\left[p_\ell + \frac{p_x x^{1-\alpha_h}}{\alpha_h A_h}\right]\frac{1+\phi_0\phi_1[(p_\ell - R^{-1}\theta_b p_h)A_h x^{\alpha_h} + p_x x - w]}{1+\theta_b\phi_0\phi_1[(p_\ell - R^{-1}\theta_b p_h)A_h x^{\alpha_h} + p_x x - w]}.$$

It is worth mentioning that a builder builds new construction only if $p_h > Rp_\ell$; i.e., the revenue should at least cover the future value of the land cost.

B Representative Household and Exogenous Housing Supply

In this appendix, I show that representative households cannot provide a rich analysis as a heterogeneous household setting. I assume a constant income, a short-term mortgage, and housing adjustment with adjustment costs. I also assume that the initial condition is $m_{-1} = 0$.

$$V(h, m; r) = \max_{\{c,h',a',m'\}} \frac{[c^{1-\alpha} h'^{\alpha}]^{1-\gamma} - 1}{1-\gamma} + \beta V(h', m'; r)$$

s.t.

$$\begin{aligned} &c + p_h[h' - (1-\delta_h)h + \kappa_h(1-\delta_h)h] + (1+r)m \leq y + m', \\ &(1+r)m' \leq \theta_h(1-\delta_h)p_h h'. \end{aligned}$$

Let μ and λ be the multiplier of the budget constraint and the collateral constraint respectively. The FOCs are

$$\begin{aligned} &c: && U_c = \mu, \\ &h': && U_h + \theta_h(1-\delta_h)p_h\lambda + \beta V_{h'} = p_h\mu, \\ &m': && \mu + \beta V_{m'} = (1+r)\lambda \end{aligned}$$

Envelope Conditions are:

$$\begin{aligned} &h: && V_h = -p_h(1-\kappa_h)(1-\delta_h)\mu, \\ &m: && V_m = -(1+r)\mu. \end{aligned}$$

The market clearing condition is:

$$h' = \bar{H},$$

where $\bar{H}$ is the exogenous housing supply.

We consider the steady-state equilibrium. After rearranging equations, the equilibrium conditions are:

$$\begin{aligned} &\text{MCC:} && h = \bar{H}, \\ &\text{FOC of c/h:} && \frac{\alpha}{1-\alpha}\left(\frac{c}{\bar{H}}\right)^{\alpha} = p_h\left[1 + \beta(1-\kappa_h)(1-\delta_h) - \theta_h(1-\delta_h)\left(\frac{1}{1+r} - \beta\right)\right], \\ &\text{BC:} && c + p_h[\delta_h + \kappa_h(1-\delta_h)]\bar{H} = y - rm, \\ &\text{Borrowing Constraint:} && (1+r)m \leq \theta_h(1-\delta_h)p_h\bar{H}. \end{aligned}$$

Note that for the existence of the equilibrium, $\beta(1+r) \leq 1$.

Case 1: $\beta(1+r) = 1$

This implies that households are unconstrained in the steady state. Since households are endowed with constant amount of goods, y, the steady state $m = 0$. (This argument needs to be proved) That is, households do not have to smooth consumption throughout the mortgage/saving. The equilibrium becomes:

$$\begin{cases} h' = \bar{H}, \\ m' = 0, \\ c = \left\{p_h \frac{1-\alpha}{\alpha} \left[1 + \beta(1-\kappa_h)(1-\delta_h)\right]\right\}^{\frac{1}{\sigma}} \bar{H}, \\ \left\{\left\{p_h \frac{1-\alpha}{\alpha} \left[1 + \beta(1-\kappa_h)(1-\delta_h)\right]\right\}^{\frac{1}{\sigma}} + p_h[1-(1-\kappa_h)(1-\delta_h)]\right\} \bar{H} = y. \end{cases}$$

The last equation solves p_h. Since the left-hand side is increasing from 0, there exists a unique p_h.

Case 2: $\beta(1+r) < 1$

This implies $\lambda > 0$ and the collateral constraint is always binding. Households borrow to the limit when the economy starts, and they always want to borrow more. However, they are capped by the borrowing limit. They will repay only the interest expense and keep the debt level at the borrowing limit. The equilibrium is:

$$\begin{cases} h' = \bar{H}, \\ m' = \frac{\theta_h(1-\delta_h)p_h\bar{H}}{1+r}, \\ c = \left\{p_h \frac{1-\alpha}{\alpha} \left[1 + \beta(1-\kappa_h)(1-\delta_h) - \theta_h(1-\delta_h)\left(\frac{1}{1+r} - \beta\right)\right]\right\}^{\frac{1}{\sigma}} \bar{H}, \\ c + rm' + p_h[1-(1-\kappa_h)(1-\delta_h)]\bar{H} = y. \end{cases}$$

By analyzing the equilibrium conditions, p_h decreases while r increases. Given p_h, an increase in r will increase rm' and c, so p_h will decrease to hold the equality of the last equation.

If households are representative and homogeneous, there is no heterogeneous responses in policy functions. The distribution effect is degenerate to one point. Therefore, we need heterogeneity in the household side.

C Details of Moments

This section specifies the calculation of moments from data in table 2. I first summarize moments generated from SCF in 2022. The average house price is the mean primary residence \$471.06 thousand. Normalized by the average income, it is 3.3316. The average wealth for homeowners and renters are \$1525.16 thousand and \$153.47 thousand, so the ratio is 9.94. The average housing debt for homeowners is from aggregation of mortgages or home-equity loans \$215.3 thousand, home-equity lines of credit \$44.33 thousand, and other residential real estate debt \$245.21 thousand, which is \$504.84.[22] It equals 3.57 after being normalized. The average income for homeowners and renters are \$177.2 thousand and \$71.71 thousand, so the ratio is 2.47. The average wealth is \$1059.47 thousand, which is normalized to be 7.49.

There are two moments generated from ACS. The number of total occupied housing units and owner-occupied units are $125,736,353$ and $81,497,760$, so the share of owner-occupied houses is 64.8%. Among owner-occupied units, there are $50,148,459$ housing units with a mortgage. Therefore, the share of owners with mortgages is 61.5%.

I calculate the new construction sales share from AEI-Zillow new construction index. We can get 12.9% from taking average of quarterly new construction share of sales.

D Numerical Computation

This section elaborates how I implement the numerical solution of the stationary equilibrium and transitional dynamics.

D.1 Stationary Equilibrium

The computational solution faces three key challenges. First, there are four state variables– income, liquid, housing position, and mortgage balance the non-uniqueness solution of liquid assets and mortgages. In transitional dynamics, the interest rate attached with the existing mortgage is an additional state variable. Second, the different terms between long-term mortgages and liquid assets cause non-uniqueness portfolio in the solution. Third, the endogenous mortgage borrowing constraint causes problems in assigning mortgage grids and interpolating the objective function. To resolve these problems, I assume that households can only move to $h_o \in \mathrm{H} = \{h^1, h^2, h^3, ..., h^N\}$, where $h^1 < h^2 < ... < h^N$, and the duration of the house $h_{dur} = 10$.[23] These two assumptions ensure that the households' housing state space is a finite set with $h^N * h_{dur} + 1$ elements.[24] Without loss of generality, I can assume that the mover always borrows to the limit, and the stayer always repay the minimum repayment. The reason lies in the fact that they can always save the amount exceeding the optimal mortgage balance. For example, if a household borrows 1 dollar more in her mortgage balance, she can always save this dollar in the liquid asset and use the gross return R to repay the additional borrowing next period. This assumption reduces one state variable, mortgages, since the mortgage balance attached with each housing state is certain. It simultaneously resolves the dimensionality problem and the interpolation problem.

The numerical exercise solves the stationary problem as the following:

1. Given exogenous r, first guess a housing price p_h and assign mortgage balance for each housing grid.

[22] The structure of SCF debt variables can be found here.

[23] The duration assumption does not affect the result significantly when it is not too small. It is always applicable to assign a higher duration. Here, I assume $h_{dur} = 10$ considers both the reality and the computation efficiency.

[24] The additional one means that a household does not own a house; i.e., $h = 0$.

2. Inner loop (Value function iteration): Guess an initial value function V_0. Solve household optimality under choice of moving to $h' \in \mathrm{H}$, staying, and renting separately, and find the maximum as the optimal housing choice. The corresponding value function V_1 is obtained. Check $||V_1 - V_0||$. If the difference exceeds the tolerance level, update the initial value function and keep implementing the process until the difference is smaller than the tolerance level.

3. Use the policy function from the inner loop to get the stationary distribution F. To get a finer distribution, we find out the threshold of liquid asset $\bar{a_n} \in [a_{n-1}, a_n]$ when $h'(m, h, a_{n-1}, y) \neq h'(m, h, a_n, y), \forall n \in \mathbb{N}$ such that $V(m, h, \bar{a_n}, y)$ is indifferent between choosing $h'(m, h, a_{n-1}, y)$ and $h'(m, h, a_n, y)$. With this refinement, we get a more continuous distribution mass along with liquid asset a. Check the market clearing condition.

4. If the absolute value of the excess demand is smaller than the tolerance level, we claim that the equilibrium price is found. Otherwise, adjust the price and redo the process above with the updated price until the market clears.

D.2 Transitional Dynamics

The transitional dynamics of the fixed-rate mortgage structure needs to track the existing mortgage rate. This would not be a problem because we can make the same assumption as in D.1 and pin down the attached mortgage balance for each housing grid during the transition. The only concern is that repaying the minimum repayment might not be optimal when the current rate is smaller than the existing mortgage rate. Therefore, I assume that the existing mortgage rate is automatically refinanced to the current rate if the current rate is lower than the existing mortgage rate.[25]

The numerical exercise solves the transitional dynamics as the following:

1. Guess a price sequence along the transitional path.

2. Backward: Given the price sequence, back out the value function sequence along the transitional path.

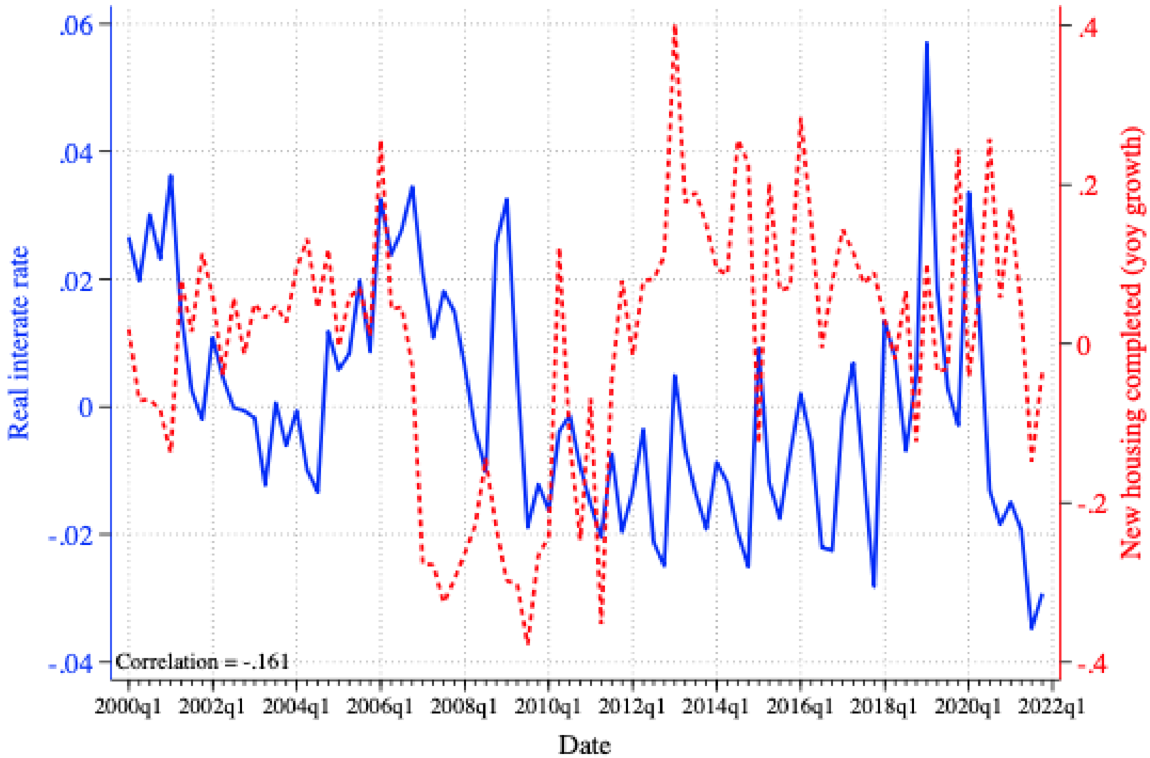
3. Forward: Given the derived value function sequence, clear the market by solving the policy function, updating distribution, and updating the price period by period from the beginning of the transition.

4. Check the distance between the new price sequence and the old price sequence. If the distance is smaller than the tolerance level, we claim that we find the transitional dynamics path.

5. Otherwise, redo the above process until the price sequence converges.

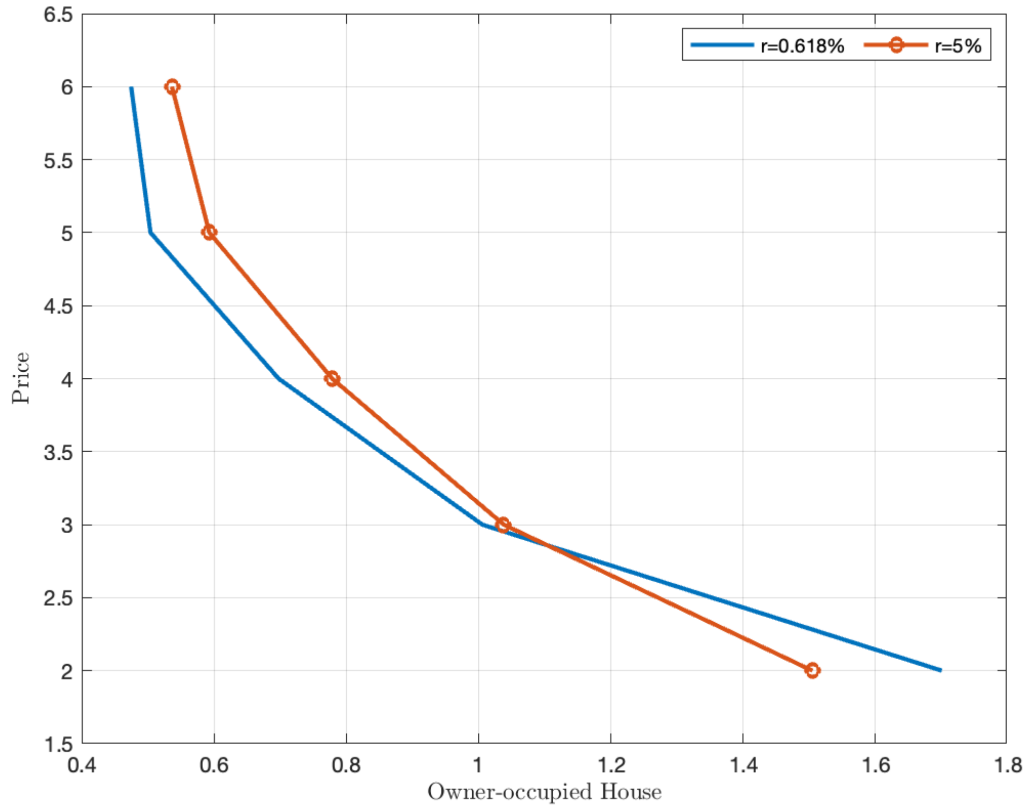
[25]For a more detailed discussion about refinance behaviors, we can check Berger et al. (2024) and Boar et al. (2022).

E Figures



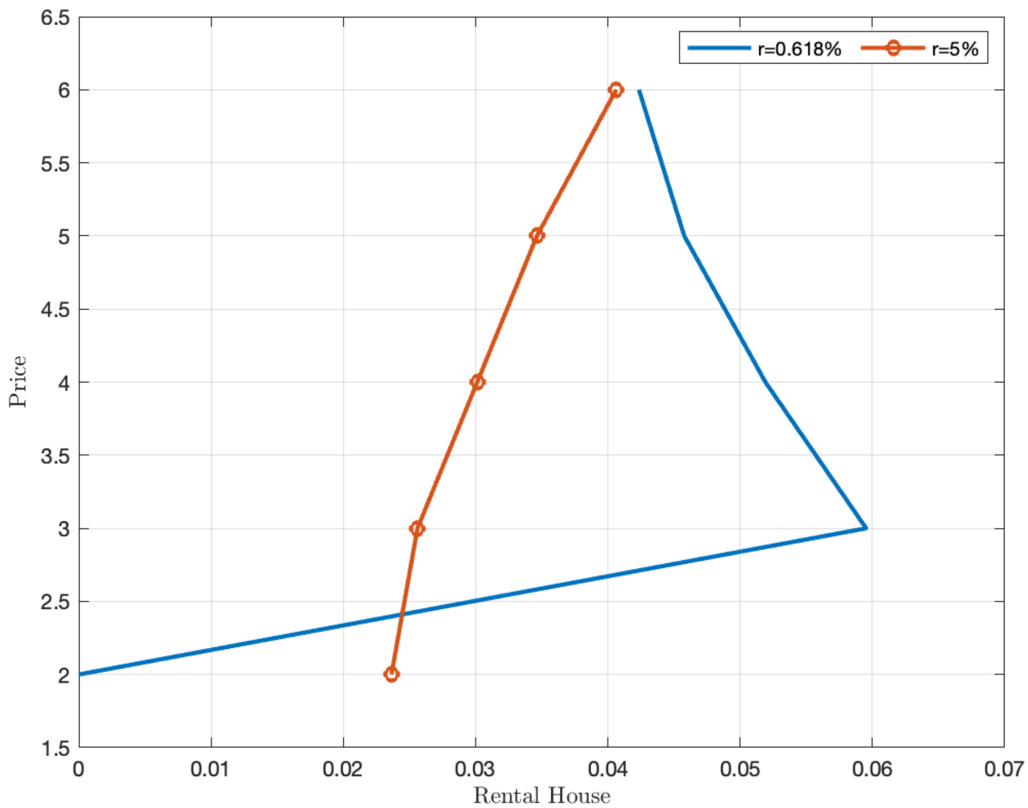
Note: This figure displays the quarterly time series 1-year real interest rate by the blue solid line (left y-axis) and builder's housing completion growth rate by the red dashed line (right y-axis) from Q1 2000 to Q1 2022 in the U.S.

Figure E1: Real Interest Rate and Housing Completion Growth (Q1 2000-Q1 2022)



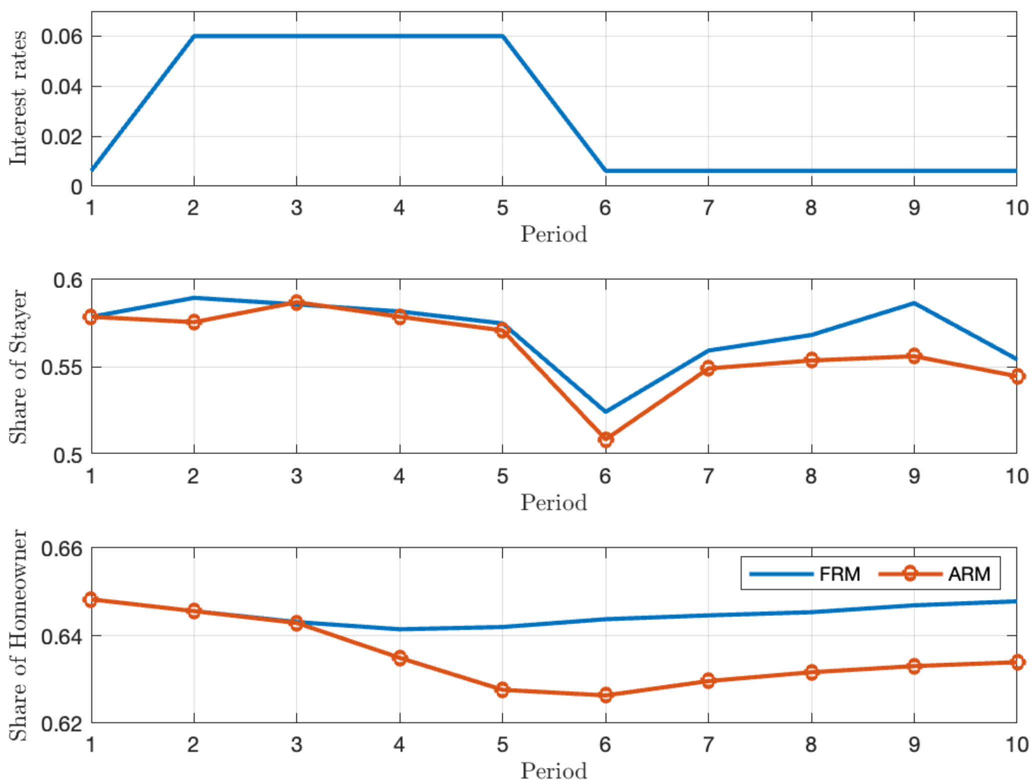
Note: This figure displays household aggregate owner-occupied housing demand curve. Specifically, the blue solid line depicts owner-occupied housing demand under different housing prices given $r = 0.618\%$. The orange line with circle depicts owner-occupied housing demand under different housing prices given $r = 5\%$.

Figure E2: Owner-occupied House



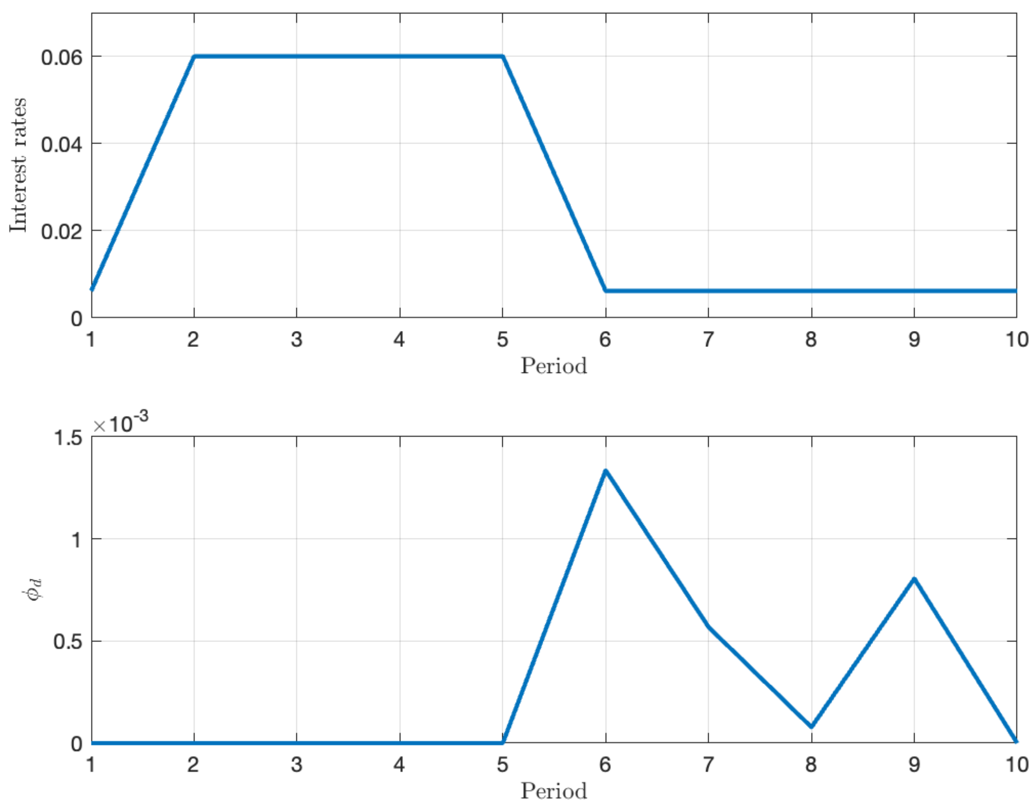
Note: This figure displays household aggregate rental housing demand curve. Specifically, the blue solid line depicts rental housing demand under different housing prices given $r = 0.618\%$. The orange line with circle depicts rental housing demand under different housing prices given $r = 5\%$.

Figure E3: Rental House



Note: This figure illustrates the aggregate response of the economy with builders under FRM and ARM respectively to a temporary increase in interest rates. The top panel plots the exogenous change in the interest rate. The middle panel plots the transition of share of stayers in an economy with FRM (blue solid line) and with ARM (orange dashed line). The bottom panel plots the transition of the new construction in an economy with FRM (blue solid line) and with ARM (orange dashed line). All sectors and agents have perfect foresight of dynamic path of all variables after the unexpected interest shock is realized.

Figure E4: Transitional Path of Share of Stayer and Homeowner to Interest Rate Shock–FRM and ARM



Note: This figure illustrates the aggregate response of the economy under FRM and builders with and without builder's financial constraint respectively to a temporary increase in interest rates. The top panel plots the exogenous change in the interest rate. The bottom panel plots the transition of marginal cost of equity issuance without builder's financial constraint (blue solid line) and with builder's financial constraint (orange dashed line). All sectors and agents have perfect foresight of dynamic path of all variables after the unexpected interest shock is realized.

Figure E5: Transitional Path of Marginal Cost of Equity Issuance to Interest Rate Shock–with and without Builder's Financial Constraint