Run-up in the House Price-Rent Ratio: How Much Can Be Explained by Fundamentals?* †

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Abstract

This paper studies the joint dynamics of real house prices and rents over the past decade. We build a dynamic general equilibrium stochastic life cycle model of housing tenure choice with fully specified markets for homeownership and rental properties, and endogenous house prices and rents. Houses are modeled as discrete-size durable goods which provide shelter services, confer access to collateralized borrowing, provide sizeable tax advantages, and generate rental income for homeowners who choose to become landlords. Mortgages are available, but home-buyers must satisfy a minimum down payment requirement, and home sales and purchases are subject to lumpy adjustment costs. Lower interest rates, relaxed lending standards, and higher incomes are shown to account for over one-half of the increase in the U.S. house price-rent ratio between 1995 and 2005, and to generate the pattern of rapidly growing house prices, sluggish rents, increasing homeownership, and rising household indebtedness observed in the data. The model highlights the importance of accounting for equilibrium interactions between the markets for owned and rented property when analyzing the housing market. These general equilibrium effects can either magnify or reverse the partial equilibrium effects of changes in fundamentals on house prices, rents, and homeownership.

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1 Introduction

The sharp increase and subsequent collapse in U.S. house prices over the past decade has been well documented. Real house prices rose by only 3.7 percent between 1985 and 1995, but increased by 46 percent between 1995 and 2005. In sharp contrast, real rents remained virtually unchanged during the recent increase in house prices, so that in 2006 the house price-rent ratio peaked at approximately forty percent above its level in the year 2000 (Figure 1). Although the house price-rent ratio is widely used as an indicator of over and undervaluation of the housing market, surprisingly little is known about the theoretical relationship between the price-rent ratio and market fundamentals such as interest rates, income, and down payment requirements.

This paper bridges the gap in the existing literature by quantitatively studying the joint dynamics of endogenously determined house prices and rents in a dynamic equilibrium model of housing tenure choice with fully specified markets for homeownership and rental properties. We show that approximately one-half of the run-up in the U.S. house price-rent ratio can be explained as the equilibrium response of the housing market to recent changes in fundamentals.

Our framework is an Aiyagari-Bewley-Huggett style economy with a stochastic life cycle and heterogeneous households who are subject to idiosyncratic earnings shocks. Households derive utility from nondurable consumption and shelter services which are obtained either via renting or through homeownership. Markets are incomplete. Households can partially self-insure earnings risk by accumulating precautionary financial assets: deposits. In addition to deposits, households can hold a non-financial asset: houses. Houses are modeled as durable, indivisible, discrete-sized items which provide housing services, grant access to collateralized borrowing, and can serve as a source of rental income for homeowners who choose to become landlords. The supply of rental housing is thus determined endogenously within the model, as homeowners weigh their utility from shelter space against rental income, taking into account the tax implications of their decisions.\(^1\)

Mortgages are available to finance purchases of housing, but home-buyers must satisfy a minimum down payment requirement. Moreover, home purchases and sales are subject to lumpy transaction costs and the housing stock is subject to depreciation. Households who do not own houses rent housing services in the rental market and do not have access to borrowing or to the preferential tax treatment of owner-occupied housing and rental properties embedded in the U.S. tax code. Both house prices and rents are determined in equilibrium through clearing of housing and rental markets.

The calibrated model is used to study the impact of macroeconomic factors such as incomes, interest rates, and borrowing constraints on the equilibrium price-rent ratio. Our rational expectations model of the housing market demonstrates that the rising incomes, historically low interest rates, and easing of down payment requirements observed in the data can explain about one-half of the increase in U.S. house prices between 1995 and 2005.\(^2\) In addition, the model predicts that changes in these factors will have only a small positive effect on equilibrium rents, a result that is consistent with the U.S. data.\(^3\) The price and rent dynamics generated by the model coincide with

\(^1\) Using the data from the Property Owners and Managers Survey, Chambers, Garriga, and Schlagenhauf (2008) use micro data evidence to document that a vast majority of U.S. rental property is owned by households, rather than firms. Namely, 86 percent of the U.S. rental property is owned by individual investors (or husband and wife), and fully 94 percent of all rental property is owned by non-institutional investors. The remainder is controlled by real estate corporations, other corporations, non-profit organizations, or church.

\(^2\) A large body of empirical literature has investigated the relationship between house prices and macroeconomics aggregates. For example, regression analysis by by Englund and Ioannides (1997), Malpezzi (1999), Muellbauer and Murphy (1997), Muellbauer and Murphy (2008), Otrok and Terrones (2008) show that real interest rates, income, income growth, and financial liberalization have a statistically significant effect on the dynamics of real house prices.

\(^3\) Poterba (1984), Topel and Rosen (1988) and Muellbauer and Murphy (1997) model the relationship between house prices and rents using asset pricing models which predict that the expected return on housing equals (up to a constant) the rate of return on alternative investments. In general, this type of model cannot explain the coexistence
increases in the homeownership rate and household debt-to-income ratio that are also similar to the actual developments in the U.S. housing market between 1995 and 2005.\footnote{The total household debt to disposable income ratio has increased from 80 percent in 1985 to 93 percent in 1995 and to a whopping 141 percent in 2007. At the same time, the U.S. homeownership rate, initially flat at 64 percent between 1983 and 1995, rose to 69 percent by 2005.}

The key mechanism in the model generating the run-up in the equilibrium price-rent ratio as macroeconomic conditions change is that the supply of rental property available on the rental market and the demand for rental units by tenants are endogenously determined jointly with the demand for housing. When the mortgage interest rate and required down payment fall, the demand for rental units by tenants falls because households switch from renting to owning as homeownership becomes more affordable. At the same time, the supply of rental property from landlords increases because investment in rental property becomes more attractive relative to the alternative of holding bank deposits as the interest rate falls.\footnote{In the United States, the buy-to-let markets have grown substantially since the mid-1990s (OECD, 2006). The portion of sales attributable to such investors has risen sharply since the late 1990s, reaching around 15 percent of all home purchases in 2004, much higher than the normal 5 percent (Morgan Stanley, 2005).} As a result, the equilibrium rent falls. At the same time, the demand for housing increases because more households can afford to purchase homes, and existing homeowners can afford larger homes. Given that the supply of housing is fixed, the equilibrium house price rises. An increase in income that is symmetric across all wage groups leads to a roughly proportional increase in house prices and rents, leaving the price-rent ratio unchanged, as it roughly...
offsets the initial decline in rents while further boosting house prices.

The model provides a number of additional insights about the mechanisms that jointly determine house prices and rents. Both the house price and rent are relatively inelastic with respect to the down payment requirement, so a lessening of credit constraints cannot by itself account for the run-up in the house prices observed in recent years. The key to understanding the small effect of decreases in the required down payment on equilibrium house prices is to realize that changes in equilibrium house prices are primarily driven by shifts in the housing demand by households who find the minimum down payment a binding constraint and, therefore, increase their demand for housing when the lending standards are relaxed. However, relative to the entire market demand for housing, this increase in demand is relatively small, so the resulting house price increase is small. The corresponding increase in household borrowing as credit constraints are relaxed is skewed toward low-income households, as poorer households gain access to mortgage markets and borrow large amounts relative to their labor income to finance their home purchases.

Furthermore, we find that falling interest rates create large increase in house prices, since cheap credit and a low opportunity cost of borrowing boost household willingness and ability to purchase big properties and to finance them using large mortgages. In our economy with a fixed supply of housing, a falling interest rate thus pushes up house prices. As expected, falling interest rates lead to a large increase in household borrowing, since the low interest rate decreases the cost of mortgage financing and, at the same time, lowers the return on household savings. Somewhat surprisingly, a decline in the interest rate reduces the homeownership rate. This happens because as the interest rate falls and equilibrium house prices rise, some low-income households are no longer able to afford the minimum down payment on a house.

This paper builds on the growing body of literature which studies housing using quantitative macroeconomics models with heterogeneous households. See, for example, Díaz and Luengo-Prado (2008), Chambers, Garriga, and Schlagenhauf (2008), Chambers, Garriga, and Schlagenhauf (2009a), Chambers, Garriga, and Schlagenhauf (2009b), Chatterjee and Eyigungor (2009), Favilukis, Ludvigson, and Van Nieuwerburgh (2009), Kiyotaki, Michaelides, and Nikolov (2008), Nakajima (2008), Ríos-Rull and Sánchez-Marcos (2008), Ortalo-Magné and Rady (2006), and Iacoviello and Neri (2007). The studies most closely related to ours are Chambers, Garriga and Schlagenhauf (2008, 2009a, 2009b) and Díaz and Luengo-Prado (2008) in terms of the model, and Chatterjee and Eyigungor (2009), Favilukis, Ludvigson, and Van Nieuwerburgh (2009) and Kiyotaki, Michaelides, and Nikolov (2008) in terms of the theme. Díaz and Luengo-Prado (2008) build a partial equilibrium economy with a number of realistic features such as collateral borrowing, non-convex adjustment costs, taxes, and idiosyncratic earnings risk. However, in their model, housing and rental markets exist only insofar as both house prices and rents follow exogenous processes. Chambers, Garriga and Schlagenhauf (2008, 2009a, 2009b) use the American Housing Survey to document that the vast majority of U.S. rental property is owned by households instead of firms, and develop a model where rental property is supplied by households who choose to become landlords as a result of optimal investment strategies. However, the authors allow rents but not house prices to be determined endogenously within their model. This paper adopts the structure of rental markets from Chambers, Garriga, and Schlagenhauf (2009a), but also allows both house prices and rents to be determined in an equilibrium. Turning to the dynamics of the price-rent ratio, Kiyotaki, Michaelides, and Nikolov (2008) briefly explore the equilibrium relationship between house prices and rents in a more stylized model where production capital (i.e., factories) can be costlessly transformed into housing structures, and where rent is determined as a factor price of this production capital. The authors, however, focus primarily on the response of welfare to changes in fundamentals. Favilukis, Ludvigson, and Van Nieuwerburgh (2009) study the evolution of the price-rent

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6Chambers, Garriga and Schlagenhauf (2008, 2009a, 2009b) have, however, other equilibrium objects, such as interest rates.
ratio, but their model does not include a rental market. Instead, they impute rent for homeowners using the marginal rate of substitution between consumption and housing.\textsuperscript{7} Moreover, the supply of housing in their economy is highly elastic, as the authors abstract from features such as a fixed supply of land or fixed supply of housing. Lastly, Chatterjee and Eyigungor (2009) study the effects of changes in housing supply on the house price dynamics and mortgage default since 2005 in a calibrated model with a representative stand-in rental firm, where house prices and rents which are linked through a simple arbitrage condition. In their model, as well as in other models of the housing market with a representative stand in firm (see, for example, Gervais (2002) or Nakajima (2008)), house prices and rents always co-move. Our model is the first model with a non-trivial relationship between house prices and rents. In our model, as in the data, house prices and rent need not co-move. Section 7 highlights the important role of housing market frictions (such as transaction costs) in generating such behavior. Moreover, this paper studies the behavior of the U.S. house prices and rents between 1995 and 2005 – the main period of divergence, whereas the diverging behavior of house prices and rents is not the focus of Chatterjee and Eyigungor (2009).

This paper is organized as follows. In Section 2, we develop a quantitatively rich stochastic life cycle model of the housing market with fully specified household choices with respect to consumption, saving, and homeownership, and provide rationale for our modeling assumptions. Section 3 defines the equilibrium of the economy, while Section 4 describes the model’s calibration and discusses the fit of the benchmark model. In Section 5, we discuss predictions of the benchmark model, and reconcile these with the actual dynamics of house prices and rents in the U.S. data. Section 8 concludes with a discussion of possible extensions and directions for the future research.

2 The Model Economy

To study the impact of changes in interest rates and down payment requirements on house prices and rents, we build a stochastic life cycle model with incomplete markets and uninsurable idiosyncratic earnings risk, exogenous down payment requirements and interest rates, and endogenous house prices and rents. We depart from a representative-agent framework to build an economy where – as in the data – renters and homeowners differ in terms of income and wealth. Building on the idea of houses as durable, lumpy consumption goods that provide shelter services but can also be used as rental investments, we endogenize the buy vs. rent decision, and also allow homeowners to lease out their properties in the rental market. Households in the model make joint decisions about their consumption of nondurable goods and housing services, their house size, mortgage size, and deposits holdings.

The model mirrors the following assumptions. Young households start their life cycle as renters with zero asset holdings and have limited access to credit because all borrowing in the model is tied to ownership of housing. Households face idiosyncratic earnings shocks which can be partially insured through precautionary savings (deposits), or through collateralized borrowing in the form of liquid home equity lines of credit (HELOCs). Households prefer homeownership to renting, in part because of the tax advantages to homeownership imbedded in the U.S. tax code, but may be forced to rent due to the down payment requirement and the financing cost of homeownership. An important feature of our model is that houses can be used as a rental investment: they provide a source of income when leased out, and tax deductions available to landlords can be used to offset non-rental income.

The recent housing literature argues that non-convex transaction costs, tax advantages to homeownership, and higher depreciation of rental properties relative to owner-occupied properties are likely to be important determinants of housing demand and rental supply. We therefore incorporate

\textsuperscript{7}In a model such as ours with discrete choices, lumpy adjustment costs, and borrowing constraints, the relationship between the MRS, market rent, and the cost of housing is theoretically ambiguous.
these frictions into our baseline economy to assess their quantitative importance for both the level and responsiveness of house prices and rents to changes in the required down payment and interest rate.

2.1 Demography and Labor Income

The model economy is inhabited by a continuum of overlapping generations households with identical preferences. The model period is one year. Following Heathcote (2005) and Castaneda, Diaz-Gimenez, and Ríos-Rull (2003), we model the life cycle as a stochastic transition between various labor productivity states that also allows household’s income to rise over time. The stochastic-aging economy is designed to capture the idea that liquidity constraints may be most important for younger individuals who are at the bottom of an upward-sloping lifetime labor income profile without enforcing that household’s age be integrated into our already large state space.

In our stochastic life cycle model, households transit from state \( w \) via two mechanisms: (i) aging and (ii) productivity shocks, where the events of aging and receiving productivity shocks are assumed to be mutually exclusive. The probability of transiting from a state \( w_j \) via aging is equal to \( \phi_j = 1/(p_jL) \), where \( p_j \) is the fraction of population with productivity \( w_j \) in the ergodic distribution over the discrete support \( W \), and \( L \) is a constant equal to the expected lifetime. Similarly, the conditional probability of transiting from a working-age state \( w_i \) to a working-age state \( w_j \) due to a productivity shock is defined as \( P(w_i|w_j) \). The overall probability of moving from state \( j \) to state \( i \), denoted by \( \pi_{ji} \), is therefore equal to the probability of transition from \( j \) to \( i \) via aging, plus the probability of transition from \( j \) to \( i \) via a productivity shock, conditional on not aging, so that

\[
\Pi = \begin{bmatrix}
0 & \phi_1 & 0 & 0 \\
0 & 0 & \ddots & 0 \\
0 & 0 & 0 & \phi_{j-1} \\
\phi_j & 0 & 0 & 0
\end{bmatrix} + \begin{bmatrix}
(1 - \phi_1) & 0 & 0 & 0 \\
0 & \ddots & 0 & 0 \\
0 & 0 & (1 - \phi_{j-1}) & 0 \\
0 & 0 & 0 & (1 - \phi_j)
\end{bmatrix} P. \tag{1}
\]

The fractions \( p_j \) are the solutions to the system of equations \( p = p\Pi \). A detailed description of this process is available in the Appendix of Heathcote’s paper.

Young households are born as renters. In this model, we do not allow for inter-generational transfers of wealth (financial or non-financial) or human capital. Instead, we assume that, upon death, estates are taxed at a 100 percent rate by the government and immediately resold.

2.2 Preferences

In spirit of Ríos-Rull and Sánchez-Marcos (2008), Kiyotaki, Michaelides, and Nikolov (2008) and Chatterjee and Eyigungor (2009), we assume that each household has a per-period utility function of the form:

\[ U(c, s, h') \]

where \( c \) stands for nondurable consumption, \( s \) represents the consumption of shelter services, and \( h' \) is the household’s current period holdings of the housing stock after the within-period labor income shock has been realized. Shelter services can be obtained either via rental market at a constant price \( \rho \) or though homeownership at a constant price \( q \) per unit of housing. A linear technology is available that transforms one unit of housing stock, \( h' \), into one unit of shelter services, \( s \).

The household’s choices about the amount of housing services consumed relative to the housing stock owned, \( (h' - s) \), determine whether a household is renter \( (h' = 0) \), owner-occupier \( (h' = s) \), or landlord \( (h' > s) \). Landlords lease \( (h' - s) =: t \) to renters at rental rate \( \rho \). Many recent studies assume that renters receive lower utility from a unit of housing services than homeowners (see,
for example, the studies named above). In this model, we assume that renters receive the same utility from housing services as homeowners, but landlords face a utility loss caused by the burden of maintaining and managing a rental property.

2.3 Assets and market arrangements

There are three assets in the economy: houses \((h \geq 0)\), deposits \((d \geq 0)\) with an interest rate \(r\), and collateral debt \((m \geq 0)\) with a mortgage rate \(r^m\). Households may alter their individual holdings of the assets \(h, d, m\) to the new levels \(h', d', m'\) at the beginning of period after observing their within-period income shock \(w\).

Houses are big items with discrete sizes, \(h \in \{0, h(1), ..., h(m)\}\), and there is a minimum house size available for purchase, \(h(1)\). Households may choose not to own a house \((h = 0)\), in which case they obtain shelter through the rental market. Agents also make a discrete choice about shelter consumption. Households can rent a small unit of shelter, \(g\), which is smaller that than the minimum house size available for purchase, \(g < h(1)\). To maintain symmetry between shelter sizes available to homeowners and renters, we assume that all other levels of shelter consumption must match a point on the housing grid, so \(s \in \{g, h(1), ..., h(m)\}\). The total housing stock, \(H\), is fully owned by households and its size does not change over time.\(^8\) Our set-up with endogenous house prices and inflexible housing supply thus represents an alternative to a production economy where land – the input factor into the housing production – is in fixed supply.

Houses are costly to buy and sell. Households pay a non-convex transactions costs of \(\tau^b\) percent of the house value when buying a house, and pay \(\tau^s\) percent of the value of the house when selling a house. The total transactions costs incurred when buying or selling a house are \(\tau^b q h'\) and \(\tau^s q h\). The presence of transactions costs reduces the transaction volume in the economy, and generates sizeable inaction regions with regard to the household decision to buy or sell. In particular, only a part of the total housing stock is traded every period in a model with non-convex transaction costs. The total housing supply and demand are thus determined endogenously, and are respectively upward and downward sloping functions of the house price. Similarly, the demand and supply of property in the rental market are endogenously determined, with the rental supply determined by the individual demands for housing and shelter, \(h' - s\).

Homeowners incur maintenance expenses, which offset physical depreciation of housing properties. The actual expense depends both upon the value of housing and upon the level of \(s\) in relation to \(h'\) (e.g., the amount of the property that is rented to other households). Housing which is consumed by the owner depreciates at rate \(\delta_o\). We assume that a moral hazard problem exists in the rental market for housing services, namely that housing occupied by a renter depreciates more rapidly than owner occupied housing. This problem arises because renters decide how intensely to utilize a house but may not actually pay the resulting cost, which creates an incentive to overutilize the property. The depreciation rate for rented property is \(\delta_r\), and \(\delta_r > \delta_o\). Thus, current total maintenance costs facing an agent who has just chosen housing equal to \(h'\) are given by

\[
M(h', s) = I^{h' \neq 0} [\delta_0 s + \delta_r (h' - s)],
\]

with the binary indicator \(I^{h' \neq 0}\) denoting that a household is a homeowner.

\(^8\) The available empirical evidence suggests that the housing supply grew in the U.S. metropolitan regions grew only modestly since 1995. Namely, according to the Census data, the median square footage per housing unit increased by 4 percent between 1997 and 2007 in the United States, but most of these increases were observed outside the metropolitan statistical areas. For example, outside MSAs, the median square foot increased by 13 percent between 1997 and 2007. In a sharp contrast, the median square foot per housing unit in MSA cities decreased at -0.2 percent between 1997 and 2007, while in MSA suburbs the square foot per house grew by 1.5 percent over the period. Moreover, the increases in the aggregate housing supply coincided with population growth which increased the U.S. population increased by 12.5 percent between 1997 and 2007 (4.7 percent between 2000 and 2005).
Homeownership confers an access to collateralizes borrowing at a constant markup over the risk-free deposit rate, \( r \), so that \( r^m = r + \kappa \). Borrowers must, however, satisfy the minimum equity requirement given by the constraint
\[
m' \leq (1 - \theta)qh',
\]
with \( \theta > 0 \). The equity requirement effectively disposes of free-entry to the housing market, since households interested in buying a house with a market value \( qh' \) must put down at least a fraction \( \theta \) of the value of the house. By the same token, households who wish to sell their house and move to a different size house or become renters must repay all the outstanding debt, since the option of a mortgage default is not available. The accumulated housing equity above the down payment can, however, be used as collateral for home equity loans.\(^9\)\(^10\)

2.4 The Government

We follow Díaz and Luengo-Prado (2008) in modeling a tax system with a preferential tax treatment of owner-occupied housing that mimics the U.S. system in a stylized way. Namely, in addition to the taxation of household labor and asset income, the government imposes a proportional property tax on housing which is fully deductible from income taxes, and allows deductions for interest payments on collateral debt (mortgages and home equity). As in the U.S. tax code, the imputed rental value of owner-occupied housing is excluded from taxable income. We expand on the tax treatment of rental property in existing models of the housing market by allowing landlords to deduct depreciation of the rental property from their taxable income. For simplicity, we assume proportional income taxation at the rate \( \tau^y \). We do not require a balanced budget every period.

The total taxable income is thus defined as
\[
\tilde{y} = w + rd + I^{h'}\neq 0 \left[ -\tau^m r^m m - \tau^h qh' \right] + I^{h'>s} \left[ \rho (h' - s) - \tau^{LL} q (h' - s) - \delta r q (h' - s) \right], \tag{4}
\]
where \( w + rd \) represents household labor income plus earned interest. The first term in brackets represents the tax deduction received by homeowners, where \( \tau^m r^m m \) is the mortgage interest deduction, and \( \tau^h qh' \) is the fully deductible property tax payment made by the household. The next term in brackets represents the taxable rental income of landlords, which equals total rents received, \( \rho (h' - s) \), minus the tax deductions available to landlords. The term \( \tau^{LL} q (h' - s) \) represents the tax deduction for depreciation of the rental property, where \( \tau^{LL} \) represents the fraction of the total value of the rental property that is tax deductible in each year. The final term that determines taxable rental income, \( \delta r q (h' - s) \), represents tax deductible maintenance expenses. If the tax deductions for the rental property exceed rental income, so \( \rho (h' - s) < \tau^{LL} q (h' - s) + \delta r q (h' - s) \), then rental losses will reduce the households’ tax liability by offsetting income from wages and interest, \( w + rd \).

At this point it is useful to discuss the current U.S. tax treatment of landlords and explain how the key features of the tax code are incorporated into our model. Landlords must pay income taxes on rental income. However, landlords are permitted to deduct many different expenses associated with operating a rental property from their gross rental income when determining the amount of rental income that is subject to income taxes. Among the major tax deductible rental expenditures incorporated into our model are mortgage interest payments, property taxes paid on the rental property, depreciation of the rental structure, and maintenance expenditures.\(^\text{11}\) The amount of

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\(^9\)Similarly to Díaz and Luengo-Prado (2008), we abstract from income requirements when purchasing houses. See their paper for further discussion.


\(^\text{11}\)Other expenses that are tax deductible but not incorporated in our model are expenses related to advertising, travel to the rental property, commissions, insurance, legal and professional fees, management fees, supplies, and
the depreciation deduction is specified in the U.S. tax code, and we discuss the exact depreciation rate used in our model in Section 4. In addition, landlords who meet a minimum standard of involvement with their rental property may use rental losses to offset income earned from sources other than real estate.\footnote{A maximum of $25,000 in rental property losses can be used to offset income from other sources, and this deduction is phased out between $100,000 and $150,000 of income. In our stylized model we abstract away from the $25,000 limit and we do not incorporate the phasing out of this deduction for high income households into our model of the tax system.}

### 2.5 The Dynamic Programming Problem

A household starts any given period $t$ with a stock of residential capital, $h \geq 0$, deposits, $d \geq 0$, and collateral debt (mortgage- and equity loans), $m \geq 0$. Households observe the idiosyncratic earnings shocks, $w$, and – given the current prices $(q, \rho)$ – solve the following problem:

$$v(w, d, m, h) = \max_{c,s,h^\prime,d^\prime,m^\prime} U(c, s, h^\prime) + \beta \sum_{w^\prime \in W} \pi(w^\prime | w)v(w^\prime, d^\prime, m^\prime, h^\prime)$$

subject to

$$c + \rho (s - h^\prime) + d^\prime - m^\prime + q(h^\prime - h) + I^s\tau^s qh + I^b\tau^b qh^\prime \leq w + (1 + r)d - (1 + \tau^m)m - \tau^y \tilde{y} - \tau^h qh^\prime - qM(h^\prime, s)$$

$$m^\prime \leq (1 - \theta) qh^\prime$$

$$m^\prime \geq 0$$

$$d^\prime \geq 0$$

$$h^\prime \geq s.$$  

by choosing the non-durable consumption, $c$, shelter services’ consumption, $s$, as well as current levels of housing, $h^\prime$, deposits, $d^\prime$, and collateral debt, $m^\prime$. The term $\rho (s - h^\prime)$ represents either a rental payment by renters (i.e., households with $h^\prime = 0$), or the rental income received by landlords (i.e., households with $h^\prime > s$). The term $q(h^\prime - h)$ captures the difference between the value of the housing purchased at the start of the time period ($h^\prime$) and the stock of housing that the household entered the period with ($h$). Transactions costs enter into the budget constraint when housing is sold ($\tau^sqh$) or bought ($\tau^b qh^\prime$), with the binary indicators $I^s$ and $I^b$ indicating the events of selling and buying, respectively. Household labor income is represented by $w$, and it follows the process $\pi_w(w_t | w_{t-1})$ which is described in Section 2.1. Households earn interest income $rd$ on their holdings of deposits in the previous period, and pay mortgage interest $\tau^m m$ on their outstanding collateral debt in the last period. The income and property tax payments are represented by $\tau^y \tilde{y}$ and $\tau^h qh^\prime$, with $\tau^y$ denoting the marginal income tax rate, $\tilde{y}$ representing the total taxable income from Equation 4, and $\tau^h$ being the property tax rate. Finally, $qM(h^\prime, s)$ represents the maintenance expenses for homeowners which is described in Equation 2.

### 3 Definition of a Stationary Equilibrium

In the benchmark economy, we restrict ourselves to stationary equilibria. The individual state variables are deposit holdings, $d$, mortgage balances, $m$, housing stock holdings, $h$, and the household wages, $w$; with $x = (w, d, m, h)$ denoting the individual state vector. Let $d \in \mathcal{D} = \mathbb{R}_+$, $m \in \mathbb{R}_+$ utilities. See IRS publication 527 for details on the tax treatment of residential rental property.
\[ M = \mathbb{R}_+, \ h \in \mathcal{H} = \{ h_1, ..., h_{11} \}, \ \text{and} \ w \in \mathcal{W} = \{ w_1, ..., w_7 \}, \ \text{and let} \ S = \mathcal{D} \times M \times \mathcal{H} \times \mathcal{W} \ \text{denote} \ \ \ \text{the individual state space. Next, let} \ \lambda \ \text{be a probability measure on} \ (S, \mathcal{B}_s), \ \text{where} \ \mathcal{B}_s \ \text{is the Borel} \ \sigma-\text{algebra. For every Borel set} \ B \in \mathcal{B}_s, \ \text{let} \ \lambda(B) \ \text{indicate the mass of agents whose individual state} \ \text{vectors lie in} \ B. \ \text{Finally, define a transition function} \ P : S \times \mathcal{B}_s \rightarrow [0, 1] \ \text{so that} \ P(x, B) \ \text{defines} \ \text{the probability that a household with state} \ x \ \text{will have an individual state vector lying in} \ B \ \text{next period.}

\text{Definition (Stationary Equilibrium): A stationary equilibrium is a collection of value functions} \ v(x), \ \text{a household policy} \ \{ c(x), s(x), d'(x), m'(x), h'(x) \}, \ \text{probability measure}, \ \lambda, \ \text{and price vector} \ (q, \rho) \ \text{such that:}

1. \ c(x), s(x), d'(x), m'(x), \ \text{and} \ h'(x) \ \text{are optimal decision rules to the households'} \ \text{decision problem from 2.5, given prices} \ q \ \text{and} \ \rho.

2. \ \text{Markets clear:}
   \begin{enumerate}
   \item \ \text{Housing market clearing:} \ \int_S h'(x) d\lambda = H, \ \text{where} \ H \ \text{is fixed}
   \item \ \text{Rental market clearing:} \ \int_S (h'(x) - s(x)) d\lambda = 0,
   \end{enumerate}
   \text{where} \ S = \mathcal{D} \times M \times \mathcal{H} \times \mathcal{W}.

3. \ \lambda \ \text{is a stationary probability measure:} \ \lambda(B) = \int_S P(x, B) d\lambda \ \text{for any Borel set} \ B \in \mathcal{B}_s.

4 \ \text{Calibration}

The model is calibrated in two stages. In the first stage, values are assigned to parameters that can be determined from the data without the need to solve the model. In the second stage, the remaining parameters are estimated by the simulated method of moments (SMM). Table 1 summarizes the parameters determined in the first stage. These parameters were drawn from other studies or were calculated directly from the data. Table 2 contains four remaining parameters that we estimate in the second stage based on moments constructed using the data from the American Housing Survey (AHS) and the Census Tables. These moments are listed in Table 3.

\begin{table}[h]
\centering
\begin{tabular}{|c|c|}
\hline
\textbf{Parameter} & \textbf{Value} \\
\hline
Autocorrelation \( \rho_w \) & 0.90 \\
Standard Deviation \( \sigma_w \) & 0.20 \\
Risk Aversion \( \sigma \) & 2.00 \\
Down Payment Requirement \( \theta \) & 0.20 \\
Selling Cost \( \tau^s \) & 0.07 \\
Buying Cost \( \tau^b \) & 0.025 \\
Risk-free Interest Rate \( r \) & 0.04 \\
Spread \( \kappa \) & 0.015 \\
Depreciation Rate for Homeowner-Occupiers \( \delta_0 \) & 0.025 \\
Property Tax Rate \( \tau^h \) & 0.01 \\
Mortgage Deductibility Rate \( \tau^n \) & 1.00 \\
Deductibility Rate for Depreciation of Rental Property \( \tau^{LL} \) & 0.023 \\
Income Tax \( \tau^y \) & 0.20 \\
\hline
\end{tabular}
\caption{Exogenous Parameters}
\end{table}
4.1 Demography and Labor Income

To calibrate the stochastic aging economy, we assume that households live, on average, 50 periods (e.g., \( L = 50 \)). In terms of the process for household productivity, many papers in the quantitative macroeconomics literature adopt simple AR(1) specification to capture the earnings dynamics for working-age households that is characterized by the serial correlation coefficient, \( \rho_w \), and the standard deviation of the innovation term, \( \sigma_w \).\(^\text{13}\) Using the data from the Panel Study of Income Dynamics (PSID), work by Card (1991), Hubbard, Skinner, and Zeldes (1995) and Heathcote, Storesletten, and Violante (2008) indicates a \( \rho_w \) in the range 0.88 to 0.96, and a \( \sigma_w \) in the range 0.12 to 0.25. For the purposes of this paper, we set \( \rho_w \) and \( \sigma_w \) to 0.90 and 0.20, respectively, and follow Tauchen (1986) to approximate an otherwise continuous process with a discrete number (7) of states.

4.2 Preferences

Following the literature on housing choice (see, for example, Díaz and Luengo-Prado (2008), Chatterjee and Eyigungor (2009), Kiyotaki, Michaelides, and Nikolov (2008)), the preferences over the consumption of non-durable goods \( (c) \) and housing services \( (s) \) are modeled as non-separable of the form

\[
U(c, s, h') = (1 - \chi I_{h'>s}) \left(\frac{c^{\alpha}s^{1-\alpha}}{1-\sigma}\right)^{1-\sigma}.
\]

(10)

The risk aversion parameter, \( \sigma \), is set to 2. The remaining parameters that characterize preferences are the weight on non-durable consumption, \( \alpha \), of the Cobb-Douglas aggregator; the discount factor, \( \beta \); and the landlord utility loss parameter, \( \chi \), with the binary variable \( I_{h'>s} \) indicating that a homeowner is also a landlord. These three parameters are estimated in the second stage. Section 4.5 discusses our strategy for identifying these parameters and explains the role of the landlord utility loss in the model.

4.3 Market Arrangements

Using data from the Consumer Expenditure Survey (CE), Gruber and Martin (2003) document that selling cost for housing can be up to 7 percent, while buying costs are around 2.5 percent. We use the authors’ estimates and set \( \tau^h = 0.025 \) and \( \tau^s = 0.07 \). In terms of the maintenance cost function \( M(h',s) \) in Equation (2), Harding, Rosenthal, and Sirmans (2007) estimate the depreciation rate for housing units used as shelter between 2.5 and 3 percent. We thus set \( \delta_0 = 0.025 \). The depreciation rate of rental property, \( \delta_r \), is estimated in the second stage (see Section 4.5).

To calibrate the interest rates on deposits \( r \), we use the interest rate on the 30-year constant maturity Treasury deflated by year-to-year headline CPI inflation. Using the data from the Federal Reserve Statistical Release, the Treasury rate averaged at 3.8 percent for the period between 1977 and 2008.\(^\text{14}\) We thus set the real interest rate to 4 percent so that \( r = 0.04 \). In terms of the mortgage rate \( r_m = r + \kappa \), we calibrate the markup \( \kappa \) to represent the spread between the nominal interest rate on a 30-year fixed-rate conventional home mortgage and the interest rate on nominal 30-year constant maturity Treasury. The average spread between 1977 and 2008 is 1.5 percent, so \( \kappa \) is set to 0.015. In the baseline model, a minimum down payment of 20 percent is required to purchase a home.\(^\text{15}\)

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\(^\text{13}\) Heathcote (2005) discusses alternatives to the AR(1) specification in a technical appendix which is available on the Review of Economic Studies web site.

\(^\text{14}\) See Federal Reserve Statistical Release, H15, Selected Interest Rates.

\(^\text{15}\) Using the American Housing Survey 1993, Chambers, Garriga and Schlagenhauf document that the average down payment is approximately 20 percent.
4.4 Taxes

Using data from the 2007 American Community Survey, Díaz and Luengo-Prado (2010) compute the median property tax rate for the median house value and report a housing property tax rate of 0.95 percent. Moreover, the authors, using information from TAXSIM, the deduction percentage for interest payments of 0.9. We thus set \( \tau^h = 0.01 \), and allow mortgages to be fully deductible so that \( \tau^{m} = 1 \). The U.S. tax code assumes that a rental structure depreciates over a 27.5 year horizon, which implies an annual depreciation rate of 3.63 percent. However, only structures are depreciable for tax purposes, and the value of a house in our model includes both the value of the structure and the land that the house is situated on. Davis and Heathcote (2007) find that on average, land accounts for 36 percent of the value of a house in the U.S. between 1975 and 2006. Based on their findings, we set the depreciation rate of rental property for tax purposes to \( \tau^{LL} = (1 - 0.36) \times 0.0363 = 0.023 \). Lastly, we follow Díaz and Luengo-Prado (2008) and Prescott (2004) and set the income tax rate, \( \tau^y \), to 0.20.

4.5 Estimation

Based on the previous discussion, four structural parameters must be estimated: the Cobb-Douglas consumption share, \( \alpha \), the discount factor, \( \beta \), the landlord utility loss, \( \chi \), and the depreciation rate on rental property, \( \delta_r \). Let \( \Phi = \{\alpha, \beta, \chi, \delta_r\} \) represent the vector of parameters to be estimated. Let \( m_k \) represent the \( k \)-th moment in the data, and let \( m_k(\Phi) \) represent the corresponding simulated moment generated by the model. The SMM estimate of the parameter vector is chosen to minimize the squared difference between the simulated and empirical moments,

\[
\hat{\Phi} = \arg \min_{\Phi} \sum_{k=1}^{4} (m_k - m_k(\Phi))^2. \tag{11}
\]

Minimizing this function is computationally expensive because it requires numerically solving the agents’ optimization problem and finding the equilibrium house price and rent for each trial value of the parameter vector.

The four moments targeted during estimation are the homeownership rate, the landlord rate, the imputed rent-to-wage ratio, and the fraction of homeowners who hold collateral debt. The remainder of this section details the data sources for the targeted moments and discusses how the parameters (\( \Phi \)) impact the simulated moments. The share parameter \( \alpha \) affects the allocation of income between non-durable consumption and shelter by agents in the model. This motivates our use of the imputed rent-to-wage ratio as a targeted moment. Using data from 1980, 1990, and 2000 Decennial Census of Housing, Davis and Ortalo-Magné (2008) estimate the share of expenditures on housing services by renters to be roughly 0.25, and find that the share has been constant across time and MSA regions. The discount factor, \( \beta \), directly impacts the willingness of agents to borrow, so we attempt to match the fraction of owner-occupiers with collateral debt. According to data from the 1994-1998 American Housing Survey (ASH), approximately 65 percent of homeowners report collateral debt balances.\(^{16}\)

The final two targeted moments are the homeownership rate and landlord rate. The homeownership rate averaged 0.66 in the United States between 1995 and 2005. Chambers, Garriga and Schlagenhaft (2008) use the American Housing Survey data to compute the fraction of homeowners who claim to receive rental income. The authors find that approximately 10 percent of the homeowners...
sampled homeowners receive rental income. Targeting the homeownership and landlord moments implies that we are also implicitly targeting the fraction of households who are renters (0.34) and owner-occupiers (0.56) because the landlord, renter, and owner-occupier categories are mutually exclusive and collectively exhaustive. The homeownership and landlord moments provide information about the magnitude of the landlord utility loss parameter ($\chi$) and the depreciation rate of rental property ($\delta_r$). Within the model, the parameters $\chi$ and $\delta_r$ both impact the decision to become a landlord, but they have different implications for household behavior. When the landlord utility loss parameter $\chi$ is greater than zero, a household will only become a landlord if rental income increases utility by enough to offset the fact that $\chi$ reduces the utility received by a landlord from all consumption of housing and shelter. Owners of large houses are able to rent out more space, and consequently are able to obtain more rental income than owners of small houses, so they are more likely to find it optimal to pay the landlord utility cost $\chi$ in order to obtain rental income. In this sense, $\chi$ operates much as a fixed cost of being a landlord would operate in the model. In contrast, an increase in $\delta_r$, holding $\rho$ fixed, reduces the profitability of renting out a unit of housing for all households, and is effectively an increase in the marginal cost of being a landlord.

**Estimated Parameters ($\Phi$):** Table 2 shows the estimated parameters, and Table 3 demonstrates that the model matches the empirical moments used in estimation well. The estimate of the discount factor, 0.959, appears reasonable. To put the estimate of $\delta_r$ in context, recall that we assume that owner occupied housing depreciates at rate $\delta_0 = 0.025$, so our estimate of $\delta_r$ indicates that the depreciation rate for rented property is 1.2 percentage points greater than the depreciation rate of owner occupied property. The estimate of the landlord utility loss parameter, $\chi$, indicates that landlords incur only a 2.4 percent utility loss due to the burden of managing a rental property. The relatively small magnitude of $\chi$ indicates that the decision about whether or not to become a landlord is primarily determined by economic factors which impact the rate of return to investing in rental property, and credit constraints which limit the ability of households to purchase rental property.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Discount Factor $\beta$</td>
<td>0.959</td>
</tr>
<tr>
<td>Consumption Share $\alpha$</td>
<td>0.720</td>
</tr>
<tr>
<td>Depreciation of Rental Property $\delta_r$</td>
<td>0.037</td>
</tr>
<tr>
<td>Landlord Utility Loss $\chi$</td>
<td>0.024</td>
</tr>
</tbody>
</table>

**Table 2: Estimated Parameters**

<table>
<thead>
<tr>
<th>Moment</th>
<th>Data</th>
<th>Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Home-ownership rate</td>
<td>0.66</td>
<td>0.66</td>
</tr>
<tr>
<td>Landlord rate</td>
<td>0.10</td>
<td>0.10</td>
</tr>
<tr>
<td>Imputed rent-to-wage ratio</td>
<td>0.25</td>
<td>0.25</td>
</tr>
<tr>
<td>Fraction of homeowners with collateral debt</td>
<td>0.65</td>
<td>0.64</td>
</tr>
</tbody>
</table>

**Table 3: Calibration Targets**
### Table 4: Other Moments

<table>
<thead>
<tr>
<th>Moment</th>
<th>Model</th>
<th>Data</th>
<th>Data Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Net worth to total income ratio for homeowners</td>
<td>2.94</td>
<td>2.76</td>
<td>SCF 2007</td>
</tr>
<tr>
<td>Housing value to total income ratio for homeowners</td>
<td>3.64</td>
<td>3.60</td>
<td>SCF 2007</td>
</tr>
<tr>
<td>Loan to total income ratio for homeowners</td>
<td>1.19</td>
<td>1.16</td>
<td>SCF 2007</td>
</tr>
<tr>
<td>Loan to value ratio for homeowners</td>
<td>0.31</td>
<td>0.32</td>
<td>SCF 2007</td>
</tr>
<tr>
<td>Rental income receipts to income ratio for landlords</td>
<td>0.28</td>
<td>0.31</td>
<td>AHS 2005</td>
</tr>
<tr>
<td>House price-rent ratio</td>
<td>11.3</td>
<td>8 - 15.5</td>
<td>Various studies*</td>
</tr>
</tbody>
</table>

Notes*: The U.S. Department of Housing and Urban Development and the U.S. Census Bureau report a price-rent ratio of 10 in the 2001 Residential Finance Survey (chapter 4, Table 4-2). Garner and Verbrugge (2009), using Consumer Expenditure Survey (CE) data drawn from five cities over the years 1982-2002, report that the house price to rent ratio ranges from 8 to 15.5 with a mean of approximately 12. The cities included in this analysis are Chicago, Houston, Los Angeles, New York, and Philadelphia.

### 4.6 Moments not Targeted in the Estimation

As an external test of our model, Table 4 reports several other key statistics generated by the model that were not targeted in the estimation, and compares these with the estimates that are either drawn from other studies or the official AHS tables, or are computed from the 2007 Survey of Consumer Finances (SCF). Appendix B describes how we compute the SCF statistics in the data. As can be seen in the table, the reported statistics fall well within the range of recent estimates based on U.S. data. Overall, the ability of the model to replicate a number of key moments that were not targeted during the calibration is encouraging.

### 4.7 Cross-sectional Implications of the Model

There are twelve discrete shelter sizes in our model economy: eleven self-standing discrete-size housing structures that can be purchased in the housing market, and a very small living space that can be rented out but is not available for sale. Discreteness in housing captures the idea that housing units typically come in discrete sizes, such as one bedroom, two bedroom, or four bedroom. At the same time, the smallest-size shelter unit, which we call a “room,” captures the idea that agents can also rent a very small living space that is not, however, available for sale so that, for example, a person can share a room with a roommate or can rent a room while sharing the kitchen. For clarity of exposition, we divide the properties owned by households into three groups called small, medium, and large size properties. The small properties represent starter homes, while medium sized properties are owned by agents who represent the average households in terms of wealth and income. Finally, large properties are in general used for investment, as these often serve as rental units.

Table 5 shows the relationship between units of housing owned and units of shelter consumed in the simulated data. Each row of the table corresponds to ownership of a particular size property, and the columns of the table trace out the distribution of shelter consumption for each level of ownership. For example, the first row of the table shows that 67.9 percent of renters \((h = 0)\) live in a room, while the remaining 32.1 percent of renters inhabit the small size house. The renters are typically hand-to-mouth agents who are at the bottom of the wealth distribution and have savings that are below the minimum down payment requirement for the smallest house. For homeowners \((h > 0)\), the diagonal elements of the table reveal the percentage of agents who own each size house and choose to consume all of the services provided by their house \(h = s\). We refer to these non-landlord homeowners as owner occupiers in the remainder of the paper. Cells below the diagonal in Table 5 refer to landlords, who choose to be a landlord by setting \(s < h\), and renting out \(h - s\)
Table 5: Distribution of Households Across House Sizes

<table>
<thead>
<tr>
<th>Housing Owned (h)</th>
<th>Shelter Services Consumed (s)</th>
<th>% HHs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Room</td>
<td>Small shelter-size</td>
</tr>
<tr>
<td>Renter (h = 0)</td>
<td>67.90</td>
<td>32.10</td>
</tr>
<tr>
<td>Small-size property</td>
<td>0.63</td>
<td>99.37</td>
</tr>
<tr>
<td>Medium-size property</td>
<td>1.57</td>
<td>6.31</td>
</tr>
<tr>
<td>Large-size property</td>
<td>0.00</td>
<td>0.52</td>
</tr>
<tr>
<td>% HHs</td>
<td>23.74</td>
<td>27.77</td>
</tr>
</tbody>
</table>

Table 6: Distribution of Landlords by Labor Income

<table>
<thead>
<tr>
<th>Income group</th>
<th>% Landlords</th>
<th>% Total Rental Property</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 1</td>
<td>3.32</td>
<td>1.7</td>
</tr>
<tr>
<td>Group 2</td>
<td>15.02</td>
<td>10.2</td>
</tr>
<tr>
<td>Group 3</td>
<td>33.85</td>
<td>20.7</td>
</tr>
<tr>
<td>Group 4</td>
<td>15.44</td>
<td>20.8</td>
</tr>
<tr>
<td>Group 5</td>
<td>14.47</td>
<td>20.8</td>
</tr>
<tr>
<td>Group 6</td>
<td>12.32</td>
<td>17.7</td>
</tr>
<tr>
<td>Group 7</td>
<td>5.58</td>
<td>7.8</td>
</tr>
</tbody>
</table>

units of shelter on the rental market.

Landlords are typically highly leveraged and often low earnings households who partially lease out their homes to boost their income level. Table 5 shows that 8.1 percent of the owners of medium sized properties are landlords, and supply 41 percent of the total amount of shelter that is rented. Virtually all owners of large properties are landlords (99.9 percent). Although these households comprise only 5.6 percent of the population, they supply 59 percent of the shelter services that are obtained through the rental market. Table 6 shows that low and middle income agents account for a large fraction of the landlords in the model economy. This prediction is consistent with the findings of Chambers, Garriga and Schlagenhauf (2007) who, using the 1996 Property Owners and Managers Survey, find that 25 percent of households receiving rental income are low-income households with annual earnings below $30,000, compared to 30 percent of high-income households with annual earnings over $100,000 (see their Table 4).

Owner-occupiers consume all of the housing services provided by their property. The vast majority of owner-occupiers are divided between the small and medium house sizes and represent the average household in terms of earnings and financial wealth. The remaining owner occupiers live in large properties, represent only 0.1 percent of the population, and are very rich people with medium to high wages.

In general, homeownership is preferred to renting. Households who can afford a down payment on a house typically enter the housing market and become homeowners. Interestingly, the option to become a landlord plays an important role in our model economy, as rental income helps low and medium income households who are typically highly leveraged to keep up with homeownership expenses and payments. For example, the average owner-occupier of a medium-size house has a large amount of financial wealth and receives a wage endowment that is roughly 30 percent higher than the economy’s average, while an average landlord who owns the same size house earns a wage that is 8 percent lower than average, and is in debt. The option to become a landlord is, however,
also popular among rich homeowners who purchases sizeable properties as an investment.

5 What Explains the Changes in the Price-Rent Ratio?

The estimated model is employed to analyze the observed changes in the house prices, rents, and the price-to-rent ratio since mid-1990s. We first study the model’s predictions about the responsiveness of house prices and rents, and the price-rent ratio, to changes in interest rates, borrowing constraints, and household incomes. Then we consider the combined effects of these macroeconomic factors on the housing market equilibrium. As a cross-check, we also study the model’s implications for the homeownership rate, loan-to-income, and loan-to-value ratios.

5.1 Relaxation of Down Payment Requirements

Since the early 1990s, a number of developments have occurred with respect to the financing of housing investment. Financial innovations such as interest-only loans and combo mortgages provided households with greater choices in mortgage debt financing and significantly reduced down payment requirements. Moreover, policies enacted by the Clinton and Bush Administrations targeted lowering of the down payment requirement to increase households’ access to mortgage financing and to generate additional first-time home buyers. As a result, the average down payment declined from about 20 percent in the mid-1990s to 15 percent in the 2000s.

Figure 2 illustrates the impact of variation in the minimum down payment requirement, \( \theta \), on equilibrium housing market outcomes. As the down payment requirement falls from 40 percent to 15 percent, the equilibrium house price rises by 2.5 percent while the rent decreases by slightly less than 1 percent, so the price-rent ratio increases by 3.4 percent. A reduction in the down payment requirement in line with the recent U.S. experience from 0.20 to 0.15 leads to a 1.8 percent increase in the house price and a 0.04 percent decrease in rent. The price-rent ratio is relatively inelastic with respect to the required down payment, so a lessening of credit constraints cannot by itself explain the large run-up in the price-rent observed in recent years.

That said, a lower required down payment leads to large increases in the homeownership rate as poorer households gain access to mortgage markets and borrow larger amounts to finance home purchases. When \( \theta \) falls from 0.40 to 0.15, the homeownership rate increases from 60 percent to 81 percent. At the same time, the loan-to-wage ratio jumps up from 0.7 to 1.4, while the fraction of homeowners in debt rises from 54 percent to 64 percent. The increase in household borrowing is skewed toward low-earnings households, as relatively more low-wage households enter the housing market.

The key to understanding the small effect of decreases in the required down payment on house prices is to realize that the housing market responses are primarily driven by households who find

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17 The Clinton Administration enacted policies through the Federal Home Administration (FHA) to lower the downpayment requirements with mortgage insured loans, while the Bush Administration developed the Zero-Downpayment Initiative for FHA to generate additional first-time buyers.

18 Chambers, Garriga and Schlagenhauf (2008), using the data from the American Housing Survey (AHS), document that between 1995 and 2003 the average downpayment for FHA loans declined from 21.6 percent in 1995 to 13.8 percent in 1999 before rising again to 16.3 percent in 2003. At the same time, the average downpayment on a non-FHA loan has decreased from 29.8 percent in 1995 to 24.1 percent by 2003. Chomsisengphet and Pennington-Cross (2006) document similar trends in the subprime lending markets. In addition, the fraction of households with a loan to value ratio greater than 90 percent rose from 10 percent in 1990 to 25 percent by 1995 before retracting slightly to 18 percent in 2005, according to the Federal Finance Board. More generally, the down payment requirements were significantly relaxed during the periods 1995-1998 and 2001-2004, although the financial markets tightened slightly temporarily in the wake of the 1998 Asian crisis.

19 The U.S. real house prices rose by 11 percent while the real rents grew by 3 percent between 1995 and 2000. During this period, the real deposit rate on 10 year constant maturity T-bonds oscillated in a relatively narrow range between 3 and 4 percent.
the minimum down payment to be a binding constraint. Decreasing the down payment requirement thus primarily affects low-income, low-savings households who wish to become homeowners but are unable to because of the high equity requirement. As a result, when the down payment requirement falls from 20 percent to 15 percent, the proportion of renters decreases from 34 to 19 percent as previously credit constrained households switch from renting to owning a small-sized house (Table 7).

Table 8 provides further details on how changes in the down payment requirement affect the housing market. Column (2) shows the impact of a decline in the down payment requirement from 20 to 15 percent under the restriction that house prices and rents are not allowed to change (i.e., both house prices and rents are held fixed at their equilibrium values from the baseline version of the model). Column (3) reports the impact of a decrease on the down payment requirement when both house prices and rents are allowed to adjust to clear the housing and rental markets at the lower down payment requirement. As can be seen in Table 8, the share of renters in the economy declines from 0.34 to 0.19 in both the partial and full equilibrium experiments when the required down payment falls (Columns (2) and (3)). In the partial equilibrium experiment, the share of landlords in the economy rises from 0.10 to 0.11 because when the house price and rent are held constant, a decrease in $\theta$ allows households to become landlords who were previously excluded from the market by credit constraints. However, Column (3) shows that when prices are allowed to adjust, the share of landlords actually falls from 0.10 to 0.08. This decline occurs because the increase in the equilibrium house price coupled with the constant equilibrium rent reduces the
Table 7: The Distribution of Owned Housing Under Different Downpayment Requirements

<table>
<thead>
<tr>
<th>House Size</th>
<th>20% Downpayment</th>
<th>15% Downpayment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>% Households</td>
<td>% Housing Stock</td>
</tr>
<tr>
<td>Renter</td>
<td>33.8</td>
<td>0.0</td>
</tr>
<tr>
<td>Small-size property</td>
<td>13.9</td>
<td>11.3</td>
</tr>
<tr>
<td>Medium-size property</td>
<td>48.5</td>
<td>70.8</td>
</tr>
<tr>
<td>Large-size property</td>
<td>3.84</td>
<td>17.7</td>
</tr>
</tbody>
</table>

Table 8: The Partial and Equilibrium Effects of a Reduction in the Equity Requirement to 15%

<table>
<thead>
<tr>
<th></th>
<th>Baseline</th>
<th>15% Equity Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fixed Prices</td>
<td>Equilibrium Prices</td>
</tr>
<tr>
<td>House Price</td>
<td>2.55</td>
<td>2.55</td>
</tr>
<tr>
<td>Rent</td>
<td>0.22</td>
<td>0.22</td>
</tr>
<tr>
<td>Share of Homeowners</td>
<td>0.66</td>
<td>0.81</td>
</tr>
<tr>
<td>Share of Renters</td>
<td>0.34</td>
<td>0.19</td>
</tr>
<tr>
<td>Share of Landlords</td>
<td>0.10</td>
<td>0.11</td>
</tr>
<tr>
<td>Share of Owner-Occupiers</td>
<td>0.56</td>
<td>0.70</td>
</tr>
<tr>
<td>Share of Homeowners in Debt</td>
<td>0.64</td>
<td>0.69</td>
</tr>
</tbody>
</table>

rate of return to being a landlord. As the rate of return declines, fewer households choose to become landlords. Finally, while approximately 15 percent of all households switch from renting to homeownership when the down payment declines, only a 2% increase in the house price is needed to clear the market and accommodate these new homeowners.

Table 7 shows how the steady state distribution of households across house sizes changes when the down payment requirement falls from 20 to 15 percent. While the fraction of households who own small-size houses jumps up by 19 percentage points because of the influx of new homeowners into the housing market, the fraction of households owning the medium-size-property declines by 1.5 percentage points. In addition, the percentage of households who purchase the large houses which are exclusively occupied by landlords falls from 3.8 percent to 1.5 percent, while the percentage of the total housing stock owned by this group declines sharply from 17.7 percent to 7.1 percent. The ownership of this housing is shifted from large property owners to owners of small size properties, who see their share of the housing stock increase from 11 percent to 26 percent. When the down payment declines from 20 percent to 15 percent, the equilibrium response of landlords is to sell housing to their tenants, and they are willing to do this because the house price has risen while the rent has remained constant.20

Our results are consistent with several recent studies which document the positive correlation between the size of the down payment requirement and homeownership (e.g., Chambers, Garriga, and Schlagenhaft (2008), Díaz and Luengo-Prado (2008), and Ortalo-Magné and Rady (2006)). These studies suggest that, while financial sector innovations have minimal impact for existing homeowners, lower down payment requirements do affect households who are excluded from the housing market due to a high down payment constraint. The authors suggest that when down payment requirements are relaxed, the initially excluded households enter the housing market and the

20 This statement is not literally true since the decrease in the downpayment discussed in this section is based on a comparison of two different steady state economies.
homeownership rate rises. This mechanism is supported by the empirical findings in Ortalo-Magné and Rady (1999) who document that decreases in the down payment requirements in England and Wales after the financial liberalization of the early 1980s were associated with unprecedented increases in the homeownership for young households. Using regression analysis, Muellbauer and Murphy (1990), Muellbauer and Murphy (1997) show that while income and short-term demographic changes were the most important factors behind the U.K. house price boom during the 1980s, the increase in homeownership was mostly due to credit market liberalization and extrapolative price expectations.

In summary, the model clearly indicates that in the absence of changes in other factors, a relaxation of borrowing constraints cannot by itself account for the magnitude of the recent increase in the price-rent ratio. With this result in mind, the next sections of the paper examine the impact of changes in the interest rate and income on the equilibrium price-rent ratio.

5.2 Changes in the Interest Rate

Figure 3 shows the evolution of the real contract and effective mortgage rates on conventional single-family mortgages in the United States between 1985 and 2005.\textsuperscript{21} As can be seen in the figure, the real mortgage rate for residential property oscillated around the 5 percent mark between 1990 and 1997, but started to fall following the 1998 Asian Financial Crisis, before falling to 2.5 percent in 2005.

Figure 4 captures the impact of changes in the real risk-free rate, \( r \), on the steady state equilibrium of the housing market. Changes in the risk-free rate interest rate in our model directly translate into changes in the mortgage interest rate because the mortgage interest rate is determined

\[ \text{Effective Rate} = \text{Contract Rate} + \text{Discounted Initial Fees and Charges} \]

The effective rate represents the sum of the contract rate and the discounted initial fees and charges. The estimates provided by the Federal Housing Financing Board.

\textsuperscript{21} The effective rate represents the sum of the contract rate and the discounted initial fees and charges. The estimates provided by the Federal Housing Financing Board.
by a constant markup, $\kappa$, over the risk-free rate.\footnote{The mortgage spread, defined as the difference between the real mortgage rate on a 30-year conventional fixed-rate mortgage and the interest rate on a 30-year constant maturity Treasury, fluctuated in a relatively narrow range between 1 and 2 percent since 1995, although the mark-up fell temporarily below one percent between 1991 and 1993.} Therefore, changes in the risk-free interest rate affect both the cost of borrowing and the rate of return on saving. As can be seen in the figure, when the real interest rate falls from 6 percent to 1 percent, the equilibrium house price increases by 33 percent, the equilibrium rent decreases by 14 percent, and the price-rent ratio increases by 54 percent from 9.9 to 15.2. When the interest rate declines from 4 percent to 2 percent – a decrease broadly consistent with the actual decline between 1995 and 2005 – the house price level rises by 16.4 percent, the rent falls by 2.6 percent, and the price-rent ratio rises by 20 percent from its initial level of 11.3.\footnote{The large effect of changes in the interest rate on the equilibrium house price-rent ratio is consistent with the empirical findings in Campbell et al. (2009) who show that the recent run-up in the price-rent ratio owes significantly to a decline in real interest rates and a decline in the housing premium.} The fact that our model is capable of generating equilibrium increases in house prices that coincide with declining rents is a key distinction between our model and models of the housing market that are based on a representative rental firm. In these representative firm models, rents are set by an arbitrage condition that governs the behavior of the representative firm, so house prices and rents must always move in the same direction. This is contrary to the recent U.S. data, where constant or declining rents coincided with large increases in house prices.

As expected, a lower interest rate leads to a large increase in household borrowing, since the low interest rate decreases the cost of mortgage financing and, at the same time, lowers the rate of...
Table 9: The Distribution of Owned Housing and Landlords Under Different Interest Rates

<table>
<thead>
<tr>
<th>House Size</th>
<th>6% Interest Rate</th>
<th>4% Interest Rate</th>
<th>2% Interest Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>% HHs % Landlords</td>
<td>% HHs % Landlords</td>
<td>% HHs % Landlords</td>
</tr>
<tr>
<td>Renter</td>
<td>18.9 0.0</td>
<td>33.7 0.0</td>
<td>34.2 0.0</td>
</tr>
<tr>
<td>Small property</td>
<td>46.2 25.6</td>
<td>13.9 0.9</td>
<td>12.3 0.9</td>
</tr>
<tr>
<td>Medium property</td>
<td>31.4 28.1</td>
<td>48.5 62.3</td>
<td>48.0 45.9</td>
</tr>
<tr>
<td>Large property</td>
<td>3.4 46.4</td>
<td>3.8 36.8</td>
<td>5.6 53.2</td>
</tr>
</tbody>
</table>

Table 10: The Partial and Equilibrium Effects of the Interest Rate Reduction to 2%

<table>
<thead>
<tr>
<th></th>
<th>Baseline ($r = 0.04$)</th>
<th>Reduction of Interest Rate to 2%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1) Fixed Prices</td>
<td>(2) Equilibrium Prices</td>
</tr>
<tr>
<td>House Price</td>
<td>2.55</td>
<td>2.55</td>
</tr>
<tr>
<td>Rent</td>
<td>0.22</td>
<td>0.22</td>
</tr>
<tr>
<td>Share of Homeowners</td>
<td>0.66</td>
<td>0.81</td>
</tr>
<tr>
<td>Share of Renters</td>
<td>0.34</td>
<td>0.19</td>
</tr>
<tr>
<td>Share of Landlords</td>
<td>0.10</td>
<td>0.49</td>
</tr>
<tr>
<td>Share of Owner-Ocupiers</td>
<td>0.56</td>
<td>0.32</td>
</tr>
<tr>
<td>Share of Homeowners in Debt</td>
<td>0.64</td>
<td>0.94</td>
</tr>
</tbody>
</table>

return on household savings. The average loan-to-wage ratio increases from 0.66 to 3.0 when the interest rate permanently declines from 6 percent to 1 percent, while the fraction of homeowners with mortgage debt rises from 40 percent to 88 percent. For a decline in the interest rate from 4 percent to 2 percent, the loan-to-wage ratio roughly doubles, rising from 1.4 to 2.9.

Turning to the rental market, lower interest rates increase the supply of rental property because, holding the rent fixed, a lower interest rate increases the rate of return to investing in rental property for landlords with mortgages. In addition, investing in rental properties also becomes more attractive relative to the alternative of holding bank deposits. The increase in rental supply decreases the equilibrium rent, so rents are falling even though house prices are rising. For example, when the interest rate decreases from 4 to 2 percent, the aggregate supply of rental property rises increases by 4 percent while the rent falls from 0.22 to 0.21.

Table 9 shows the effects of changes in the interest rate on the distribution of households and landlords across house sizes. At a 6 percent interest rate, owners of small properties account for 25.6 percent of all landlords, because these households use rental income to keep up with high mortgage interest payments. When the interest rate declines from 6 percent to 4 percent, there are more renters in the economy, fewer small homeowners, and more owners of medium size properties. At the same time, owners of medium size properties now account for the majority (62.3 percent) of landlords. As the interest rate declines further to 2 percent, the composition of landlords shifts towards owners of large properties, who make up 5.6 percent of all households, and account for 53.2 percent of all landlords in the economy.

Figure 4 shows that the steady state homeownership rate is constant for interest rates between 2 and 4 percent. One might expect the homeownership rate to rise as the interest rate decreases from 4 to 2 percent because a falling risk-free interest rate both decreases the cost of mortgage financing and reduces the attractiveness of saving relative to housing investment. However, this is a situation where accounting for equilibrium price effects is critical, as Table 10 illustrates. As
can be seen in Column (2), a reduction in $r$ from 4 percent to 2 percent under the restriction that the house price and rent are not allowed to adjust would result in a 15 percent increase in the homeownership rate from 0.66 to 0.81, and an increase in household borrowing because of the lower cost of mortgage financing. At the same time, the fraction of landlords in the economy would rise by 39 percent from 0.10 to 0.49, because households would purchase bigger properties and use rental income to keep up with the mortgage payments. However, in the general equilibrium where the house prices and rents can adjust (Column (3)), the homeownership rate remains constant. In equilibrium, the decline in the interest rate has no effect on the homeownership rate because the higher house price increases the minimum down payment requirement while a lower $r$ decreases the speed at which the aspiring first-time buyers are able to save up for it. Also, the equilibrium rent decreases slightly from 0.22 to 0.21 even though house prices are rising, which further discourages households from becoming homeowners. All of these effects offset the fact that mortgage interest payments decrease when the interest rate falls.

5.3 Changes in Income

A large body of empirical literature identifies the level and growth rate of income as an important determinant of house price dynamics (see, for example, Poterba (1991), Englund and Ioannides (1997), Mullerbauer and Murphy (1997), Malpezzi (1999), and Sutton (2002)). In the United States, real hourly wages increased by 9.4 percent between 1995 and 2005.²⁴

Figure 5 summarizes the impact of changes in income on the housing market equilibrium. In our experiment, we assume that household wages rise at the same rate across all wage groups. The model suggests that both house prices and rents increase linearly at about the same rate as wages.²⁵ For example, when the wage level increases by 10 percent relative to the benchmark economy, the equilibrium house price and the rent rise by approximately 11 percent. As a result, the house price-rent ratio stays approximately flat. Since the relative price of obtaining housing services through the rental market compared to the market for owned housing remains unchanged, symmetric changes in income of the sort examined here have no effect on the homeownership and landlord rates.

Table 11 helps to explain why the homeownership rate does not rise with income. Again, Column (2) shows the impact of a 10 percent increase in income under the restriction that house prices and rents are not allowed to change (i.e., both house prices and rents are fixed at their equilibrium values from the baseline version of the model). Column (3) reports the impact of a 10 percent increase in income when both house prices and rents are allowed to adjust to clear the housing and rental markets at the higher income level. When house prices and rents are not allowed to adjust, rising income has a substantial impact on the housing market, with the homeownership rate increasing from 66 to 92 percent as more households are able to afford the down payment and mortgage payments required to purchase a house. In addition, many households stop renting out their units as they can more easily cover their mortgage payments: the share of owner-occupied housing increases from 0.56 to 0.71. However, once the house prices and rents are allowed to adjust to higher incomes, homeownership returns approximately to its baseline level (Column (3)). When income increases by 10 percent, the equilibrium house price increases by about the same rate from

²⁴This calculation is based on the BLS Current Employment Statistics (CES) real wage data, series ID CES0500000032.

²⁵The actual changes in the income levels were not, however, symmetric. Heathcote, Perri, and Violante (2009) document the changes in the U.S. earnings inequality between 1967 and 2006. Using the CPS data, the authors find that the real earnings of the bottom decile of the earnings distribution did not, on average, grow between 1985 and 2000, although the earnings of the top earnings distribution grew steadily over the sample period (see their Figure 7). The authors also find that the wage dynamics of the bottom decile of the earnings distribution is very similar to those for the median workers (e.g., workers in the 45-55 percentile of the earnings distribution).
2.55 to 2.85, while the equilibrium rent increases from 0.22 to 0.25. The relative cost of renting and owning remains unchanged, keeping the proportions of renters, homeowners, landlords, and owner-occupiers in the economy essentially the same as in the benchmark specification.

5.4 Combined Effects of Changes in Market Fundamentals

As discussed in the preceding sections, neither declines in the real interest rate, relaxation of borrowing constraints, nor rising incomes can on their own account for the increase in the price-rent ratio, homeownership rate, and household debt between 1995 and 2005. This section examines the combined effects of changes in these fundamentals on equilibrium housing market outcomes. Figure 6 depicts the percentage deviation of the steady state price-rent ratio from the baseline economy for a range of interest rates and required down payments. Point A represents the calibrated baseline economy with an interest rate on deposits, \( r \), of 4 percent and a required down payment, \( \theta \), of 20 percent. As the interest rate and the required down payment decrease, the price-rent ratio steadily rises. The price-rent ratio increases by 20 percent over its baseline value when the interest rate is 2 percent and the required down payment is 15 percent. These changes in the interest rate and down payment seem to be a reasonable representation of the recent U.S. experience. For comparison, the U.S. price-rent ratio increased by 36 percent from 1995 to 2005, and by 26 percent between 2000 and 2005.

Table 12 provides a more comprehensive analysis of the simulated effects by showing the per-
Table 11: The Partial and Equilibrium Effects of a 10% Increase in Income

<table>
<thead>
<tr>
<th></th>
<th>Baseline</th>
<th>10% Increase in Income</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Fixed Prices</td>
<td>Equilibrium Prices</td>
</tr>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
</tr>
<tr>
<td>House Price</td>
<td>2.55</td>
<td>2.55</td>
<td>2.85</td>
</tr>
<tr>
<td>Rent</td>
<td>0.22</td>
<td>0.22</td>
<td>0.25</td>
</tr>
<tr>
<td>Share of Homeowners</td>
<td>0.66</td>
<td>0.92</td>
<td>0.67</td>
</tr>
<tr>
<td>Share of Renters</td>
<td>0.34</td>
<td>0.21</td>
<td>0.33</td>
</tr>
<tr>
<td>Share of Landlords</td>
<td>0.10</td>
<td>0.08</td>
<td>0.11</td>
</tr>
<tr>
<td>Share of Owner-Occupiers</td>
<td>0.56</td>
<td>0.71</td>
<td>0.56</td>
</tr>
<tr>
<td>Share of Homeowners in Debt</td>
<td>0.64</td>
<td>0.70</td>
<td>0.64</td>
</tr>
</tbody>
</table>

Table 12: The Combined Effects of Interest Rate, Required Downpayment, and Income Changes

<table>
<thead>
<tr>
<th></th>
<th>Baseline</th>
<th>Changes in r and $\theta$ (%Δ from Baseline )</th>
<th>U.S. Data (%Δ)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>r=0.04 $\theta=0.2$</td>
<td>1995-2005</td>
</tr>
<tr>
<td></td>
<td></td>
<td>r=0.02 $\theta=0.15$</td>
<td>(1)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$\Delta w = 0%$</td>
<td>(3)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$\Delta w = 10%$</td>
<td>(5)</td>
</tr>
<tr>
<td>house price</td>
<td>2.55</td>
<td>16.1%</td>
<td>46.3%</td>
</tr>
<tr>
<td>rental price</td>
<td>0.22</td>
<td>-3.5%</td>
<td>7.5%</td>
</tr>
<tr>
<td>price-rent ratio</td>
<td>11.3</td>
<td>20.0%</td>
<td>36.1%</td>
</tr>
</tbody>
</table>

Notes: Columns (2) - (3) show percent changes in the equilibrium value of each variable from the baseline model shown in column (1). Columns (4) and (5) show the actual percent changes observed in the U.S. over two different time periods.
Figure 6: Percentage Deviations of the House Price-Rent Ratio from the Baseline (Point A) Under Different Interest Rates and Required Downpayment

percentage deviations in house prices, rents, and the price-rent ratio from their baseline values (Column (1)). To facilitate a comparison of the model’s predictions to the data, Columns (4) and (5) show recent changes in the U.S. data. Column (2) shows that when income is held constant, lowering $\theta$ and $r$ raises house prices, lowers rents, and consequently increases the price-rent ratio. Column (3) of Table 12 shows that increasing wages by 10 percent while decreasing $\theta$ and $r$ does not change the price-rent ratio compared to the scenarios where income is held constant.\(^{26}\) However, the model also predicts that higher income will cause a small increase in rents that is quite close to the growth in rents observed in the United States. As noted above, the actual increase in the house price-rent ratio from 1995 to 2005 was about 36 percent, so a plausible calibration of the model can account for over one-half of the observed increase. These results suggest that the changes in the interest rate and required down payment observed in the United States had a substantial impact on the price-rent ratio. In addition, the ability of our model to simultaneously predict large increases in house prices and sluggish rents is consistent with recent developments in the U.S. housing market and stands in marked contrast with predictions of simpler models of the housing market which imply that equilibrium house prices and rents must change in the same direction and at the same rate.

In our model, holding house prices and rents constant, when the mortgage interest rate and required down payment fall, the demand curve for rental property shifts inward because households

\(^{26}\) A 10 percent increase in real wages is approximately what was observed in the U.S. between 1995 and 2005.
switch from renting to owning as homeownership becomes more affordable. At the same time, the supply curve for rental property shifts to the right because when \( \theta \) and the interest rate decrease, more households are able to afford down payments and mortgage payments on rental properties. In addition, since both the mortgage rate and rate of return on deposits fall when interest rates decrease, investing in rental property becomes more attractive relative to the alternative of holding bank deposits. The net result of the declining demand and increasing supply in the rental market is a decrease in the equilibrium rent. At the same time, the demand for housing (or homeownership) increases when the interest rate and the required down payment decrease because more households can afford to purchase homes, and existing homeowners can afford larger homes. Given that the supply of housing is fixed, the equilibrium house price rises. It follows that the price-rent ratio increases as the house price increases and rent falls in response to the change in fundamentals.

6 Transitional Dynamics

Up to this point, we have confined our analysis to comparisons of different steady state economies. This section studies the transitional dynamics of the housing market between two steady states. We assume that the economy is initially in a steady state that corresponds to the baseline calibration of the model, where the interest rate is 0.04 and the required down payment is 20 percent. Starting

\(^{27}\) When the downpayment requirement declines from 20 to 10 percent and the interest rate falls from 4 to 2 percent, the homeownership rate increases by 1.4 percent from 0.66 to 0.674.
from this initial steady state, the interest rate and required down payment unexpectedly and permanently fall to $r = 0.02$ and $\theta = 0.15$. We solve for the rational expectations transition path for the house price and rent which ends in the new steady state. Along the transition path, all agents correctly forecast the sequence of equilibrium house prices and rents which leads to the new steady state, and the housing market clears in each time period.

Figure 7 shows the transition path for the house price, rent, and price-rent ratio. In the first period of the transition, both the house price and rent overshoot the values that they will eventually converge to in the new steady state. In the first period of the transition, the house price increases by 25 percent, the rent increases by 15 percent, and the price-rent ratio increase by 9 percent. After the initial spike in the house price and rent, the market clearing prices decline gradually over time, and the price-rent ratio steadily increases to its new steady state level. After the initial unexpected shock, it takes many years for the economy to converge to the low interest rate and low down payment steady state.

The most interesting feature of the transition path is the overshooting displayed by both the house price and rent in the first period of the transition. The first mechanism driving this result is a portfolio reallocation between deposits and housing by households. In the initial steady state economy, households hold a relatively large amount of financial wealth (deposits) because of the 4 percent rate of return on the risk free financial asset and relatively high 20 percent minimum down payment. When the interest rate and required down payment unexpectedly decline in the first period of the transition, households have an incentive to shift their portfolios from deposits into housing. This happens because the fall in the interest rate lowers the rate of return on deposits and lowers the cost of mortgage financing. The shift from deposits into housing is magnified by the fall in the required down payment from 20 to 15 percent, which further increases the ability of households to finance purchases of housing. As a result, the house price and rent jump upwards in the first period. However, the initial spike in the house price and rent are not sustainable as a long run equilibrium because they are fueled by the large amount of financial wealth that households are able to accumulate in the high interest rate steady state. Over time, the house price and rent decrease as households draw down their financial wealth, and live for more time periods with the low interest rate.

The second mechanism driving the overshooting in the house price and rent is a capital gains mechanism. The initial increase in the house price allows existing homeowners in the first period of the transition to capitalize gains and move up to larger houses. Over time this effect fades as capital gains dissipate, and households adjust to the new level of interest rates and required down payment. This mechanism operates in the same manner as the one discussed in Ortalo-Magné and Rady (2006).

7 Taxes, Transactions Costs, and the Price-Rent Ratio

This section examines the effect of the preferential tax treatment of homeowners and landlords on the level of the price-rent ratio and the responsiveness of the price-rent ratio to changes in the interest rate.\(^{28}\) The results show that both the tax system and the presence of transactions costs impact the level of the price-rent ratio and its responsiveness to changes in the interest rate.

Table 13 shows the percent change in the equilibrium house price, rent, and price-rent ratio from the baseline economy under two counterfactual tax systems. In the first counterfactual, shown in column (1), the mortgage interest and property tax deductions for homeowners are eliminated. The elimination of these tax deductions causes the equilibrium house price to decrease by 4.9 percent because the demand for housing declines. At the same time, the rent increases by 1.3 percent.

\(^{28}\) We focus on the interest rate in this section because changes in taxes and transactions costs have little impact on the responsiveness of the price-rent ratio to changes in the required downpayment.
Table 13: The Effect of Homeowner and Landlord Tax Deductions on the Price-Rent Ratio

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eliminate Homeowner Deductions</td>
<td>Eliminate Landlord Deductions</td>
<td></td>
</tr>
<tr>
<td>House price</td>
<td>-4.9%</td>
<td>2.1%</td>
</tr>
<tr>
<td>Rent</td>
<td>1.3%</td>
<td>16.0%</td>
</tr>
<tr>
<td>Price-rent ratio</td>
<td>-6.3%</td>
<td>-12.0%</td>
</tr>
</tbody>
</table>

because the demand for rental property by tenants increases. The decrease in the house price and the increase in the rent cause the price-rent ratio to fall by 6.3 percent.

Interestingly, the model predicts that eliminating the preferential tax treatment of owner occupied housing would actually cause the steady state homeownership rate to increase slightly from 66 percent to 67 percent. This result is contrary to the popular perception that the current U.S. tax treatment of homeowners increases the homeownership rate by lowering the after tax interest cost of mortgages. This prediction of the model is driven by the equilibrium price changes caused by tax deductions. Although the tax deductions available to homeowners reduce the cost of homeownership when prices are held fixed, this is not the case when the house price and rent are allowed to adjust to clear the housing market. In equilibrium, the preferential tax treatment of housing causes the house price to be higher and the rent to be lower than they would be if these deductions were not available to homeowners. The relative price change between homeownership and renting caused by the tax deductions reduces the steady state homeownership rate below what it would be in an economy without the homeowner tax deductions currently present in the U.S. tax code.

Column (2) of Table 13 shows the effect of eliminating landlord tax deductions for mortgage interest, property taxes, and depreciation. Eliminating these deductions causes the house price to increase by 2 percent, and causes the rent to increase by 16 percent. As a result, the price-rent ratio declines by 12 percent when the landlord tax deductions are eliminated. The large relative price change between renting and owning is driven by a reduction in the supply of rental property. In equilibrium, the percentage of landlords in the economy declines by approximately one-half when the landlord tax deductions are eliminated. At the lower equilibrium price-rent ratio, households shift from renting to owning, and the homeownership rate increases by 18 percent, while the percentage of renters in the economy falls by 38 percent.

In addition to its impact on the level of the price-rent ratio, the preferential tax treatment of homeowners and landlords also increases the responsiveness of the price-rent ratio to changes in interest rates. A decrease in the interest rate from 4 percent to 2 percent causes a 22 percent increase in the price-rent ratio under the baseline tax system. When homeowner or landlord tax deductions are eliminated, this response falls to 14 percent and 11 percent, respectively. From the point of view of tax policy, these results suggest that the preferential tax treatment of housing in the U.S. causes the house price-rent ratio to be more volatile than it would be if these deductions were eliminated.

Transactions costs play an important role in determining the equilibrium house price and rent. When the costs of buying ($\tau^b$) and selling ($\tau^s$) a house are set equal to zero, the equilibrium house price increases by 32 percent, the equilibrium rent increases by 24 percent, and the price-rent ratio increases by approximately 7 percent. These effects arise because eliminating transactions costs directly increases the demand for housing and decreases the demand for rented shelter by tenants. In addition, there is an income effect that increases the level of both house prices and rents because agents are wealthier, all else constant, in an economy without transactions costs. In the economy without transactions costs, when the interest rate falls from 4 percent to 2 percent, the price-rent ratio increases by 16 percent versus 22 percent in the baseline economy. These results demonstrate the importance of accounting for the lumpy transactions costs incurred during home sales and
purchases when modeling the housing market. Ignoring these transactions costs would lead to an understatement of the responsiveness of the price-rent ratio to changes in interest rates and would lead to an overstatement of the level of the price-rent ratio.

8 Conclusion

This paper develops a dynamic equilibrium model of the housing market in which both house prices and rents are determined endogenously. We use the model to study the relationship between the steady state house price-rent ratio and fundamentals such as the interest rate, required down payment, and income. This analysis is motivated by the fact that although the price-rent ratio is a widely used economic indicator, its determinants are not well understood. Without a theoretical understanding of how the price-rent ratio is determined, it is not possible to determine whether observed changes in the relationship between house prices and rents reflect changing fundamentals or an asset price bubble.

The model predicts that the combination of low interest rates, reduced down payment requirements, and rising wages observed in the United States leads to a large increase in the steady state, rational expectations equilibrium price-rent ratio. However, changes in these fundamentals are capable of explaining only about one-half of the 36 percent increase in the price-rent ratio observed between 1995 and 2005. At the same time, changes in fundamentals generate increases in the homeownership rate and household debt that are consistent with the recent U.S. experience.

9 Appendix A

9.1 Finding Equilibrium in the Housing and Rental Markets

Equilibrium in the housing and rental markets is formally defined by the conditions presented in Section 3. In practice, the market clearing rent \( \rho^* \) and house price \( q^* \) are found by finding the \( (q^*, \rho^*) \) pair that simultaneously clear both the housing and shelter markets in a simulated economy. The market clearing conditions for a simulated cross section of \( N \) agents are

\[
\sum_{i=1}^{N} h_i'(q^*, \rho^*|x) = H
\]

\[
\sum_{i=1}^{N} s_i'(q^*, \rho^*|x) = H.
\]

The optimal housing and shelter demands for each agent are functions of the market clearing steady state prices and the agents other state variables \( x \). Solving for the equilibrium of the housing market is a time consuming process because it involves repeatedly re-solving the optimization problem at potential equilibrium prices and simulating data to check for market clearing until the equilibrium prices are found. The algorithm outlined in the following section exploits theoretical properties of the model such as downward sloping demand when searching for market clearing prices. Taking advantage of these properties decreases the amount of time required to find the equilibrium far below that of a more naive search algorithm.

9.2 The Algorithm

Let \( q_k \) represent the \( k \)th guess of the market clearing house price, let \( \rho_k \) represent a guess of the equilibrium rent, and let \( \rho_k(q_k) \) represent the rent that clears the market for housing conditional
The following algorithm is used to find the market clearing house price and rent. The equilibrium prices \( q^* \) and \( \rho^* \) simultaneously clear the markets for housing and shelter, so

\[
ED^h_k(q_k, \rho_k) = 0 \quad \text{and} \quad ED^s_k(q^*, \rho^*) = 0.
\]

The following algorithm is used to find the market clearing house price and rent.

1. Make an initial guess of the market clearing house price \( q_k \).

2. Search for the rent \( \rho_k(q_k) \) which clears the market for owned housing conditional on the current guess of the equilibrium house price, \( q_k \). The problem is to find the value of \( \rho_k(q_k) \) such that \( ED^h_k(q_k, \rho_k(q_k)) = 0 \). This step of the algorithm requires re-solving the agents’ optimization problem at each trial value of \( \rho_k(q_k) \), simulating data using the policy functions, and checking for market clearing in the simulated data. One useful property of the excess demand function \( ED^h_k(q_k, \rho_k(q_k)) \) is that conditional on \( q_k \), it is a strictly decreasing function of \( \rho_k \). Based on this property, \( \rho_k(q_k) \) can be found efficiently using bisection.

3. Given that the \textit{housing} market clears at prices \((q_k, \rho_k(q_k))\), check if this pair of prices also clears the market for \textit{shelter} by evaluating \( ED^s_k(q^*, \rho^*) \).

   (a) If \( ED^s_k(q^*, \rho^*) < 0 \) and \( k = 1 \), the initial guess \( q_1 \) is too high, so set \( q_{k+1} = q_k - \varepsilon \) and go to step (2). This initial house price guess \( q_1 \) is too high if \( ED^s_k(q_k, \rho_k(q_k)) < 0 \) because \( ED^s_k(q_k, \rho_k(q_k)) \) is decreasing in \( q_k \).

   (b) If \( ED^s_k(q_k, \rho_k(q_k)) > 0 \) set \( k = k + 1 \) and \( q_{k+1} = q_k + \varepsilon \) and go to step (2).

   (c) If \( ED^s_k(q^*, \rho^*) = 0 \), the equilibrium prices are \( q^* = q_k, \rho^* = \rho_k(q_k) \), so stop.

10 Appendix B: SCF

The Survey of Consumer Finances (SCF) 2007 is used to construct the moments summarized in Table 4. The SCF is a triennial survey of the balance sheet, pension, income, and other demographic characteristics of U.S. families. The total housing wealth is constructed as the total sum of all residential real estate owned by a household, and is taken to represent the housing wealth \( qh' \) in the model. Secured debt (i.e., debt secured by primary or other residence) is used as a model analog of the collateralized debt, \( m' \). The model analogue of the total net worth (i.e., \( d' + qh' - m' \)) is constructed as the sum of household’s deposits in the transaction accounts and the housing wealth (as defined above), net of the secured debt. The total household income reported in the SCF is taken to represent the total household income defined in the model as \( y = w + rd' + h' > s[p(h' - s)] \). Data and the STATA code are available at request.
References


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