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The equilibrium effect of fundamentals on house prices and rents

Kamila Sommer[a], Paul Sullivan[b,*], Randal Verbrugge[b]

[a] Federal Reserve Board, United States
[b] U.S. Bureau of Labor Statistics, Postal Square Building Room 3105, 2 Massachusetts Ave., N.E., Washington, DC 20212-0001, United States

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ABSTRACT

Using a dynamic equilibrium model of housing tenure choice with fully specified markets for homeownership and rental properties, and endogenous house prices and rents, this paper studies the effect of fundamentals on equilibrium house prices and rents. Lower interest rates, relaxed lending standards, and higher incomes are shown to account for approximately one-half of the increase in the U.S. house price–rent ratio between 1995 and 2006, and to generate the pattern of rapidly growing house prices, sluggish rents, increasing homeownership, and rising household indebtedness observed in the data.

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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. While real house prices rose by only 3.7% between 1985 and 1995, they increased by 50% between 1995 and 2006.[1] 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 40% above its level in the year 1995 (Fig. 1). Over the same time period, real interest rates reached historically low levels and availability of mortgage credit expanded greatly. Especially because of the significant drop in house prices since 2007, and the role played by the housing market in the Great Recession, there is considerable interest in understanding the driving forces behind changes in house prices and rents.

This paper quantitatively studies the effects of changes in fundamentals, such as the interest rate and required down payment, on endogenously determined house prices and rents using a dynamic equilibrium model of the housing market that features fully specified markets for both homeownership and rental properties. The primary contributions of this paper relative to the existing literature are incorporating household decisions about rental property investment into a model of the housing market, and endogenizing both house prices and rents. This model is the first model of the housing market that allows rental supply to be determined endogenously by the optimizing investment decisions of heterogenous households, and where two distinct relative prices – rents and house prices – are determined in equilibrium via market clearing.

To study the impact of changes in interest rates and down payment requirements on house prices and rents, this paper develops a stochastic life cycle Aiyagari–Bewley–Huggett economy with incomplete markets, 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

* Corresponding author. Tel.: +1 202 691 6593; fax: +1 202 691 6583.
E-mail addresses: pauljsullivan@gmail.com, sullivan.paul.joseph@bls.gov (P. Sullivan).

[1] The house price and rent statistics are based on the FHFA house price index and the Bureau of Labor Statistics (BLS) Rent of Primary Residence.

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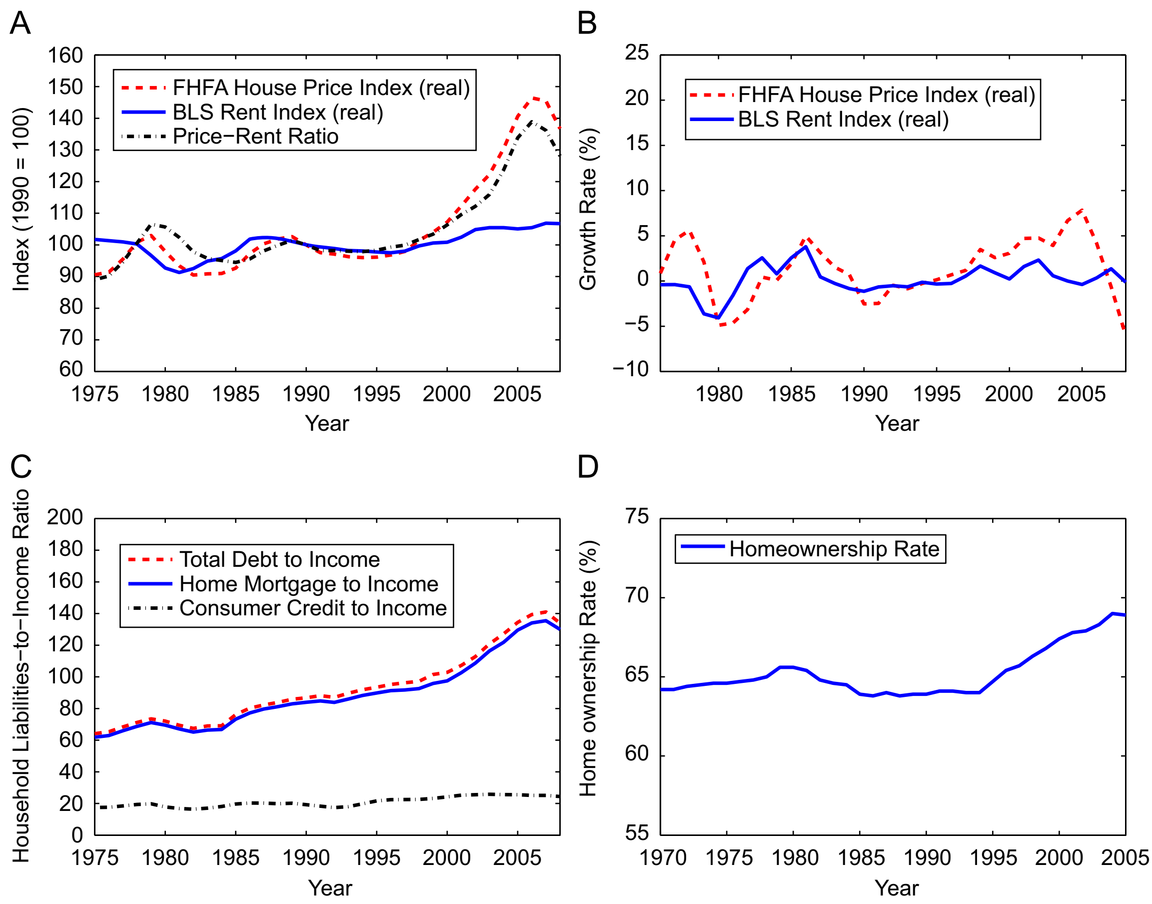

Fig. 1. FHFA house price index and BLS rent of primary residence index.

in terms of income and wealth. Building on the idea of houses as durable, lumpy consumption goods that provide shelter services, confer access to collateralized borrowing, offer tax advantages to their owners, and can also be used as rental investments, the model endogenizes the buy vs. rent decision and also allows homeowners to lease out their properties in the rental market. 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. Mortgages are available to finance purchases of housing, but home-buyers must satisfy a minimum down payment requirement. Both house prices and rents are determined in equilibrium through clearing of housing and rental markets.

The calibrated model is well suited to study the impact of macroeconomic factors on equilibrium house prices and rents in a steady state, and along a deterministic transitional path between steady states. This rational expectations model of the housing market demonstrates that rising incomes, historically low interest rates, and easing of down payment requirements can plausibly explain about one-half of the increase in U.S. house prices between 1995 and 2006. 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. In our view, the fact that this rational expectations equilibrium model leaves a substantial fraction of the run-up in house prices during the boom unexplained provides indirect evidence that overly optimistic expectations about house prices contributed to a bubble in the housing market.

The key mechanism in the model generating the run-up in the equilibrium price–rent ratio in response to changed macroeconomic conditions 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 desire to switch from renting to owning as homeownership becomes more affordable. Simultaneously, 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.[2] As a result, the equilibrium rent falls. At the same time, the demand for housing increases because

[2] In the United States, the buy-to-let markets have grown substantially since the mid-1990s (Girouard et al., 2006). The portion of sales attributable to such investors has risen sharply since the late 1990s, reaching around 15% of all home purchases in 2004, much higher than the pre-1995 average of 5% (Morgan Stanley, 2005).

more households can afford to purchase homes, and existing homeowners can afford larger homes. Given that the stock of housing is fixed, the equilibrium house price rises.

The model provides a number of additional insights about the mechanisms that jointly determine house prices and rents. Both house prices and rents 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 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 from this source are primarily driven by renters entering the housing market when down payment requirements are relaxed. Since renters are marginal in terms of income and wealth, the increase in housing demand relative to the entire market demand for housing is small, so the resulting house price increase is small.

Conversely, the model predicts that falling interest rates create large increases in house prices but reduced homeownership. Cheap credit reduces the cost of mortgage financing, boosting household willingness and ability to purchase big properties and to finance them using large mortgages. At the same time, a lower interest rate lowers the return on household savings, making it more difficult to save up for a down payment – itself now higher, thanks to higher house prices – and prompting investors to seek higher returns by becoming landlords. The equilibrium effects are higher house prices, higher rental supply, and a lower homeownership rate.[3]

This paper builds on the growing body of literature which studies housing using quantitative macroeconomic models where household heterogeneity is generated via labor income shocks (see, for example, Gervais, 2002; Díaz and Luengo-Prado, 2008; Ríos-Rull and Sánchez-Marcos, 2008; Chatterjee and Eyigungor, 2009).[4] Most closely related to our paper, Chambers et al. (2009a,b,c) 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. This paper adopts the structure of rental markets from Chambers, Garriga, and Schlagenhauf, but also allows both house prices and rents to be determined in an equilibrium.[5]

Kiyotaki et al. (2011) explore the relationship between the price of housing equity and rent in a model where households costlessly trade housing shares. Similar to this paper, homeownership is preferred to renting, so a minimum down payment prevents marginal households from entering the housing market. Consistent with the findings of this paper, the authors find that a relaxation of credit constraints has a surprisingly small effect on house prices, despite increasing the homeownership rate substantially.[6]

Favilukis et al. (2011) study house prices and imputed rents in a two sector real business cycle model. In sharp contrast to this paper and to Kiyotaki et al. (2011), the authors find that financial liberalization can explain most of the observed increase in the price–rent ratio, while a reversal of the financial liberalization can explain much of the bust. The absence of equilibrium market rent, the role of risk premia, and the larger assumed change in financial conditions likely explain some of the marked divergence between the effects of financial liberalization on the housing market found by Favilukis et al. (2011) compared to the findings of Kiyotaki et al. (2011) and this paper.

2. The model economy

The model is an Aiyagari–Bewley–Huggett style economy with heterogeneous households. Households derive utility from nondurable consumption and from shelter services which are obtained either via renting or through ownership. Households supply labor inelastically, receive an idiosyncratic uninsurable stream of earnings in the form of endowments, and make joint decisions about their consumption of nondurable goods and shelter services, house size, mortgage size, and holdings of deposits. Idiosyncratic earnings shocks 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 embedded in the U.S. tax code, but may be forced to rent due to the down payment requirement and high transaction costs. An important feature of the 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 and rental property related depreciation expenses. House prices and rents are determined in equilibrium through clearing of housing and rental markets.

[3] The finding that interest rates can be linked to a higher price–rent ratio is supported by the user cost literature (see, for example, Poterba, 1984; Himmelberg et al., 2005; Hubbard and Mayer, 2009). Moreover, the interest rate elasticity of house prices implied by the model closely matches the empirical estimate of Glaeser et al. (2010).

[4] A detailed discussion of these studies is available in an online supplementary appendix.

[5] Gervais (2002) provides an alternative framework for modeling the rental market where a representative financial intermediary supplies rental properties. In this framework, the price of housing is always equal to the price of consumption, which is normalized to unity, so this framework is not appropriate for examining the response of house prices to changes in fundamentals. This framework is also adopted in Nakajima (2010).

[6] The mechanism behind their result is the same as in this paper, even though the structure of the rental market differs greatly between the two papers. Tenants and credit-constrained homeowners are relatively poor and own a small share of aggregate wealth as a group. As a result, the effect of relaxing the collateral constraint on house prices is largely absorbed by a modest conversion from rented to owned units.

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 Castaneda et al. (2003) and Heathcote (2005), the life cycle is modeled as a stochastic transition between various labor productivity states that also allows a household's expected income to rise over time.[7]

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 $\phi_j = 1/(p_j L)$, where p_j is the fraction of the population with productivity w_j in the ergodic distribution over the discrete support $\mathcal{W}$, and L is a constant equal to the expected lifetime. Similarly, the conditional probability of transiting from a working-age state w_j to a working-age state w_i 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 π_{ji}, is therefore defined as

$$\Pi = \begin{bmatrix} 0 & \phi_1 & 0 & 0 \\ 0 & 0 & \ddots & 0 \\ 0 & 0 & 0 & \phi_{J-1} \\ \phi_J & 0 & 0 & 0 \end{bmatrix} + \begin{bmatrix} (1-\phi_1) & 0 & 0 & 0 \\ 0 & \ddots & 0 & 0 \\ 0 & 0 & (1-\phi_{J-1}) & 0 \\ 0 & 0 & 0 & (1-\phi_J) \end{bmatrix} P. \tag{1}$$

The fractions p_j are the solutions to the system of equations $p = p\Pi$.[8]

Young households are born as renters. The model does not allow for intergenerational transfers of wealth (financial or non-financial) or human capital. Instead, upon death, estates are taxed at a 100% rate by the government and immediately resold. All proceeds of these sales are not re-distributed, but are instead used to finance government expenditures that do not affect individuals.

2.2. Preferences

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 the rental market at price ρ per unit or through homeownership at price q per unit of housing.[9] 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 a renter $(h'=0)$, an owner–occupier $(h'=s)$, or a landlord $(h'>s)$. Landlords lease $(h'-s)=:l$ to renters at rental rate ρ. Many recent studies assume that renters receive lower utility from a unit of housing services than homeowners (see, for example, Kiyotaki et al., 2011). In contrast, our model assumes 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, and m to the new levels h', d', and m' at the beginning of the period after observing their within-period income shock w.

Houses are big items that are available in $K=11$ discrete sizes, $h \in \{0, h(1), \ldots, h(K)\}$. 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, $\underline{s}$, which is smaller than the minimum house size available for purchase, $0 < \underline{s} < h(1)$. Renters are also free to rent a larger amount of shelter. To maintain symmetry between shelter sizes available to homeowners and renters, all levels of shelter consumption must match a point on the housing grid, so $s \in \{\underline{s}, h(1), \ldots, h(K)\}$.

Households pay non-convex transaction costs $\tau^b qh'$ and $\tau^s qh$ when buying or selling a house.[10] Homeowners also incur maintenance expenses, which offset physical depreciation of housing properties, so that the total stock of housing, H, in the

[7] 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 requiring that household age be incorporated into the already large state space.

[8] A detailed description of this process is available in the Appendix of Heathcote's paper.

[9] The specification of a per-unit price of housing follows recent work in quantitative macroeconomics that studies the housing market; see for example Chatterjee and Eyigungor (2009). Allowing for multiple house prices would be very difficult because a model with N house prices and M rents requires searching in $N \times M$-dimensional space for the equilibrium house prices and rents while repeatedly re-solving the household optimization problem. See Ríos-Rull and Sánchez-Marcos (2008) for a model with multiple house prices, but no rental market.

[10] The presence of transactions costs reduces the transaction volume in the economy, and generates inaction regions with regard to the household decision to buy or sell.

economy is fixed.[11] We assume that housing occupied by a renter depreciates more rapidly than owner occupied housing.[12] Housing which is consumed by the owner depreciates at rate δ_o while the depreciation rate for rented property is δ_r, with $\delta_r > \delta_o$. Thus, current total maintenance costs facing an agent who has just chosen housing capital equal to h' are given by[13]

$$qM(h',s) = q(\delta_0 s + \delta_r \max\{h' - s, 0\}). \tag{2}$$

Homeownership confers access to collateralized borrowing at a constant markup over the risk-free deposit rate, r, so that $r^m = r + \kappa$. Borrowers must, however, satisfy a minimum equity requirement. In a steady state where the house price does not change across time, the minimum equity requirement is given by the constraint

$$m' \le (1-\theta)qh', \tag{3}$$

with $\theta > 0$. The equity requirement limits entry to the housing market, since households interested in buying a house with a market value qh' must put down at least a fraction θ 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 to become renters must repay all the outstanding debt, since the option of mortgage default is not available. The accumulated housing equity above the down payment can, however, be used as collateral for home equity loans. Along the transitional path where house prices fluctuate, the operational constraint becomes[14]

$$m' I^{\{(m' > m) \cup (h' \neq h)\}} \le (1-\theta)qh'. \tag{4}$$

Following the existing literature, mortgages are modeled in a HELOC fashion, where loans are essentially payment-option mortgages with a required interest rate payment and a pre-approved home equity line of credit.[15] Effectively, this means that a borrower must cover mortgage interest payments every period, but is not obligated to pay down principal. Section 3.3 discusses how these features of mortgages in the model affect the calibration.

2.4. The government

Following Díaz and Luengo-Prado (2008), the tax system in the model mimics the preferential tax treatment of owner-occupied housing in the U.S. system in a stylized way. 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. As discussed below, the model expands on the tax treatment of rental property in existing models of the housing market by allowing landlords to deduct depreciation of rental property from their taxable income. For simplicity, income is taxed proportionally at the rate τ^y.

The total taxable income is thus defined as

$$\tilde{y} = w + rd + I^{h' \neq 0}[-\tau^m r^m m - \tau^h qh'] + I^{h' > s}[\rho(h'-s) - \tau^{LL} q(h'-s) - \delta_r q(h'-s)], \tag{5}$$

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, which are discussed next.

In the current U.S. tax treatment, landlords must pay income taxes on rental income, but are permitted to deduct many different expenses associated with operating a rental property from their gross rental income. In addition to the mortgage interest and property tax deductions available to owner–occupiers, landlords can also deduct depreciation of the rental structure and maintenance expenditures.

Accordingly, the term $\tau^{LL} q(h'-s)$ in Eq. (5) represents the tax deduction for depreciation of rental property, where τ^{LL} represents the fraction of the total value of the rental property that is tax deductible in each year, and $\delta_r q(h'-s)$ represents the tax deductible maintenance expenses. In the model, as in the U.S. tax code, if the tax deductions from the rental property exceed rental income, then rental losses will reduce the household's tax liability by offsetting income from wages and interest.[16]

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[11] Although the stock of housing (as well as population size) is fixed in the model, there is evidence that the stock of housing increased over the boom period. For example, according to the National Income and Product Accounts (NIPA) tables, residential investment as a fraction of fixed investment hovered at about 15% between 1949 and 2000, while it rose from 18.2% to 25.2% between 2000 and 2005. The effect of changes in housing supply on the housing market equilibrium is examined in a footnote in Section 5.

[12] See Chambers et al. (2009c) for a detailed discussion of this assumption.

[13] Modeling depreciation as proportional to housing value follows the existing literature in quantitative macro (Díaz and Luengo-Prado, 2008; Chambers et al., 2009c). It is also consistent with user cost theory and the tradition of the National Income and Product Accounts (NIPA).

[14] This modified version of the constraint shown in Eq. (3) implies that homeowners need not decrease their collateral debt balance during house price declines, as long as they do not sell their house. On the other hand, when house prices rise, households can access the additional housing equity through a pre-approved home equity loan. In a steady-state environment where prices are constant, Eq. (4) reduces to Eq. (3).

[15] See, for example, Díaz and Luengo-Prado (2008), Gervais (2002), Ríos-Rull and Sánchez-Marcos (2008) or Nakajima (2010). Chambers et al. (2009b) and Campbell and Cocco (2003) offer a more complete analysis of mortgage choice.

[16] 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. The model abstracts away from these upper limits.

Finally, as in Díaz and Luengo-Prado (2008), all proceeds from taxation are used to finance government expenditures that do not affect individuals.[17]

2.5. The dynamic programming problem and definition of stationary equilibrium

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, ρ) – solve the following problem:

$$v(w,d,m,h) = \max_{c,s,h',d',m'} U(c,s,h') + \beta \sum_{w' \in W} \pi(w'|w) v(w',d',m',h') \tag{6}$$

subject to $E \leq Y$, where

$$Y = w + (1+r)d - \rho(s-h') - q(h'-h) + m' - d' \tag{7}$$

$$E = c + (1+r^m)m + I^s \tau^s qh + I^b \tau^b qh' + \tau^y \tilde{y} + \tau^h qh' + qM(h',s) \tag{8}$$

$$(1-\theta)qh' \geq m' I^{\{(m' > m) \cup (h' \neq h)\}} \tag{9}$$

$$m' \geq 0 \quad \text{and} \quad d' \geq 0 \tag{10}$$

$$h' \geq s > 0 \quad \text{if } h' > 0 \tag{11}$$

$$s > 0 \quad \text{if } h' = 0, \tag{12}$$

by choosing non-durable consumption, c, shelter services consumption, s, as well as current levels of housing, h', deposits, d', and collateral debt, m'.

Stationary equilibrium: A stationary equilibrium is a collection of optimal household policy functions $\{c(x), s(x), d'(x), m'(x), h'(x)\}$ which are functions of the state vector $x = (w,d,m,h)$, a probability measure, λ, and a stationary price vector (q, ρ) such that decision rules are optimal, markets clear, and λ is a stationary probability measure. A formal definition of the equilibrium is presented in a supplemental appendix.

3. Calibration

The model is calibrated in two stages; all parameters are shown in Table 1. 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).

3.1. 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 a simple AR(1) specification to capture the earnings dynamics for working-age households that is characterized by the serial correlation coefficient, ρ_w, and the standard deviation of the innovation term, σ_w. For the purposes of this paper, the terms ρ_w and σ_w are set to 0.90 and 0.20, respectively. The otherwise continuous earnings process is approximated with a discrete number (7) of states.[18]

3.2. Preferences

Following the literature on housing choice (see, for example, Díaz and Luengo-Prado, 2008; Chatterjee and Eyigungor, 2009; Kiyotaki et al., 2011), the preferences over the consumption of non-durable goods (c) and housing services (s) are modeled as non-separable of the form

$$U(c,s,h') = (1 - \chi I^{h' > s}) \frac{(c^\alpha s^{1-\alpha})^{1-\sigma}}{1-\sigma}. \tag{13}$$

The binary variable $I^{h' > s}$ indicates that a homeowner is also a landlord. The risk aversion parameter, σ, is set to 2. The remaining parameters that characterize preferences are the weight on non-durable consumption of the Cobb–Douglas

[17] The treatment of proceeds from taxation is consistent with the treatment of proceeds from sales of estates of deceased agents, previously discussed in Section 2.1.

[18] Using data from the Panel Study of Income Dynamics (PSID), work by Card (1994) and Heathcote et al. (2010b) indicates ρ_w in the range 0.88–0.96, and σ_w in the range 0.12–0.25.

Table 1
Parameters and moments.

Exogenous parameters	Value	
Autocorrelation ρ_w	0.90	
Standard deviation σ_w	0.20	
Risk aversion σ	2.00	
Down payment requirement θ	0.20	
Selling cost τ^s	0.07	
Buying cost τ^b	0.025	
Risk-free interest rate r	0.04	
Spread κ	0.015	
Depreciation rate for owner–occupiers δ_0	0.025	
Property tax rate τ^h	0.01	
Mortgage deductibility rate τ^m	1.00	
Deductibility rate for depreciation of rental property τ^{LL}	0.023	
Income tax τ^y	0.20	
Estimated parameters		
Discount factor β	0.959	
Consumption share α	0.720	
Depreciation of rental property δ_r	0.037	
Landlord utility loss χ	0.024	
Targeted moments	**Model**	**Data**
Home-ownership rate	0.66	0.66
Landlord rate	0.10	0.10
Imputed rent-to-wage ratio	0.25	0.25
Fraction of owner with collateral debt	0.64	0.65
Other moments (average ratios)	**Model**	**Data**
Loan-to-value ratio for homeowners	0.31	0.35[a]
Housing value-to-total income ratio for homeowners	4.02	4.43[a]
Loan-to-total income ratio for homeowners	1.34	1.28[a]
Net worth to total income ratio for homeowners	3.16	3.53[a]
House price–rent ratio	11.3	8–15.5[b]

[a] Calculated using the 1998 SCF.
[b] 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.

aggregator, α, the discount factor, β, and the landlord utility loss parameter, χ.[19] These three parameters are estimated in the second stage.[20]

3.3. Market arrangements

Using data from the Consumer Expenditure Survey (CE), Gruber and Martin (2003) document that selling costs for housing are on average 7%, while buying costs are around 2.5%, so the transactions costs of buying and selling a house are set to the values $\tau^b = 0.025$ and $\tau^s = 0.07$. In terms of the maintenance cost function $M(h', s)$ in Eq. (2), Harding et al. (2007) estimate that the depreciation rate for housing units used as shelter is between 2.5% and 3%. Thus, the depreciation rate for housing consumed by a homeowner is set to $\delta_0 = 0.025$. The depreciation rate of rental property, δ_r, is estimated in the

[19] Cobb–Douglas preferences imply that households tend to spend constant fractions of their income on housing and non-housing consumption. This is consistent with empirical findings in Davis and Ortalo-Magné (2011). At the same time, Cobb–Douglas preferences have implications for the degree of substitutability between c and s. Various studies have attempted to estimate the degree of complementarity between housing and non-housing consumption. Piazzesi et al. (2007) estimate a high degree of substitutability in aggregate data. In contrast, combining PSID and AHS data, Flavin and Nakagawa (2008) estimate that the intra-temporal substitutability between housing and non-durable consumption is low.
[20] A supplemental appendix discusses the identification of these parameters and explains the role of the landlord utility loss in the model.

second stage (see Section 3.5). To calibrate the cost of mortgage credit, the interest rate on deposits is set to $r=0.04$, and the mortgage markup is set to $\kappa=0.015$, so the mortgage rate $r^m = r+\kappa$ is equal to 5.5% in the baseline model.[21]

Consistent with the existing literature, the baseline down payment requirement (θ) is set at 20%.[22] In this class of model, homeownership is preferred to renting, mortgages are modeled in the HELOC fashion with no fixed payments, and there is no loan approval, so real world features of mortgages such as credit score or income requirements are absent. As such, the minimum down payment requirement in the model serves as a proxy for the overall tightness of credit conditions and is, therefore, set conservatively in the baseline model. Empirically, Foote et al. (2012) show that low or no down payment loans were commonly available to qualified borrowers in the pre-boom period.

The minimum down payment plays a crucial role in this class of model. In the model, as in the U.S. data, low wage agents have very low or zero savings. There is very little cross-sectional variation in wealth across these agents. As a result, when down payment requirements are very low and other underwriting considerations are absent, small changes in parameters can cause large groups of identical, low income, low wealth agents to move between renting and homeownership. When this occurs, the homeownership rate changes discontinuously. Interestingly, this feature of the model may offer a valuable insight into the U.S. housing market boom. Even a small reduction in the minimum required down payment, combined with a relaxation of other underwriting criteria, can cause a large movement into the housing market when poor households are relatively homogeneous.

3.4. Taxes

The property tax rate in the model is $\tau^h = 0.01$, and mortgages are fully deductible so $\tau^m = 1$. 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%. 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% of the value of a house in the U.S. between 1975 and 2006. Based on their findings, the depreciation rate of rental property for tax purposes in the model is set to $\tau^{LL} = (1-0.36)\times 0.0363 = 0.023$. Lastly, following Díaz and Luengo-Prado (2008) and Prescott (2004), the income tax rate is $\tau^y = 0.20$.

3.5. Estimation

Based on the previous discussion, four structural parameters must be estimated using SMM: the Cobb–Douglas consumption share, α, the discount factor, β, the landlord utility loss, χ, and the depreciation rate of rental property, δ_r. The four moments targeted during estimation are the imputed rent-to-wage ratio (0.25), the fraction of homeowners who hold collateral debt (0.65), the homeownership rate (0.66) and the landlord rate (0.10).[23] Table 1 shows the estimated parameters and demonstrates that the model closely matches the targeted empirical moments. Details on estimation and identification of the parameters can be found in an online supplemental appendix.

3.6. Moments not targeted in the estimation

As an external test of the model, Table 1 reports several other key statistics generated by the model that were not targeted in the estimation and compares them to statistics that are either drawn from other studies or computed from the 1998 Survey of Consumer Finances (SCF). A supplemental appendix describes the calculation of the SCF statistics. Encouragingly, the model predictions fall well within the range of estimates based on U.S. data.

3.7. Cross-sectional implications of the model

In the model economy, renters are typically hand-to-mouth agents at the bottom of the wealth distribution who consume little housing. Nearly 68% of renters live in the smallest shelter space, which is called a “room,” and is not available for sale.[24] All other renters inhabit the smallest-sized house. In the model, homeownership is preferred to renting – mostly due to the favorable tax-treatment of homeownership – so households who can afford a down payment on a house typically purchase one.[25]

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[21] Using data from the Federal Reserve Statistical Release – H15 – Selected Interest Rates, the interest rate r is based on the average 30-year constant maturity Treasury deflated by year-to-year headline CPI inflation for the period between 1977 and 2008. The markup κ is based on the average spread between the nominal interest rate on a 30-year fixed-rate mortgage and 30-year Treasury.

[22] See, for example, Díaz and Luengo-Prado (2008), Gervais (2002), Ríos-Rull and Sánchez-Marcos (2008) or Nakajima (2010).

[23] The homeownership rate averaged 0.66 in the United States between 1995 and 2005. Chambers et al. (2009c) use the AHS data to compute the fraction of homeowners who claim to receive rental income. The authors find that approximately 10% of the sampled homeowners receive rental income. Davis and Ortalo-Magné (2011) estimate the share of expenditures on housing services by renters to be roughly 0.25 over the last several decades. Finally, according to the 1994–1998 AHS, approximately 65% of homeowners report collateral debt balances.

[24] The smallest-size shelter unit captures the idea that agents can rent a very small living space that is not, however, available for sale; for example, a person can share a room with a roommate, or can rent a room while sharing a kitchen.

[25] A supplemental appendix shows how the exclusion of imputed rental income from taxable income impacts the cost of housing for homeowners.

Table 2
Distribution of landlords by labor income.

Labor income group	% Landlords	% Total rental property
Group 1	3.32	1.7
Group 2	15.02	10.2
Group 3	33.85	20.7
Group 4	15.44	20.8
Group 5	14.47	20.8
Group 6	12.32	17.7
Group 7	5.58	7.8

Note: Labor income group refers to the seven discrete wage levels that are used to approximate the continuous wage process.

Interestingly, the option to become a landlord exerts an important influence on agents' decisions in the model economy, and represents an additional reason why ownership may be preferred to renting. First, rental units provide investment income. Second, the option to become a landlord is an important risk-management mechanism for homeowners facing adverse income shocks; exercising this option allows some to maintain higher consumption than would be otherwise possible, and to avoid sizable transactions costs associated with downsizing. It follows that transactions costs have an effect on household tenure in a home.[26]

While only 10% of agents are landlords in the baseline steady state, the varied motivations to become a landlord lead to a diverse landlord pool. Indeed, Table 2 indicates that landlords can be found among all income groups. While the majority of landlords are either middle or high income households owning large properties, nearly 20% of landlords are in the poorest two categories. These predictions are qualitatively consistent with the statistics reported by Chambers et al. (2009c) who, using the 1996 Property Owners and Managers Survey, find that 25% of households receiving rental income are low-income households with annual earnings below $30,000, compared to 30% of high-income households with annual earnings over $100,000 (see their Table 2).

4. House prices and rents: impact of changed fundamentals

The estimated model is employed to analyze the observed changes in house prices, rents, and the price-to-rent ratio between 1995 and 2006. The analysis is conducted in three steps. The first step, presented in this section, studies the model's predictions about the responsiveness of house prices and rents, and the price–rent ratio, to individual changes in interest rates, borrowing constraints, and household incomes in the steady-state housing market equilibrium. The second step, presented in Section 5, explores the combined effects of these macroeconomic factors on steady-state housing market outcomes. As such, all of the analysis in Sections 4 and 5 is based on comparisons of different steady state economies. The third step, presented in Section 6, extends the model to include deterministic dynamics of house prices and rents.

4.1. Relaxation of down payment requirements in a steady-state economy

Fig. 2 illustrates the impact of changes in the minimum down payment requirement, θ, on equilibrium housing market outcomes. A reduction in θ from the baseline value of 0.20–0.05 leads to a 3% increase in the house price, and a 3.4% decrease in rent.[27] Neither house prices nor rents respond strongly to θ, so lessening of credit constraints cannot by itself explain the large run-up in house prices observed in recent years.

That said, the homeownership rate does respond strongly to changes in down payment requirements. When θ is lowered from 0.30 to 0.20, the homeownership rate rises from 65% to 66%; when θ falls further to 0.05, the homeownership rate increases to 83%. The loan-to-wage ratio and the fraction of homeowners in debt also rise as θ falls.

The key to understanding the large effect of θ on homeownership, but the small effect of θ on house prices, is the fact that the housing market responses are primarily driven by households for whom the minimum down payment is a binding constraint: low-income, low-saving households. These households are numerous, but since these entrants are marginal in terms of income and wealth, their impact on house prices is modest. As low income households enter the housing market by purchasing small-size houses, there is a corresponding decrease in the amount of rented property. Thus, the equilibrium

[26] Using the 1985–2001 AHS data, Harding et al. (2007) estimate that time between sales for owner–occupiers averages roughly 6 years. Rosenthal (1988) estimate average duration in the home for homeowners at 7 years in the PSID. Ferreira et al. (2010) report average duration in house at 8.2 years using AHS data between 1985 and 2007. In comparison, our model predicts the average time in home at time of sale at 10.9 years, with the median homeowner living in the residence for 8 years.

[27] The fraction of households with high loan-to-value (LTV) mortgages increased sharply between 2000 and 2005 (Gerardi et al., 2008). Chambers et al. (2009a) and Duca et al. (2011) document a decrease in the average down payments for all borrowers and first-time home-buyers, respectively, since 1995 and use these shifts to proxy the relaxation of lending standards during the housing boom. Chomsisengphet and Pennington-Cross (2006) document similar trends in the subprime lending markets.

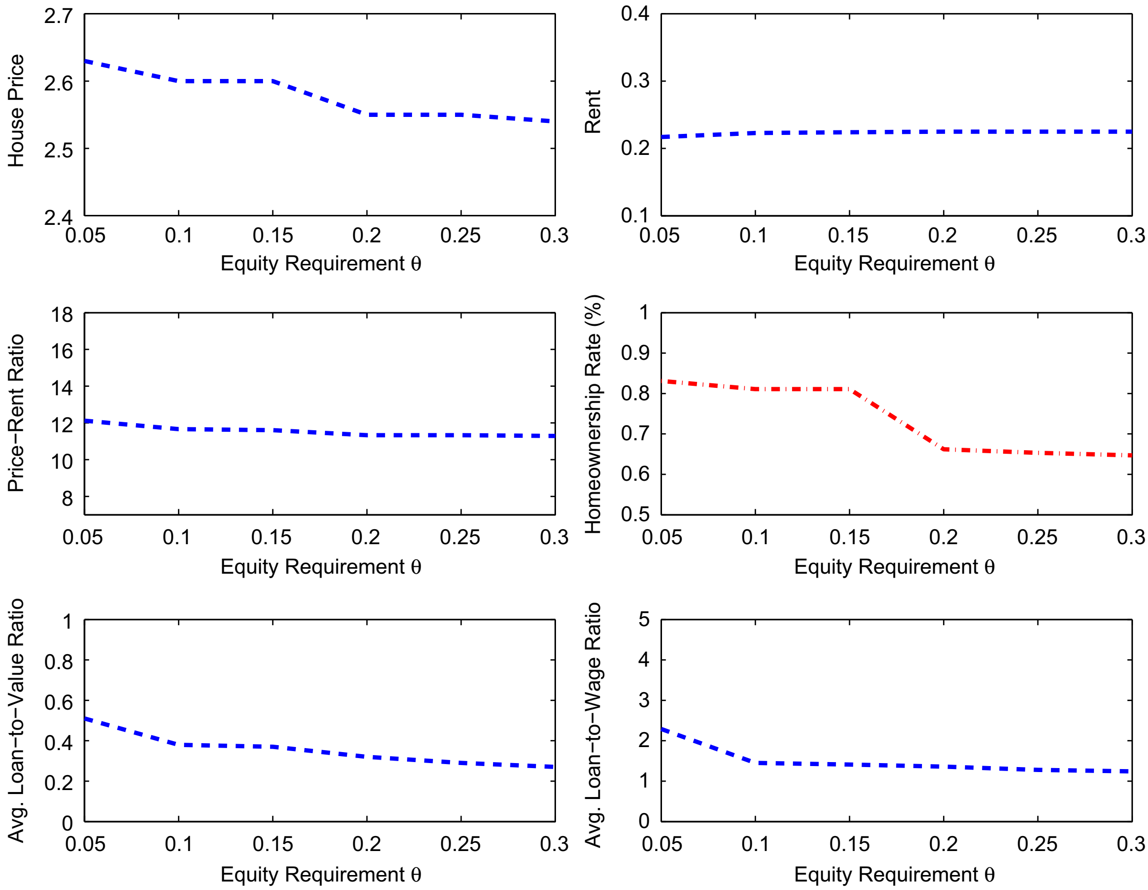

Fig. 2. The housing market equilibrium under different equity requirements.

Table 3
The partial and equilibrium effects of changes in fundamentals.

Statistics	Baseline	5% Equity requirement		2% Interest rate		10% Increase in income	
		Fixed prices	Equil. prices	Fixed prices	Equil. prices	Fixed prices	Equil. prices
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
House price	2.55	2.55	2.62	2.55	2.97	2.55	2.85
Rent	0.22	0.22	0.22	0.22	0.21	0.22	0.25
Share of homeowners	0.66	0.91	0.83	0.81	0.66	0.92	0.67
Share of renters	0.34	0.09	0.17	0.19	0.34	0.21	0.33
Share of landlords	0.10	0.14	0.16	0.49	0.10	0.08	0.11
Share of owner–occupiers	0.56	0.77	0.67	0.32	0.55	0.71	0.56
Share of homeowners in debt	0.64	0.72	0.64	0.94	0.84	0.70	0.64

Note: “Fixed prices” columns hold prices at the baseline values from column (1). “Equil. prices” columns allow prices to adjust to clear markets.

response of landlords is effectively to sell housing to their tenants, and they are willing to do this because the house price has risen while the rent has remained virtually constant.[28]

Table 3 highlights the important role of general equilibrium forces in generating housing market outcomes. Column (2) displays a partial equilibrium experiment, which counterfactually holds both house prices and rents fixed at the baseline market-clearing level while reducing θ from 20% to 5%. In contrast, column (3) reports the general equilibrium impact of this decrease in θ; here both house prices and rents adjust to clear the housing and rental markets. As noted above, rent is fairly

[28] 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.

unresponsive to θ in general equilibrium; the initial rent level of approximately 0.22 holds in both the partial and general equilibrium experiments. When prices are held fixed, homeownership sharply increases when the minimum down payment falls because previously credit constrained households shift from renting to owning. However, in the general equilibrium experiment, the increase in the house price dampens the responsiveness of homeownership to decreases in θ. As noted above, despite the large increase in homeownership, only a 3% increase in the house price is needed to clear the market and accommodate these new homeowners.

The previously discussed results are consistent with several recent studies which document a strong relationship between the size of the down payment requirement and homeownership (e.g., Chambers et al., 2009a; Díaz and Luengo-Prado, 2008; Ortalo-Magné and Rady, 2006). These studies suggest that, while financial sector innovations have minimal impact for existing homeowners, lower down payment requirements strongly affect households for whom the high down payment is a binding constraint; the initially excluded households enter the housing market and the homeownership rate rises.[29]

In summary, the model clearly indicates that in the absence of changes in other factors, a relaxation of borrowing constraints is important for understanding homeownership rates but cannot by itself account for the magnitude of the recent increase in house prices.[30] 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 house prices and rents.

4.2. Changes in the interest rate in a steady-state economy

Fig. 3 illustrates the impact of changes in the real risk-free rate, r, on equilibrium housing market outcomes. Since the mortgage interest rate r^m is determined by a constant markup, κ, over r, changes in r directly translate into changes in r^m; hence changes in r affect both the cost of borrowing and the rate of return on saving. As can be seen in the figure, interest rate changes have a large effect on house prices and rents. When r is lowered from 4% to 2%, a decrease broadly consistent with the actual decline between 1995 and 2006, the house price level rises by 16.4%, the rent falls by 2.6%, and the price–rent ratio rises by 20% from its initial level of 11.3.[31] The simulated interest rate elasticity of house prices from the model is consistent with recent empirical estimates in Glaeser et al. (2010).[32]

In the model, lower interest rates reduce the cost of household borrowing and reduce the rate of return on household savings. Both effects increase demand for owned housing. On the intensive margin, demand for housing services rises, due both to the lower opportunity cost and to the lower costs of financing a given mortgage; thus, house prices rise, which prices out some of the less wealthy. At the same time, there is a portfolio shift: rental property investment becomes relatively more attractive as borrowing costs fall and as the return to the alternative investment, deposits, falls. Despite the rise in house prices, which ceteris paribus raises the cost of becoming a landlord, the net effect is that the supply of rental properties rises, and rents fall.[33]

Perhaps surprisingly, the 50% reduction in the interest rate from 4% to 2% has almost no impact on the homeownership rate (Fig. 3). This is due to general equilibrium price effects, which are illustrated in Table 3. Column (4) displays the partial equilibrium counterfactual, while column (5) displays the general equilibrium outcome. If house prices and rents did not adjust, the homeownership rate would rise from 66% to 81%, reflecting the lower cost of consuming owned housing services and the reduced attractiveness of saving relative to housing investment. At the same time, the fraction of landlords in the economy would rise from 10% to nearly 50%, because when q and ρ are held constant, a decrease in r increases the rate of return to being a landlord and decreases the rate of return to the alternative of holding deposits. In equilibrium, however, higher house prices increase the minimum down payment, and the lower interest rate makes it difficult for prospective homeowners to save up for it. Furthermore, equilibrium rent decreases from 0.22 to 0.21, despite the fact that house prices are rising, making renting relatively more attractive, and reducing the return obtained by landlords.

To provide some intuition for the inverse relationship between the price–rent ratio and interest rates in the model, it is useful to examine a simplified model that abstracts from credit constraints, discreteness, transactions costs, and utility loss

[29] Further support is found in the empirical findings of Ortalo-Magné and Rady (1999) and Muellbauer and Murphy (1990, 1997), who document that decreases in the down payment requirements in England and Wales after the financial liberalization of the early 1980s were one of the two most important factors associated with unprecedented increases in young-household homeownership (the second factor being optimistic appreciation expectations).

[30] This section studies the effect of relaxed credit constraints by decreasing θ. An alternative approach allows for a decrease in the cost of high loan-to-value (LTV) credit. An online supplemental appendix demonstrates that relaxing credit conditions in this manner also leads to only a small change in house prices. Relaxing credit constraints, either by decreasing the minimum down payment or by decreasing the cost of financing high LTV mortgages, primarily allows low income, low wealth households to enter the housing market. Since these agents are marginal in terms of income and wealth, their entry produces only a small increase in house prices.

[31] Based on Federal Housing Financing Board data deflated by headline CPI inflation, the real effective mortgage rate for single-family residential property oscillated around the 5% mark between 1990 and 1997, but then started trending downwards, reaching 2.5% in 2005.

[32] Using the FHFA price index and 10-year Treasury rates, the authors estimate that (i) the interest rate elasticity of house prices is larger when real interest rates are already low (i.e., below 3.5%), and that (ii) a 200 basis point decrease in real rates at the already low interest rate levels is associated with approximately a 16% increase in real house prices. Our model generates virtually the same increase (16.4%), and predicts a remarkably similar non-linear relationship between q and r with a break at $r=0.03$.

[33] More specifically, when the interest rate decreases from 4% to 2%, the aggregate supply of rental property increases by 4%, while the rent falls from 0.22 to 0.21.

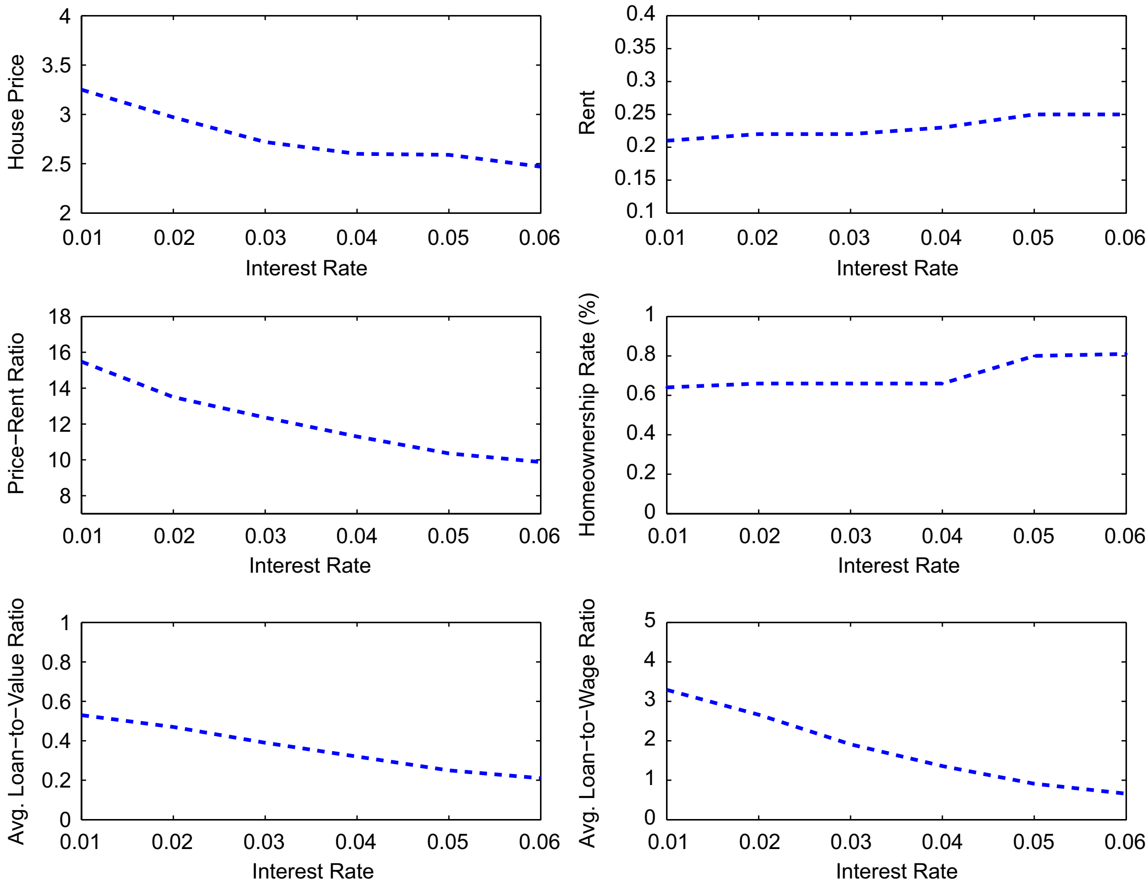

Fig. 3. The housing market equilibrium under different interest rates.

for landlords.[34] In such an environment, an optimizing landlord holding a mortgage chooses h' in order to satisfy

$$\rho = \frac{q\left(1+(1-\tau^y)(\tau^h+\delta_r)-\tau^y\tau^{LL}-\dfrac{1}{1+(1-\tau^y)r^m}\right)}{(1-\tau^y)}. \tag{14}$$

The steady state price–rent ratio (q/ρ) is inversely related to the interest rate. Of course, Eq. (14) will not hold exactly in the full model with discreteness and frictions. Furthermore, it cannot on its own predict the individual responses of house prices and rents to a change in the interest rate; determining those responses requires solving for the pair of market prices which jointly clear the markets for shelter and owned housing.[35]

4.3. Changes in income in a steady-state economy

A large body of empirical literature identifies the level and growth rate of income as an important determinant of house price dynamics. In the United States, real hourly wages increased by 9.4% between 1995 and 2005.[36]

Fig. 4 summarizes the impact of changes in income on the housing market equilibrium. In this experiment, household wages rise at the same rate across all wage groups.[37] The model suggests that both house prices and rents increase at about the same rate

[34] A supplemental appendix describes this simplified model in detail.

[35] Eq. (14) is a richer version of the arbitrage condition typically derived in widely used representative rental firm models developed by Gervais (2002). In this class of model, q is normalized to one due to the assumption of costless conversion between the consumption good and the housing good, so that only the relative price – not the individual prices – are pinned down in this model.

[36] This calculation is based on the BLS Current Employment Statistics (CES) real wage data.

[37] The actual changes in the income levels were not, however, symmetric. Heathcote et al. (2010a) document the changes in the U.S. earnings inequality between 1967 and 2006. Using the Current Population Survey data, the authors find that the real earnings of the bottom decile of the earnings distribution did not, on average, grow between 1985 and 2005, although the earnings of the top earnings distribution grew steadily over the sample period. Given the stylized income process in this paper, the exploration of asymmetric income changes is left to further work.

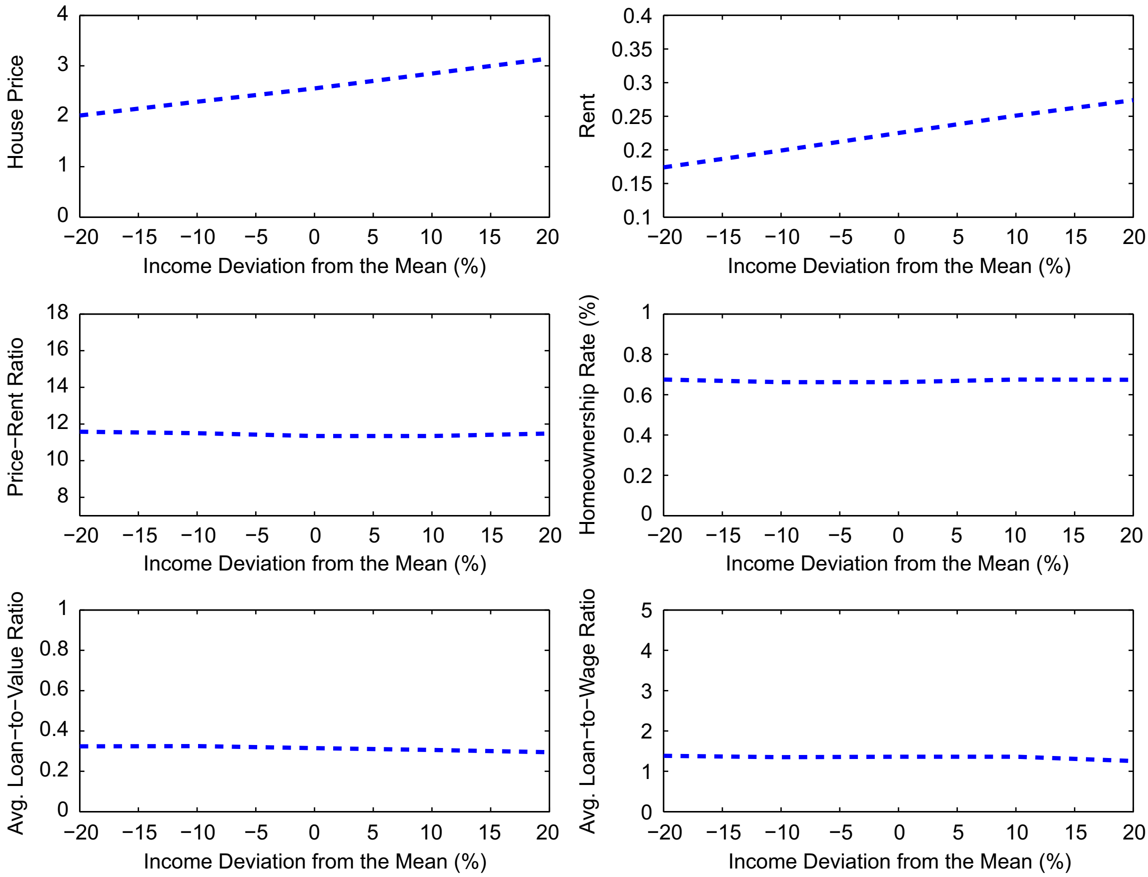

Fig. 4. The housing market equilibrium under different income levels.

as wages. Since the relative price of obtaining housing services via homeownership versus renting remains unchanged, symmetric changes in income of the sort examined here have no effect on the homeownership and landlord rates.

Once again, equilibrium price effects play a central role, as illustrated in columns (6) and (7) in Table 3. 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%, reflecting the fact that 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. But in equilibrium, house prices and rents rise proportionally, leaving the proportions of renters, homeowners, and landlords unchanged.

5. Combined changes in market fundamentals

As discussed in the preceding sections, neither declines in the real interest rate, nor relaxation of borrowing constraints, nor rising incomes can on their own account for the increases in the price–rent ratio, homeownership rate, and household debt between 1995 and 2006. This section examines the combined effects of changes in these fundamentals on equilibrium housing market outcomes. Fig. 5 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% and a required down payment, θ, of 20%. As illustrated in the figure, the price–rent ratio rises with a falling interest rate and lower down payment requirement. However, even when the minimum down payment is reduced all the way to 5%, the model generates an increase in the price–rent ratio that is significantly less than the 40% increase observed in the U.S. between 1995 and 2006.

In addition, the maximum effect of fundamentals shown in Fig. 5 likely represents an upper bound on the ability of this rational expectations model to explain the housing boom for several reasons. First, the supply of housing is fixed in the model, so there is no supply response to attenuate price increases driven by demand shifts.[38] Second, the relaxation of down

[38] Although the assumption of a fixed stock of housing implies that the model produces an upper bound on house price movements, the price–rent *ratio* is quite unresponsive to changes in supply. A 5-percent increase in the supply of housing combined with a lowered interest rate (from 4% to 2%) and

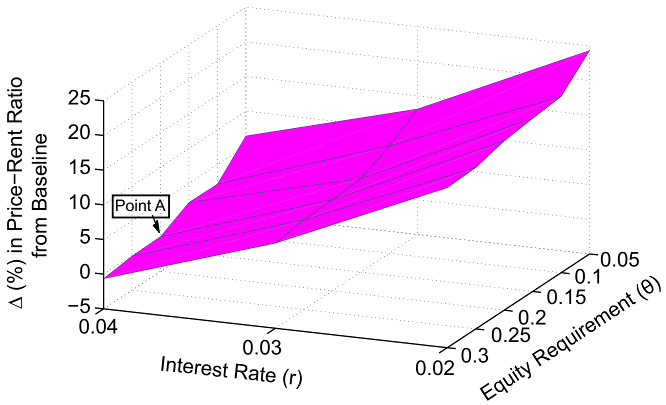

Fig. 5. Percentage deviations of the house price–rent ratio from the baseline (point A) under different interest rates and required downpayment.

Table 4
The combined effects of interest rate, required downpayment, and income changes.

Statistics	Baseline	Changes in r and θ (% Δ from Baseline)				U.S. data (% Δ)
	$r=0.04$ $\theta=0.20$ (1)	$r=0.02$ $\theta=0.15$ $\Delta w=0\%$ (2)	$r=0.02$ $\theta=0.15$ $\Delta w=+10\%$ (3)	$r=0.02$ $\theta=0.10$ $\Delta w=+10\%$ (4)	$r=0.02$ $\theta=0.05$ $\Delta w=+10\%$ (5)	1995–2006 (6)
House price	2.55	16.1%	28.1%	30.2%	31.7%	50.4%
Rental price	0.22	−3.5%	7.1%	6.6%	6.2%	7.9%
Price–rent ratio	11.3	20.0%	20.0%	22.4%	24.4%	39.4%

Notes: Columns (2)–(5) show percent changes in the equilibrium value of each variable from the baseline model shown in column (1). Column (6) shows the actual percent changes observed in the U.S.

payment requirements from 20% to 5% likely overstates the extent of relaxation of credit constraints in the economy, as available evidence (i.e., Foote et al., 2012) suggests that low-down payment loans had been commonly available to qualified borrowers in the period preceding the housing boom. Moreover, any household satisfying the down payment requirement qualifies for a high loan-to-value (LTV) mortgage in the model. In reality, additional underwriting criteria are put in place in order to qualify for high LTV loans, even though these were admittedly vastly relaxed during the boom. Finally, we treat the relaxation of credit constraints as an exogenous event. However, relaxed underwriting standards during the boom may have in part been an endogenous response by lenders to expectations of high future house price growth. To the extent that this is true, the causality may run from house prices to credit conditions, rather than in the reverse direction. As a result, the reduction of the down payment from 20% to 5% is designed with the intent of determining an upper bound of the effect of relaxed credit constraints in this type of model. With this in mind, the remainder of this section studies a range of different decreases in θ, because there is no particular decrease that unambiguously matches the relaxation observed during the housing boom.

Table 4 provides a more comprehensive analysis of the simulated effects of parameter changes by showing the 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, column (6) shows the actual changes over the U.S. housing boom. Column (2) shows that when income is held constant, lowering θ and r raises house prices, lowers rents, and consequently increases the price–rent ratio. Column (3) of Table 4 shows that increasing wages by 10% while decreasing θ and r does not change the price–rent ratio compared to the scenarios where income is held constant.[39] 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 data. Columns (4) and (5) show that further reductions in θ lead to relatively small additional increases in house prices and the price–rent ratio. We conclude that a plausible calibration of the model can account for approximately one-half of the changes in house prices and rents observed during the boom. An upper bound estimate of the fraction explained by fundamentals is approximately 60% (column (5)). These results suggest that the changes in the interest rate and required down payment observed in the United

(*footnote continued*)
down payment requirement (from 20% to 15%) leads to a proportional decrease in both the house price and rent, and does not affect the sensitivity of the price–rent ratio to changes in θ and r.

[39] A 10% increase in real wages is approximately what was observed in the U.S. between 1995 and 2005.

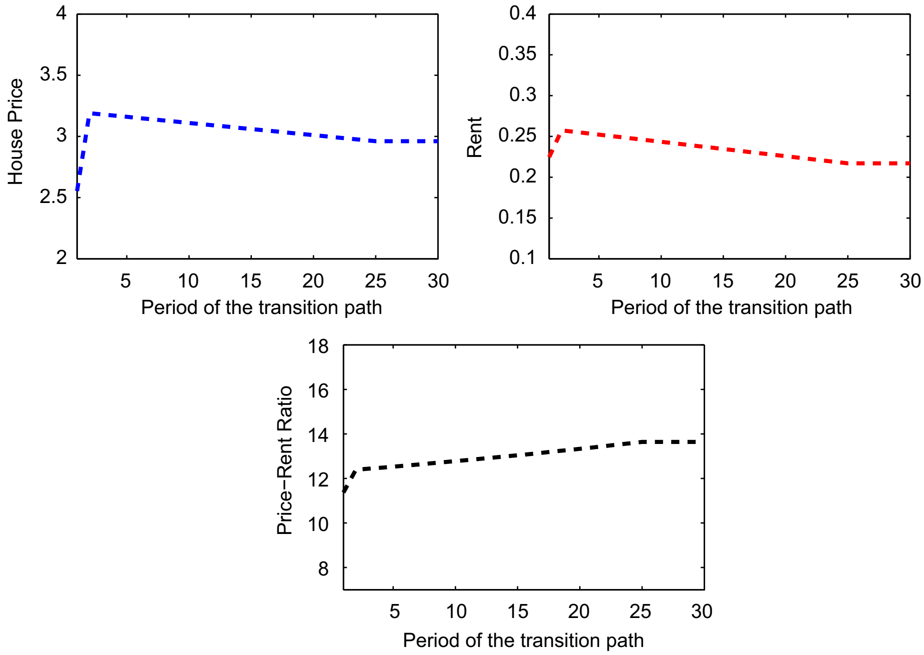

Fig. 6. Transition paths: simultaneous decrease in interest rate and minimum downpayment.

States had a considerable impact on the price–rent ratio, but also leave a significant portion of the run-up unexplained by this rational expectations model.

Turning to the mechanism, in the 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 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 θ and r 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, the analysis has been confined to comparisons of different steady state economies. This section studies the transitional dynamics of the housing market between two steady states. This experiment begins with the economy in a steady state that corresponds to the baseline calibration of the model, where the interest rate is 4% and the required down payment is 20%. Starting from this initial steady state, the interest rate and required down payment unexpectedly and permanently fall to $r=0.02$ and $\theta=0.15$. Along the perfect foresight transition path that ends at the new steady state, both house prices and rents are determined by market clearing.[40]

Fig. 6 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 their long-run steady state values: the house price increases by 25% while the rent increases by 15%. Although the price–rent ratio does not overshoot, it jumps by 9% on impact. After the initial spike in the house price and rent, the equilibrium prices decline gradually over time, and the price–rent ratio steadily increases to its new steady state level.

Why do house price and rent overshoot? Several mechanisms are jointly operative. The first mechanism is a portfolio reallocation between deposits and housing by households. The initial steady state features a relatively large amount of financial wealth (deposits), owing to the high (4%) rate of return and relatively high (20%) down payment requirement. An unexpected decline in the interest rate and the down payment requirement give households an incentive to shift their

[40] 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. A supplemental appendix describes the solution of the model along the transition path in more detail.

portfolios from deposits into housing, since the rate of return to deposits falls, the mortgage cost of financing falls, and housing consumption becomes more attractive relative to saving. In conjunction with this, a capital gains mechanism is operative. The initial increase in the house price allows existing homeowners to capitalize gains, trade-up, and move to larger homes. This mechanism operates in the same manner as the one discussed in Ortalo-Magné and Rady (2006), where a fixed supply of start-up homes bolsters the overshooting relative to our model. As a result, housing demand rises sharply, but there is a fixed housing supply, so the surge of funds into housing drives up the house price. Turning to the rental market, two forces jointly operate: on one hand, the lower interest rate reduces the cost of rental investment; on the other hand, the higher house price increases it. Initially, the house price effect dominates, and rent increases to compensate landlords for the increased cost of rental space. Initially, the homeownership rate stays roughly constant, in part due to higher shelter cost in both the homeownership and rental markets.

The initial spikes 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 accumulated 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. Moreover, as the overshooting in prices fades away, more renters shift into homeownership, the homeownership rate rises to its new long run equilibrium level, and rents fall because of the reduced demand for rental space.

7. Conclusion

The dynamic equilibrium model of the housing market presented in this paper allows both house prices and rents, not merely their ratio, to be determined endogenously. The model is used to study the effect of changes in fundamentals such as the interest rate, required down payment, and income on equilibrium in the housing market. This analysis is motivated by the fact that although house prices, rents, and their ratio are widely used economic indicators, there is no existing quantitative model of how these objects are simultaneously determined by the clearing of markets for owned and rented housing. Without an understanding of this theoretical relationship, 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.

This paper documents that interest rates and credit constraints reached very low levels by historical standards during the housing boom of 1995–2006, and uses the model as a tool to quantitatively evaluate the effects of changes in these fundamentals on house prices and rents. The model predicts that the combination of low interest rates and reduced down payment requirements leads to a large increase in the rational expectations equilibrium house price, but has little effect on the equilibrium rent. As a result, the house price–rent ratio increases. However, although the model illustrates that large increases in house prices accompanied by comparatively constant rents are consistent with the equilibrium response of the housing market to low interest rates and relaxed down payment requirements, changes in these fundamentals are capable of plausibly explaining only about one-half of the nearly 40% increase in the price–rent ratio observed between 1995 and 2006. In our view, the fact that this carefully specified and calibrated rational expectations equilibrium model can explain only a fraction of the observed increase in house prices provides indirect support for the hypothesis that overly optimistic expectations about house price growth contributed to a bubble in the housing market.

Although this paper studies the housing market boom, the housing market crash also illustrates the inherent limitations of using rational expectations, fundamentals-based models to explain recent events in the housing market. In this class of model, increased house prices and approximately constant rents are the fully sustainable, equilibrium response of the market to low interest rates and relaxed credit conditions. Within this framework, the housing market can only crash if there is an exogenous, unexpected increase in interest rates and tightening of credit conditions. We view this as an implausible explanation for the recent housing market bust.[41]

The analysis presented in this paper maintains the assumption of rational expectations about future house prices and rents. Piazzesi and Schneider (2009) examine household beliefs during the housing boom, and develop a tractable search model where optimistic traders can push up house prices. Consistent with our focus on credit conditions, these authors find that in the 2003 Michigan Survey of Consumers, the primary reason reported by households for believing that it was a good time to buy a house was favorable credit conditions. Later in the boom, they find that the proportion of households who believed that house prices would continue to increase reached a 25-year high. It is well recognized that incorporating this type of information about expectations into a model of the housing market raises many difficult conceptual and practical questions. However, given that our model leaves a large fraction of observed changes in house prices unexplained, we view this as an important avenue for future work.

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[41] See Foote et al. (2012) for a detailed discussion of rational expectations models such as Favilukis et al. (2011), which attempt to account for both the boom and bust through a single set of fundamentals.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found in the online version at http://dx.doi.org.10.1016/j.jmoneco.2013.04.017.

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