Understanding the Housing Bust: Disentangling Credit Crunch and Severe Recession*

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Abstract

Did a mortgage credit crunch cause the recent decline in the homeownership rate in the U.S.? To answer this question, I develop a lifecycle model that accommodates the expansion of alternative mortgages that featured delayed amortization. I use the model to measure the distributional consequences of two factors: (1) fade-out of alternative mortgages and (2) declines in labor earnings. I find that the declining labor income is the main driving force behind the cross-sectional feature of the housing bust: the proportionally larger decrease in homeownership among non-college educated households. The fade-out of alternative mortgages, however, predicts the opposite. This is because college educated households, who have high future earnings, are more likely to utilize alternative mortgages when those mortgages are available.

Keywords: Alternative Mortgages, Education, Homeownership, Income Profiles, Recession.

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1 Introduction

After a decade of expansion, the U.S. housing market has seen a continuous decline in the rate of homeownership. In addition, there have been noticeably different behaviors across education groups of households. According to data from the Current Population Survey (CPS), the decline in homeownership during the late 2000s was larger among non-college educated households, while the rise during the early 2000s was larger among college educated households. What can explain the housing bust that involves the distributional change in homeownership across education groups?

There are two possible explanations. One is the contraction of supply for alternative mortgages that featured delayed amortization, such as interest-only mortgages.[1] The origination share of those mortgages sharply decreased after 2007 (Amromin et al. (2010) and Corbae and Quintin (2010)).[2] Alternative explanation is a recession: declines in labor earnings.[3] There were substantial declines in real labor earnings from 2005 to 2009, especially among non-college educated households, based on the CPS data.

In this paper, I measure to what extent each of these factors can account for the observed cross-sectional features of the housing bust. The main objective of this paper is to determine which factor was quantitatively more important for the housing bust, based on their effects on the distribution of homeownership.

To answer the question, I construct a life-cycle model that accommodates a mortgage innovation. The mortgage innovation here is modeled as the introduction of an interest-only mortgage (IO),[4] which has a jump in the payment amount after the initial interest-only periods. The reason why I focus on the IO mortgage is that it was the most widely used product among delayed-amortization mortgage products in 2005, according to Barlevy and

[1]Mortgage products that involve unambiguously back-loaded payments are option-ARMs, balloon mortgages, and graduated payment mortgages.

[2]It is relevant to consider a mortgage credit crunch in the supply side during the late 2000s. For example, underwriting guidelines for non-traditional mortgages effective in October 2006 and a new consumer protection agency which is currently being created can be seen as evidence of regulation tightening that affects the supply of mortgage credits.

[3]Bajari et al. (2010) showed that one of the key driving forces of the recent increase in mortgage defaults was the increase of borrowers with high payment to income ratios.

[4]Mian and Sufi (2010) provided evidence that the credit expansion from 2002 to 2006 was supply driven. Chambers et al. (2009) and Corbae and Quintin (2010) also model the financial innovation as the introduction of new types of mortgages.

Fisher (2010). In the model without the mortgage innovation, only a standard fixed-rate mortgage (FRM), which has a constant payment over time, is available to households. Households are heterogeneous in terms of uninsurable income shocks and education levels, which determine the shape of earning profiles. I calibrate the model without the mortgage innovation so that key model statistics match the actual statistics in the year 2000.

The mortgage innovation in the calibrated model successfully captures the cross-sectional feature of the housing boom: a larger increase in homeownership among college educated households. This feature is driven by the different characteristics of earning profiles for college and non-college educated households. Since college educated households face steeper earning profiles than non-college educated households, they find the lower initial payments on the IO mortgage more useful for consumption-smoothing. Therefore, when the mortgage innovation is introduced, college educated households are more likely to utilize the innovation. This implication is consistent with recent findings from micro data. Amromin et al. (2010) document that IO mortgages were more prevalent in the area of highly educated population. Also, a typical user of IO mortgages was not a subprime borrower, but a safe and relatively rich borrower.[5]

Using this model, I measure the relative importance of two factors in accounting for the housing bust: (1) fade-out of the IO mortgage supply and (2) declines in labor earnings. Specifically, I quantify the effects of each factor on the distribution of homeownership by conducting comparative steady state analyses for these two scenarios.

The main finding is that the mortgage credit crunch per se cannot account for the cross-sectional feature of the housing bust. The fade-out of IO mortgage supply results in a proportionally larger decrease in homeownership among college educated households, contrary to the observation. This is because there are more homeowners who use IO mortgages among college educated households. On the other hand, the observed income declines gen-

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[5]Amromin et al. (2010) show that the average income and the average FICO credit score among IO mortgage borrowers were both higher than those among traditional mortgage borrowers based on the Lender Processing Services data from 1998 to 2008. Also, Landier et al. (2010) report that New Century Financial Corporation, which was a large mortgage lender in the U.S., massively issued alternative mortgages to younger, safer, and richer households from 2004 to 2006. Cocco (2010) provides empirical evidence that IO mortgages are extensively used by households who expect higher future labor earnings using the UK data.

erate a proportionally larger decline in homeownership among non-college educated households, which is consistent with the observation. The observed income decline was about four times larger for non-college educated households, according to the CPS data.

To the best of my knowledge, this is the first paper that quantifies the effects of the mortgage innovation on the distribution of homeownership across education groups. The previous literature has shown that the mortgage innovation has a sizable impact on the aggregate homeownership rate and the aggregate foreclosure boom.[6] I show that the mortgage innovation generates a proportionally larger increase in homeownership among college educated households. My results shed light on the housing wealth concentration during the recent housing boom and bust.

This paper is related to the literature that studies other aspects of the housing boom and bust in the United States. Kiyotaki et al. (2010) and Sommer et al. (2010) study house prices, rents, and homeownership by examining the roles of changes in fundamentals, such as declines in downpayment requirements and interest rates. Ríos-Rull and Sánchez-Marcos (2006), Arslan(2008), and Favilukis et al. (2010) study house price dynamics by examining the effects of financial constraints and aggregate uncertainties on earnings and interest rates. Chatterjee and Eyigungor (2009) study the effect of an unexpected increase in the housing supply on house prices and foreclosures.

This paper is also related to the literature that studies housing decisions over the life-cycle. Nakajima (2005), Fernández-Villaverde and Krueger (2010), Fisher and Gervais (2010), and Iacoviello and Pavan (2010) demonstrate the effects of uninsurable income risk on the life-cycle pattern of housing investment and provide their macroeconomic implications. Yang (2009) and Li and Yao (2007) show the importance of borrowing constraints and housing transaction costs in explaining the distribution of homeownership. My paper examines mortgage decisions in home purchasing and finds the importance of the steepness of income profiles in those decisions.

The rest of the paper consists of 4 sections. Section 2 demonstrates the distributional changes in homeownership across education groups during

[6] Chambers et al. (2008, 2009) show that the expansion of alternative mortgages accounts for a large fraction of the observed increase in the aggregate homeownership rate from 1994 to 2005. Corbae and Quintin (2010) demonstrate that the contraction of alternative mortgages significantly amplify a foreclosure boom following an unexpected house price decline.

Table 1: Change in the Composition of Homeowners

	Homeownership Rate	% of College Educated among Homeowners
1995	61 %	39 %
2000	**65 %**	**41 %**
2005	67 %	45 %
2010	**64 %**	**48 %**

Note: Data source is the March CPS Supplement.

the 2000s. Section 3 describes the model economy and defines equilibrium. Section 4 explains how I calibrate the model and shows main results. Finally, section 5 concludes.

2 Changes in U.S. Homeownership

This section documents the distributional change in homeownership across education groups, as well as the change in the homeownership rate.

Table 1 shows the homeownership rate and the share of college educated homeowners in the U.S. from 1995 to 2010. These statistics are calculated for households whose householder is aged 20-64, using the data from the March CPS Supplement.[7] The homeownership rate increased over the period of 1995-2005 but decreased thereafter. The share of college educated homeowners, on the other hand, has continuously increased since 1995. The increase in housing wealth concentration was especially evident during the 2000s. The share of college educated homeowners increased from 41% to 48%, while the homeownership rate in 2010 (64%) was almost the same as in 2000 (65%).

What contributed to the changes in the homeownership rate and the composition of homeowners? They can be driven by demographic changes and/or

[7]This paper investigates housing and mortgage decisions of households with different education levels, focusing on the different characteristics of their earning profiles. Therefore, the statistics are calculated for the working population.

The definition of householder is provided by the CPS. It refers to the person in whose name the housing unit is owned or rented.

Table 2: Change in the Homeownership Rate

	1995-2000	2000-2005	2005-2010
Change in the homeownership rate Δh_t	3.8 %	1.9 %	-3.2 %
<u>Contribution:</u>			
Homeownership (non-college)	**47 %**	4 %	**-92%**
Homeownership (college)	19 %	**58 %**	-47 %
Share of college educated	7 %	13 %	11 %
Age structure of population	29 %	23 %	24 %
Covariance terms	0 %	2 %	4 %
	100 %	100 %	-100 %

Source: March CPS Supplement

the changes in individual participation behaviors. To answer this question, I calculate the contributions of the following four factors: change in homeownership among non-college educated households, change in homeownership among college educated households, change in the share of college educated households, and the change in the age structure in the population. I use the age groups by 10 years and the education groups of non-college and college educated households. In the appendix A-1, I describe how to decompose the change in the aggregate homeownership rate into the contribution of each factor.

Table 2 shows the results for the periods of 1995-2000, 2000-2005, 2005-2010. The first row shows the difference between the homeownership rates in the year t_0 and t. The second to fifth rows show the contributions of the four factors to the change in the homeownership rate from t_0 to t. The sixth row shows the contribution of interactions among the four factors. Finally, the last row indicates that contributions of all factors sum up to 100%.

There are three messages from Table 2. First, in all periods, the changes in the group specific homeownership rates accounted for a large fraction of the change in the homeownership rate. That is, the changes in behavior were important for the changes in the aggregate homeownership rate.

Second, the decrease in the homeownership rate from 2005-2010 was mainly driven by the decline in the homeownership rate among non-college educated households (-92% vs -47%), while the increase in the homeownership rate from 2000-2005 was mainly driven by the increase in the homeownership rate among college educated households (4% vs 58%). These different behaviors of education groups can also be confirmed by looking at the homeownership rate by age and education. Table A-1 in the appendix shows that there was a proportionally larger increase in homeownership among college educated households during the early 2000s (0.9 percentage point increase vs 4.7 percentage point increase), but there was a proportionally larger decrease in homeownership among non-college educated households during the late 2000s (-3.7 percentage point decrease vs -3.4 percentage point decrease).

Third, a larger contribution of the increase in the homeownership rate among college educated households was specific to the period of 2000-2005. During the period of 1995-2000, the increase in the homeownership rate among non-college educated households contributed more to the increase in the aggregate homeownership rate (47% vs 19%). This reveals a different nature of the housing boom after 2000 and suggests the importance of factors which are specific to this period, such as the expansion of delayed-amortization mortgages.

In summary, there have been noticeably different behaviors across education groups during the recent housing boom and bust in the U.S. The empirical analysis in this section showed that those different behaviors of different education groups had sizable impacts on the aggregate homeownership rate. It also documented that the fall in the homeownership rate was mainly driven by non-college educated households during 2005-2010, while the rise in the homeownership rate was mainly driven by college educated households during 2000-2005.

3 Model

In this section, I present a life-cycle model which demonstrates how a financial innovation affects households with different education levels. Specifically, I consider the introduction of alternative mortgages with delayed amortization as a financial innovation. The key ingredients of the model are education-specific earning profiles and mortgages. Different characteristics of earning profiles induce heterogeneous mortgage choices across education groups. The mechanism behind the heterogeneous decisions is crucial for understanding the distributional effects of the financial innovation and reversion.

In the model, there are continuously many households with two levels of education, a representative production firm, a representative housing rental agency, and a government. Houses are indivisible and illiquid, play the dual role of consumption and investment goods. There are two types of mortgages with different amortization schedules, the fixed rate mortgage (FRM) and the interest-only mortgage (IO). The financial market is open to the rest of the world and thus agents face the world interest rates for financial asset and mortgage debt.

In the presence of uninsurable income risk, households make decisions on housing tenure, housing size, and mortgage type in addition to consumption and savings. Future income profiles play an important role in mortgage decisions, because mortgage repayments continue over long periods of time. The production firm produces consumption goods and housing investment goods using two different technologies. Therefore, the house price and the rental price are endogenously determined in the model. The housing rental agency rents housing units to renting households. The government collects income taxes to finance its consumption. It also runs a social security system.

3.1 Houses

Houses are traded at price P per unit of housing space, but there is a minimum size of a house to own $\bar{h}$. The minimum size of houses captures the indivisible nature of houses and generates some households who cannot own a house. Such households have no house ($h = 0$), but they rent an apartment h^R from the housing rental agency at rate R.[8]

Transaction costs of housing are introduced in the model in order to capture the nature of houses as an illiquid asset. Households have to pay transaction costs to a financial intermediary firm when they buy or sell a house. The cost function of housing transactions is

$$\chi^T(h_{-1}, h, P) = \begin{cases} \chi_0^T + \chi_b^T Ph + \chi_s^T Ph_{-1} & \text{if } h_{-1} \neq h \\ 0 & \text{otherwise.} \end{cases}$$

[8]Therefore, $h > 0$ means "own" and $h = 0$ means "rent."

where h_{-1} and h are the house to buy and the house to sell, respectively. Note that these costs are associated with transactions of owned houses.

Houses are assumed to depreciate at different rates based on their status. If a house is owned by a household, it depreciates at rate δ_h. If it is rented by a household, it depreciates at rate δ_R.

3.2 Mortgages

In the model, households must make a long-term mortgage contract. There are two types of mortgages: the FRM and the IO mortgage. The type of a mortgage is represented by $z \in \{0, 1(\text{FRM}), 2(\text{IO})\}$, where $z = 0$ means that no mortgage is held. $z = 0$ is relevant for homeowners who have paid off their mortgage in full and renters. The two types of mortgages are different in two dimensions: the rate of downpayment $\lambda(z)$ and the amortization schedule $A(z)$. The length of contract N is assumed to be common across mortgage types and to be corresponding to 30 years, for simplicity.

For both types of mortgage, the mortgage payment $m(n, z)$ consists of two parts;

$$m(n, z) = r^m D(n, z) + A(n, z) \tag{1}$$

where the interest payment part $r^m D(n, z)$ and the amortization part $A(n, z)$. The debt outstanding $D(n, z)$ follows the law of motion below;

$$D(n - 1, z) = D(n, z) - A(n, z) \tag{2}$$

where n is the remaining periods of mortgage payments and $A(n, z)$ is the amortization part of the mortgage payment.

Fixed Rate Mortgage (z=1)

A key feature of the fixed rate mortgage is a constant payment over the contract periods N. That is, $m(n-1, 1) = m(n, 1)$ for any remaining periods of payments $n = 1, \cdots, N$. Together with (1) and (2), this gives

$$m(n, 1) = \frac{r^m}{1 - (1 + r^m)^{-N}} D(N, 1) \quad \text{for } n = 1, \cdots, N.$$

where the initial amount of debt is $D(N, 1) = \lambda(1) P h$.

Interest-Only Mortgage (z=2)

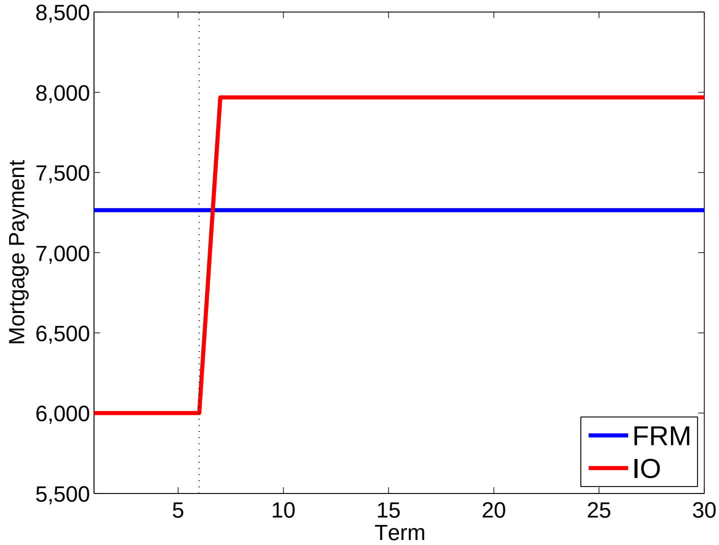

Figure 1: Payment Schedules of FRM and IO Mortgage

Note: Mortgage payment schedules for the FRM and the IO mortgage are calculated for the initial debt of $100,000 and the annual mortgage interest rate of 6%. The mortgage maturity is 30 years for both mortgages and the interest only period is 6 years.

A key feature of the interest-only mortgage is a low initial payment. For the first N^{IO} periods, the borrower pays only the interest part of the payment. Therefore, the debt outstanding $D(n,2)$ starts declining after N^{IO} periods, when the borrower starts paying the amortization part as well as the interest prat. Together with (1) and (2), this gives

$$m(n,2) = \begin{cases} r^m D(N,2) & \text{if } n = N - N^{IO}, \cdots, N \\ \frac{r^m}{1-(1+r^m)^{-(N-N^{IO})}} D(N,2) & \text{if } n = 1, \cdots, N - N^{IO} \end{cases}$$

where the initial amount of debt is $D(N,1) = \lambda(2)Ph$.

The payment schedules of these two mortgages have different characteristics due to their different amortization schedules. Figure 1 depicts typical mortgage payment schedules for the 30-year FRM and the 30-year IO mortgage. The initial loan balance is set to $100.000, the annual mortgage interest rate is set to 6%, and the initial interest-only periods are 6 years in the example. As Figure 1 shows, the payments on the IO mortgage is low during the interest-only phase and becomes high thereafter. The payments on the FRM are constant over the term of the mortgage.

The characteristics of payment schedules and earning profiles are important for mortgage decisions. For example, households who expect to have higher future earnings find the low initial payments on the IO mortgage useful for a consumption-smoothing purpose. Households use mortgages that works best with their earning profiles in home purchasing. This is the key for the heterogeneity in mortgage choices across education groups, because earning profiles exhibit different shapes for different education groups.

3.3 Households

In each period, a mass of households are born with an education level $e \in \{1 \text{ (noncollege)},\ 2 \text{ (college)}\}$, some asset ($a_0$), but no house ($h_0 = 0$). They live J periods at longest, but there is a possibility of unexpected death in every period. A household at age j survives to age $j+1$ with probability $\psi^s_{j+1} \in [0, 1]$ where $\psi^s_1 = 1$.

Households derive utility from consumption goods c and housing services. Housing services come from an owned house h or a rental housing unit h^R, and the relationship between the amount of housing service flow and housing units is assumed to be linear. Therefore, the utility function takes housing units (h or h^R) as an argument.

The expected discounted utility of a household is

$$E_0 \sum_{j=1}^{J} \beta^{t-1} \psi^s_{j+1} u(c_j, h_j), \quad \beta \in (0, 1). \tag{3}$$

Each household inelastically supplies its labor but its efficiency is heterogeneous among households. Labor efficiency of a household $\varphi_{ej}\epsilon$ consists of a deterministic component φ_{ej} and a stochastic component ε. The deterministic component depends on education e and age j and it captures a hump shape of life-cycle earnings. The stochastic component captures variation in earnings within an age-education group. Specifically, it is assumed as

$$\begin{aligned} \ln \epsilon' &= \nu' + \varepsilon' \\ \text{where} \quad \nu' &= \rho\nu + \iota' \end{aligned} \tag{4}$$

where $\varepsilon' \sim N(0, \sigma^2_\varepsilon)$ and $\iota' \sim N(0, \sigma^2_\iota)$. I assume that labor efficiency becomes zero a mandatory retirement age J_r.

Households earn labor income $w\varphi_{eij}$ at working ages, and they receive a social security benefit $\bar{y}_e$ after retirement. In addition to labor earnings, households receive interest earnings, the per-capita profit from the representative firm, and the transfer from the government. However, households have to pay income taxes and the social security tax to the government. Therefore, the after-tax income (y) of a household is given by

$$y = \begin{cases} (1+r-\delta)a + (1-\tau_p)w\varphi_{ej} + \Pi - T(\tilde{y}) & \text{if } j \leq J_r \\ (1+r-\delta)a + \bar{y}_e + \Pi - T(\tilde{y}) & \text{if } j = J_r \cdots J \end{cases}$$

where $(1 + r - \delta)$ is the gross rate on saving, τ_p is the social security tax rate and $T(\tilde{y})$ is the amount of income tax, and $\tilde{y}$ is the taxable household income.

The taxable household income $\tilde{y}$ is defined as

$$\tilde{y} = \begin{cases} (1+r-\delta)a + w\varphi_{ej} + \Pi - \Gamma & \text{if } j \leq J_r \\ (1+r-\delta)a + \bar{y}_e + \Pi - \Gamma & \text{if } j = J_r \cdots J \end{cases}$$

where Π is the per-capita profit of the representative firm, Γ is a deduction, and $\bar{y}_e$ is the social security benefit. As a deduction Γ, I consider the mortgage interest deduction, which is one of the important feature of the current U.S. tax code.[9]

This formulation of taxable income also captures the asymmetric treatment of housing in the U.S.; the implicit income from housing capital are tax-deductible, while returns on financial asset, $(1 + r - \delta)a$, are taxable. Gervais (2002) argues that the preferential tax treatment of housing distorts composition of households' saving and finds that its welfare cost is substantial. Nakajima (2010) considers the optimal capital income tax rate given the U.S. housing tax provisions and finds that it should be close to zero in order to nullify the distortion.

3.4 Households' Problem

Households make decisions on consumption c, savings a', the size of a owned house h, and the type of mortgage z' based on their budget constraints. The state variables that determine their budget constraint is the asset holding a, the previous size of the owned house h_{-1}, the type of the mortgage currently

[9]In the U.S. tax code, interest payments on up to \$ 1 million of home acquisition debt are deductible from federal income taxes.

held z, the remaining periods of mortgage payments n, the shock in labor efficiency ϵ, education e and age j.

Among these state variables, the previous housing position h_{-1} needs special attention, because the budget constraint takes different forms for a renter ($h_{-1} = 0$) and for a homeowner ($h_{-1} > 0$). This is because the set of housing choices differs depending on the previous housing position h_{-1}. The housing positions available are summarized as follows:

$$\text{Renter } (h_{-1} = 0) \quad : \quad \begin{cases} \text{(1) continue renting} \\ \text{(2) purchase a house} \end{cases}$$

$$\text{Homeowner } (h_{-1} > 0) \quad : \quad \begin{cases} \text{(3) keep the same house} \\ \text{(4) sell the house} \\ \text{(5) resize the house} \\ \text{(6) default on the mortgage} \end{cases}$$

In addition to the discrete choice in homeownership, households have to deal with another discrete choice on the mortgage type because every household have to take out a mortgage in home purchases. Households compare the value functions of all available options and choose the option which associates with the highest value. The value function of each option will be defined below.

3.4.1 Renter Yesterday ($h_{-1} = 0$)

If a household was a renter in the previous period ($h_{-1} = 0$), it has two housing choices: (1) continue renting and (2) buy a house and become a homeowner. Since the household did not have a house yesterday, at the beginning of the current period, it has no mortgage $z = 0$ and zero remaining period of mortgage payments $n = 0$. Renters lives in a space h^R rented from a rental housing retailer at a price R.

The problem of a renter is defined as follows.

$$W(a, 0, 0, 0, \epsilon, e, j) := \max_{\theta \in \{1,2\}} \Big\{ V_\theta(a, 0, 0, 0, \epsilon, e, j) \Big\}$$

where V_1 and V_2 will be defined below.

(1) Continue Renting

The value associated with continued renting is the expected present-value of life-time utility which is maximized over consumption c and asset holding tomorrow a'.

$$V_1(a,0,0,0,\epsilon,e,j) := \max_{c\geq 0,\ a'\geq 0}\left\{u(c,h^R) + \beta\psi^s_{j+1}\int_{\epsilon'} W(a',0,0,0,\epsilon',e,j{+}1)\ \mathrm{d}F(\epsilon'|\epsilon)\right\}$$
$$\text{s.t.}\quad c + Rh^R + a' = y$$

where $F(\cdot|\cdot)$ is a conditional distribution function of income shock ϵ and y is the after-tax income, which is defined in the section 3.3.

(2) Purchase a House

A renter who chooses to become a homeowner have to decide on the size of the house h and the type of a mortgage z. Since mortgage payments last for N periods, the household considers possible future streams of earnings and chooses a mortgage with a suitable payment schedule. The value to purchase a house and become a homeowner solves

$$V_2(a,0,0,0,\epsilon,e,j) := \max_{c\geq 0, a'\geq 0, h, z'}\left\{u(c,h) + \beta\psi^s_{j+1}\int_{\epsilon'} W(a',h,z',N{-}1,\epsilon',e,j{+}1)\ \mathrm{d}F(\epsilon'|\epsilon)\right\}$$
$$\text{s.t.}\quad c + a' + \chi^T(0,h,P) + \lambda(z')Ph + m(z',N) + \delta_h Ph = y$$

where $\chi^T(\cdot)$ is the transaction cost of housing, which is defined in section 3.1, and $\lambda(\cdot)$ and $m(\cdot)$ are the rate of the downpayment and the mortgage payment, which are defined in section 3.2. The household also pays the maintenance cost for the owned house, $\delta_h Ph$, at the end of the period.

3.4.2 Homeowner Yesterday ($h_{-1} > 0$)

If a household was a homeowner in the previous period ($h_{-1} > 0$), it has four choices: (3) keep the same house, (4) sell the house and become a renter, (5) sell the house and buy a different house, and (6) default on the mortgage and become a renter.[10]

The problem of a homeowner, i.e. $(h_{-1}, z, n) \neq (0,0,0)$, is

$$W(a,h_{-1},z,n,\epsilon,e,j) := \max_{\theta\in\{3,4,5,6\}}\left\{V_\theta(a,h_{-1},z,n,\epsilon,e,j)\right\}$$

where V_3, V_4, V_5, and V_6 will be defined below.

[10] Refinancing the mortgage while keeping the same house is a reasonable option, but I abstract it from the current model for simplicity.

(3) Keep the Same House
A homeowner who chooses to stay in the same house also keep the same mortgage contract. Therefore, it does not choose the housing size nor the mortgage type. The value to keep the same house solves

$$V_3(a, h_{-1}, z, n, \epsilon, e, j) := \max_{c\geq 0, a'\geq 0} \left\{ u(c, h_{-1}) + \beta\psi^s_{j+1} \int_{\epsilon'} W(a, h_{-1}, z, n{-}1, \epsilon', e, j{+}1)\ \mathrm{d}F(\epsilon'|\epsilon) \right\}$$
$$\text{s.t.} \quad c + a' + m(z, n) + \delta_h P h_{-1} = y,$$

where $m(z, n)$ is the mortgage payment and $\delta_h P h_{-1}$ is the maintenance cost of the owned house.

(4) Sell the Same House
A homeowner who chooses to sell the house and become a renter has to repay all remaining mortgage loan. The value to keep the same house solves

$$V_4(a, h_{-1}, z, n, \epsilon, e, j) := \max_{c\geq 0, a'\geq 0} \left\{ u(c, h^R) + \beta\psi^s_{j+1} \int_{\epsilon'} W(a', 0, 0, 0, \epsilon', e, j{+}1)\ \mathrm{d}F(\epsilon'|\epsilon) \right\}$$
$$\text{s.t.} \quad c + Rh^R + a' + \chi^T(h_{-1}, 0, P) = y + Ph_{-1} - D(z, n)$$

where Rh_R is the rental cost, $\chi^T(h_{-1}, 0, P)$ is the selling cost, and $D(z, n)$ is the outstanding debt on the house h_{-1}.

(5) Sell the House and Buy a Different House
A homeowner who chooses this option have to sell the house and repay the all remaining mortgage loan for the house. Then, it chooses the size of a new house h and the type a new mortgage z. The value to sell the same house and buy another house solves

$$V_5(a, h_{-1}, z, n, \epsilon, e, j) := \max_{c\geq 0, a'\geq 0, h, z'} \left\{ u(c, h) + \beta\psi^s_{j+1} \int_{\epsilon'} W(a, h, z', N{-}1, \epsilon', e, j{+}1)\ \mathrm{d}F(\epsilon'|\epsilon) \right\}$$
$$\text{s.t.} \ \ c + a' + \chi^T(h_{-1}, h, P) + \lambda(z')Ph + m(z', N) + \delta_h Ph = y + Ph_{-1} - D(z, n).$$

(6) Default on the Mortgage
A homeowner who defaults on the mortgage obtains a discharge of debts, but it has to pay a default cost $\chi^D P\tilde{h}_{-1}(n)$ and abandon the house. The value

to default on the mortgage solves

$$V_6(a, h_{-1}, z, n, \epsilon, e, j) := \max_{c\geq 0, a'\geq 0} \left\{ u(c, h^R) + \beta\psi^s_{j+1} \int_{\epsilon'} W(a', 0, 0, 0, \epsilon', e, j{+}1)\ \mathrm{d}F(\epsilon'|\epsilon) \right\}$$
$$\text{s.t.} \quad c + Rh^R + \chi^D Ph_{-1} + a' = y$$

It is assumed that households in the final period J must rent for the non-Ponzi condition to be satisfied. Therefore, every homeowner at the beginning of the final period have to choose either to sell its house or to default on its mortgage.

3.5 Production Firm

The representative firm produces consumption goods and housing investment goods using a constant returns to scale technology for each production. The production function for consumption goods is

$$Y_t = A_{Yt} K_{Yt}^{\gamma} N_{Yt}^{1-\gamma}, \quad \gamma \in (0,1) \tag{5}$$

where A_{Yt} is aggregate productivity of consumption goods production, and K_{Yt} and N_{Yt} are the capital and the labor inputs used in consumption goods production.

The production function for housing investment goods is

$$Y_H = A_H K_H^{\alpha_K} N_H^{\alpha_N} L^{1-\alpha_K-\alpha_N}, \quad (\alpha_K + \alpha_N) \in (0,1) \tag{6}$$

where A_{Ht} is aggregate productivity of housing investment goods production, and K_{Ht}, N_{Ht}, and L are the capital and the labor inputs and the new supply of land used in consumption goods production. Note that housing investment goods production requires land. I assume that aggregate supply of land is fixed as in Davis and Heathcote (2005).

Given wage rate w_t, capital rental rate r_t, and house price p_t, the firm solves the following problem:

$$\tilde{\Pi} := \max_{\{K_Y, K_H, N_Y, N_H\}} \left\{ Y + PY_H - r_t(K_Y + K_H) - w_t(N_Y + N_H) \right\} \tag{7}$$
$$s.t. \quad (5) \quad \text{and} \quad (6)$$

Since aggregate supply of land is exogenously given, the housing production technology is decreasing returns to scale with respect to capital and labor. Therefore, the profit $\tilde{\Pi}$ is positive. I assume that households own the representative firm and its profit is equally distributed across all households.

3.6 Housing Rental Agency

There is a representative firm which supplies rental housing, which is called a housing rental agency. At the beginning of each period, it sells all properties held in the previous period H^R_{-1} and purchases properties to be rented in this period H^R. Then, it obtains revenue by renting them RH^R and pays the maintenance cost $\delta_R PH^R$. Therefore, the problem of the housing rental agency is

$$V(H^R_{-1}) := \max_{H^R} \left\{ RH^R - P(H^R - H^R_{-1}) - \delta_R PH^R + \frac{1}{1+r} V(H^R) \right\}$$

where δ is the rate of depreciation, R is the rental price and P is the house price. I assume that housing transactions by the housing rental agency do not incur a transaction cost $\chi^T(\cdot)$.

The solution to the problem gives the following no-arbitrage condition,

$$R = \left(\frac{r}{1+r} + \delta^R \right) P. \tag{8}$$

This condition also imply that the agency makes zero profit and it is indifferent about how much rental housing to supply.

3.7 Housing Market Clearing

In this model, the housing market clearing condition is complicated because there are many actions involved. The supply of housing investment goods in each period is given by

$$Y_H + \int h_{-1} \cdot 1_{(\theta \in \{4,5,6\})} \, \mathrm{d}\mu + \int \frac{1 - \psi^s_j}{\psi^s_j} h_{-1} \, \mathrm{d}\mu + H^R_{-1}.$$

The first term Y_H is the new housing invest goods produced by the production firm. The second term is the sum of the housing sold by homeowners who sell or resize their houses and the housing of homeowners who default on a mortgage. The third term is the housing of homeowners who unexpectedly die at the beginning of the period and the fourth term is the housing sold by the housing rental agency.

The demand of housing in each period is given by

$$\int h \cdot 1_{(\theta \in \{2,4\})} \, \mathrm{d}\mu + H^R + \delta_h \int h \cdot 1_{(\theta \in \{2,3,5\})} \, \mathrm{d}\mu + \delta_R H^R.$$

The first term captures demand from renters who decide to buy a house and homeowners who decide to resize their houses. The second term is demand from the housing rental agency. The last two terms capture the housing investment goods demanded for a maintenance purpose by homeowners and the housing rental agency.

3.8 Equilibrium

Definition:
An equilibrium consists of prices (w, P, R), value and policy functions, and a stationary distribution μ such that

(1) Value and policy functions solve the agents' problems.

(2) Markets clear.

(3) Government budget constraint is satisfied.

(4) μ is implied by the decision rules.

4 Quantitative Analysis

This section describes calibration of the model and main results of the analysis. The main objective is to quantify the effects of a mortgage credit crunch and a recession and determine which factor is quantitatively more important for understanding the current housing bust. In the model, a mortgage credit crunch is implemented as the fade-out of IO mortgages and a recession is implemented as declines in labor earnings.

4.1 Calibration

The model parameters are calibrated so that key statistics of the model economy in the 2000 steady state match the actual statistics in the year 2000. There are parameters that can be directly specified from their implication. There are also parameters that need to be jointly determined to match a set of statistics in the model with the corresponding statistics in the data.

One period in the model corresponds to three years. Households in the model start their life at age 20 and live until age 79. The exogenous survival probabilities $\{\psi_j^s\}_{j=1}^J$ are taken from "United States Life Tables 2000" issued

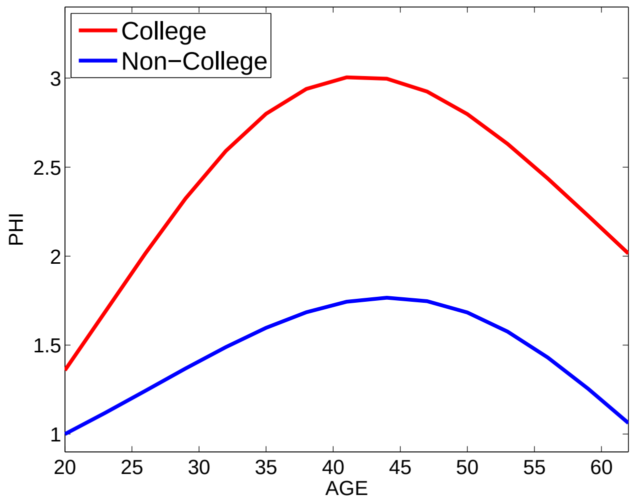

Figure 2: Estimated Profiles of Labor Efficiency φ_{ej}

Note: The data source is the March CPS supplement from 1999 to 2001.

by the National Center for Health Statistics. The mandatory retirement age is set to age 65.

I use the following utility function

$$u(c,h) = (1-\gamma_h)\frac{c^{1-\sigma_c}}{1-\sigma_c} + \gamma_h\left(1_{own}\cdot\frac{(\theta h)^{1-\sigma_h}}{1-\sigma_h} + (1-1_{own})\cdot\frac{h^{1-\sigma_h}}{1-\sigma_h}\right)$$

where $\theta \cdot 1_{own}$ capture the owner-occupied premium. The coefficients (σ_c, σ_h) are set to (2,1). The share of the utility from housing service γ_c will be jointly determined. The time discounting factor β is set to 0.98.

One of the most important parameters for the quantitative analysis is the deterministic component of labor efficiency $\{\varphi_{ej}\}_{j=1}^{J}$ for each education level e. I estimated $\ln\varphi_{ej}$ using a cubic polynomial function of age and the CPS micro data on earnings, which include salary and self-employment income, from 1999 to 2001.

Figure 2 shows the estimated $\{\varphi_{ej}\}_{j=1}^{J}$ for non-college and college educated households, which are normalized by $\varphi_{11} = 1$. They exhibit clearly different shapes: the deterministic component of labor efficiency increases at a much higher rate for college educated households than non-college educated households.

Table 3: Parameters Determined Jointly (Annual Values)

Parameter	Value	Target
Owner-occupied premium (θ)	10	Homeownership rate (college)
Min size of house ($\underline{h}$)	1.20	Homeownership rate (non-college)
Size of rental unit (h_R)	0.52	Rent to Income Ratio for Low-Income Households
Utility weight on housing services (γ_h)	0.80	Housing expenditure to GDP ratio
Relative productivity of housing production (A_H)	0.48	Housing investment to GDP ratio
Tax function coefficient (η_0)	0.46	Gov. expenditure to GDP ratio

The parameters of the stochastic component of labor efficiency are taken from Guvenen (2007).[11] Then, I discretize the process into a seven state Markov chain using the method by Tauchen (1986).

The length of the mortgage N is set at 10 which corresponds to 30 years, and the rate of downpayment λ^{FRM} is set at 20 %. The mortgage interest r_m is set so that the annual rate becomes 5.5%, following Sommer et al. (2010). The parameter values of housing transaction costs are also taken by Sommer et al. (2010) and they are $(\chi_0^T, \chi_b^T, \chi_s^T)$=(0,0.25,0.7).

In order to represent the income tax code in the U.S., I use the tax function originally given by Gouveia and Strauss (1994).

$$T(\tilde{y}) = \eta_0 \left\{ \tilde{y} - (\tilde{y}^{\eta_1} + \eta_2)^{\frac{-1}{\eta_2}} \right\}$$

where $\tilde{y}$ is the taxable income. I set η_1 to 0.768 as in Gouveia and Strauss (1994) and set η_2 to 0.371 so that the measurement units in the model become relevant. η_0 will be determined jointly.

Including those already mentioned, there are five housing related parameters and one tax parameter that need to be jointly determined. They are

[11] I used the estimates for the "restricted income profiles" process in Guvenen (2007) because it uses the same specification as in this paper.

Table 4: Steady State Statistics

Target	Data	Model
Homeownership rate (college)	72%	75%
Homeownership rate (non-college)	61%	58%
Rent to Income Ratio for Low-Income Households	40%	40%
Housing expenditure to GDP ratio	12%	15%
Housing investment to GDP ratio	5 %	5 %
Gov. expenditure to GDP ratio	15%	15%

the utility premium from owning a house θ, the rental unit size h_R, the minimum housing size $\underline{h}$, the utility weight on housing services γ_h, the relative productivity of housing A_H, and the tax function coefficient η_0. I determine these parameters so that the following six statistics in the model are close to the 2000 values in the data: the homeownership rate among college educated households, the homeownership rate among non-college educated households, the rent-to-income ratio for poor renters, the housing expenditure to GDP ratio, the housing investment to GDP ratio, and the government expenditure to GDP ratio. Table 3 reports the calibrated values of the six parameters and Table 4 shows the targeted statistics generated by the model.

4.2 Results

Using the calibrated model, I conduct comparative steady state analyses considering the steady states in 2000, 2005, and 2010. There are only FRMs available to households in the 2000 steady state while both FRMs and IO mortgages are available to households in the 2005 steady state. For the 2010 steady state, I consider three scenarios to identify the key factor during the housing bust: (1) mortgage credit crunch (2) recession and (3) both.

Before measuring the effects of these factors in the bust, I first examine the effects of the introduction of the IO mortgages. Chambers et al. (2009) showed the introduction of alternative mortgages generates a large increase in the homeownership rate. Here I quantify the effect of the mortgage inno-

Table 5: Change in the Homeownership Rate (2000-2005)

	Data	Model
Change in the homeownership rate Δh_t	1.9 %	1.9 %
Contribution:		
Homeownership (non-college)	4 %	13 %
Homeownership (college)	58 %	87 %
Other	38 %	-
	100 %	100 %

vation on the distribution of homeownership across education groups.

4.2.1 Analysis for the Period of 2000-2005

In this subsection, I compare the homeownership rates in the 2000 and 2005 steady states. The only difference between the two steady states is the availability of the IO mortgage. The IO mortgage is available in the 2005 steady state while it is not available in the 2000 steady state.

Table 5 shows the change in the homeownership rate and the contribution of each factor[12] in the data and in the model for the period of 2000-2005. The results in the model are calculated from the statistics in the 2000 steady state and in the 2005 steady state. Since the demographic changes are not considered in the model, the whole change in the homeownership rate is explained by the changes in the homeownership rate among non-college educated households and college educated households.

Table 5 shows that the introduction of the IO mortgage accounts for the observed increase in the homeownership rate (1.9%). More importantly, it also accounts for the pattern in the contributions; the increase in homeownership among college educated households contributed the most (87%). This result confirms that the calibrated model successfully captures the distributional change in homeownership during the early 2000s.

Figure 3 shows age profiles of the homeownership rate and the fraction of

[12]The measure of the contribution is explained in Appendix A-1.

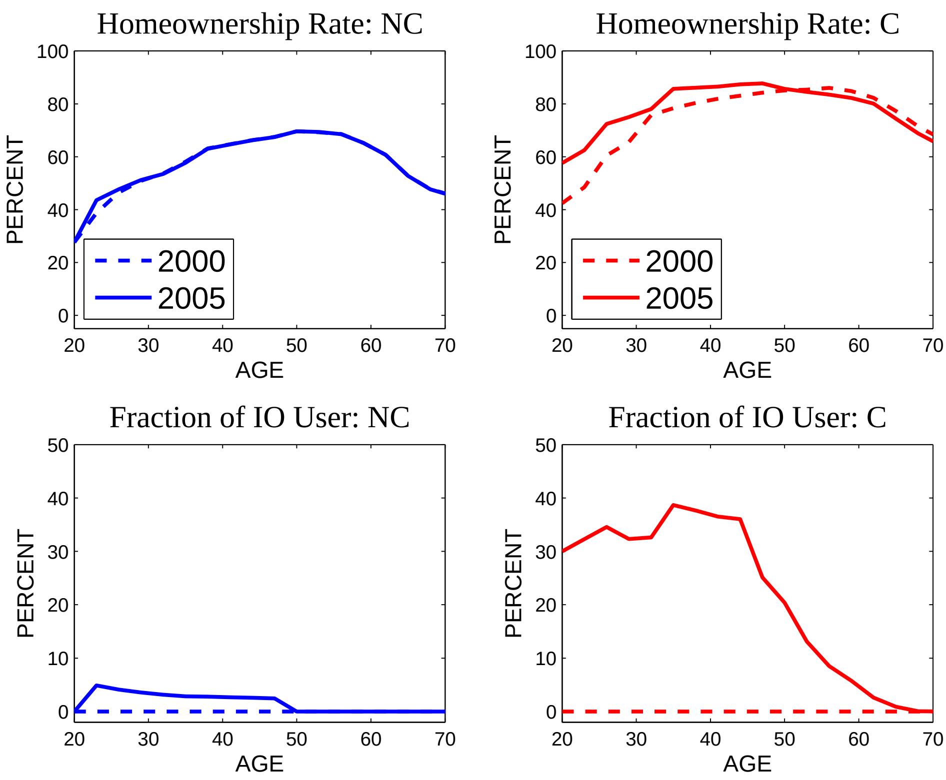

Figure 3: Changes from 2000 to 2005

Note: "NC" stands for non-college educated households and "C" stands for college educated households.

IO mortgage users in each education group. Each panel shows the age profiles in the 2000 steady state and in the 2005 steady state. In the two upper panels, we see large increases in the homeownership rate among young college educated households. In addition, the bottom two panels show that IO mortgages are most extensively used among young college educated households. This means that the introduction of IO mortgages induced new homeowners among young college educated households the most.

The shape of earning profiles is the key to understand the higher usage of IO mortgages among college educated households. As we saw in Figure 2, the income growth rate is much higher for college educated households than non-college educated households. This means that young college educated households desire more strongly to increase housing and non-housing consumption to smooth out their consumption paths over lifetime. Therefore, the initial lower payments on IO mortgages are more attractive to young college educated households than young non-college educated households.[13]

In summary, this subsection showed that the mortgage innovation accounts for the distributional feature of the housing boom during the early 2000s. Given this performance of the calibrated model, I use this model to figure out the main driving force of the housing bust during the late 2000 in the next subsection.

4.2.2 Analysis for the Period of 2005-2010

The main objective is to disentangle a mortgage credit crunch and a severe recession during the housing bust. For this purpose, I consider three scenarios for the 2010 steady state and conduct comparative steady state analysis for each scenario. In the first scenario, the IO mortgage becomes unavailable to households again (mortgage credit crunch). In the second scenario, I consider a 9.2% decline in labor earnings for non-college educated households and a 2.3% decline in labor earnings for college educated households (recession). These income declines are the observed median declines in real labor earnings from 2005 to 2009 in the CPS data. As the third scenario, I consider the case where both happen; labor income declines and the supply of IO mortgages vanishes.

Table 6 shows the change in the homeownership rate and the contribution of each factor in the data and in the model. The results in the model are calculated using the statistics in the 2005 steady state and in the 2010 steady state of each scenario. First of all, from the third and the forth columns of the table, we see that the recession generates a larger decrease in the aggregate homeownership rate than the mortgage credit crunch (-1.9% vs -2.4%). More importantly, Table 6 shows that these two factors predict different patterns of contributions across education groups. The mortgage credit crunch predicts that the decline in homeownership among college educated households contributes the most (-13% vs -87%), but the recession predicts that the decline in homeownership among non-college educated households contributes the most (-95% vs -5%).

[13]Doms and Krainer (2007) demonstrate this idea clearly using a simple 2 period model. They also document that there was a larger change in the housing consumption to income ratio among college educated young households during the period of 1995-2005.

Table 6: Change in the Homeownership Rate (2005-2010)

		Model		
	Data	Mortgage Credit Crunch	Recession	Both
Δh_t	-3.2 %	-1.9 %	-2.4 %	-4.0 %
Contribution:				
Homeownership (non-college)	-92 %	-13 %	-95 %	-55 %
Homeownership (college)	-47 %	-87 %	-5 %	-45 %
Other	39 %	-	-	-
	-100 %	-100 %	-100 %	-100 %

The credit contraction affects college educated households more because their usage of the IO mortgage is higher when it is available. Since college educated young households expect to have higher future earnings, they have more incentive to use the IO mortgage with initial lower payments. On the other hand, the recession affects non-college educated households more because they get larger income declines than college educated households. Also, non-college educated households tend to be more sensitive to income declines regarding the rent-or-own decision due to their lower income level and the presence of the minimum house size. The results suggest the importance of the observed heterogeneous income shocks to understand the housing bust.

The last column of Table 6 shows the results in the third scenario where the mortgage credit crunch and the recession both happen. Not surprisingly, the decline in the aggregate homeownership rate is the largest in this case (-4.0%). This scenario also successfully predicts that the decrease in homeownership among non-college educated households contributed the most (-55%), although it underestimates the gap between those contributions.

Given the importance of the recession, Figure 4 shows how the recession affects housing and mortgage decisions. It plots age profiles of the homeownership rate and the fraction of the IO mortgage users by education group. Each panel shows the age profiles in the 2005 steady state and in the 2010

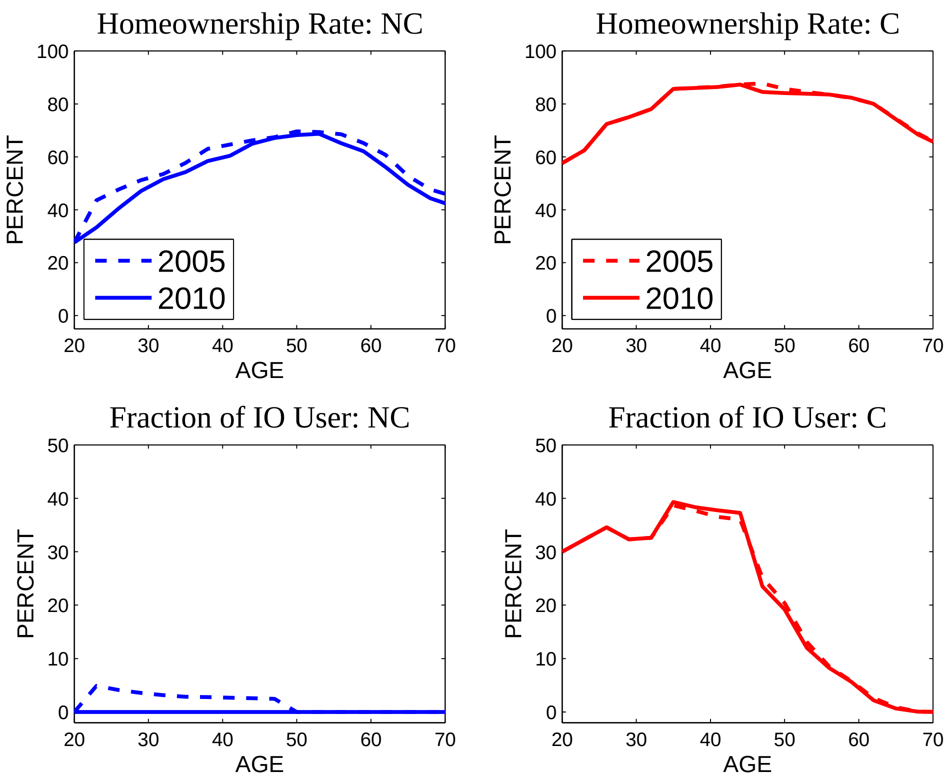

Figure 4: Changes from 2005 to 2010 (Recession)

Note: "NC" stands for non-college educated households and "C" stands for college educated households. In the 2010 steady state, non-college educated households get a 9.2% decline while college educated households get a 2.3% labor income decline.

steady state with the recession scenario. The upper two panels show that the recession generates larger declines in homeownership among non-college educated households, especially among young households.

The lower two panels of Figure 4 show that the usage of IO mortgages substantially declines among non-college educated households. That is, income declines discourage the use of IO mortgages. Remember that the incentive to use the IO mortgage comes from the desire for consumption-smoothing. Since the recession flattens earning profiles, there is less need for financial tools to increase the level of consumption at early life stages. Therefore, there is less households who benefit from the low initial payments on IO mortgages in the recession case.

In summary, there are three main findings in this subsection. The first one is that the recession was the main driving force behind the distributional feature of the housing bust. The recession generates a proportionally larger decline in homeownership among non-college educated households, which is consistent with the data. This is because the observed real income decline was larger for those households. The second finding is that the recession decreases the usage of the IO mortgage. The recession flattens earning profiles and decreases the needs for the lower initial mortgage payments. The last finding is that the mortgage credit crunch cannot account for the distributional feature of the housing bust. This is because IO mortgages are most extensively used among college educated households when they are available.

5 Conclusion

This paper documented that there has been a proportionally larger decline in homeownership among non-college educated households than college educated households since 2005 in the United States. I then investigated if either a mortgage credit crunch or a severe recession accounts for the observed pattern of declines in homeownership across education groups. In order to identify the effects of each factor, I constructed a general equilibrium life-cycle model with housing and mortgages and conducted counter-factual exercises. In the analysis, the mortgage credit crunch was implemented as the contraction of supply for delayed-amortization mortgages and the severe recession was implemented as declines in real labor earnings.

The main finding is that the mortgage credit crunch alone is not able to account for the distributional feature of the housing bust. It predicts a proportionally larger decrease in homeownership among college educated households, contrary to the observation. This is because delayed-amortization mortgages are more extensively used among college educated households, who have steeper earning profiles and find the lower initial payments on those mortgages more useful for consumption-smoothing.

The observed declines in real labor income, on the other hand, generate a larger decrease in homeownership among non-college educated households, consistent with the data. This is because the observed decline in real labor earnings was about four times larger for those households, based on the CPS data, which reflects a sharper increase in their unemployment rate. I also find that declining income also lowers the usage of delayed-amortization mortgages because households have less needs for the lower initial mortgage payments to increase the level of consumption at early stages in life.

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Appendix

A-1: Decomposition of the Change in the Homeownership Rate

Let h_t be the homeownership rate in the year t. Then, as is discussed in Chambers et al. (2009), it can be expressed as the weighted sum of the group-specific homeownership rates;

$$h_t = \sum_j \sum_e \mu_{jt} s^e_{jt} h^e_{jt}$$

where h^e_{jt} is the homeownership rate among households whose householder is at age j and has the level of education e, s^e_{jt} is the share of e-households among the j-households, and μ_{jt} is the share of j-households in the whole population.

Then, the change in the homeownership rate h_t from the year t_0 to t can be written as follows;

$$\begin{aligned} h_t - h_{t_0} &= \sum_j \mu_{jt_0} s^{nc}_{jt_0} \mathbf{\Delta h^{nc}_{jt}} && \text{(Change in ownership among noncollege)} \\ &+ \sum_j \mu_{jt_0} s^{c}_{jt_0} \mathbf{\Delta h^{c}_{jt}} && \text{(Change in ownership among college)} \\ &+ \sum_j \sum_e \mu_{jt_0} \mathbf{\Delta s^{e}_{jt}} h^e_{jt_0} && \text{(Change in the share of college educated)} \\ &+ \sum_j \sum_e \boldsymbol{\Delta\mu_{jt}} s^{e}_{jt_0} h^e_{jt_0} && \text{(Change in the age structure of population)} \\ &+ \text{(Covariance Terms)} \end{aligned}$$

where $\Delta x_t := x_t - x_{t_0}$. Dividing both sides by $h_t - h_{t_0}$ gives the contribution of each factor. Table 1 shows the results for the periods of 1995-2000, 2000-2005, and 2005-2010.

A-2: Homeownership Rate by Age and Education

Table A-1: Homeownership Rate by Age and Education of Householder

		2000	2005	2010	Percentage Change '00-'05	Percentage Change '05-'10
18 - 29						
	Non College	29.4	30.4	27.2	3.4	-10.6
	College	35.4	43.7	37.6	23.2	-13.8
30 - 39						
	Non College	55.6	54.6	48.5	-1.8	-11.1
	College	67.5	71.9	64.1	6.5	-10.8
40 - 49						
	Non College	68.1	68.3	62.2	0.3	-8.9
	College	80.9	82.2	80.4	1.6	-2.2
50 - 59						
	Non College	75.8	75.2	72.0	-0.8	-4.2
	College	85.4	86.4	84.3	1.2	-2.5
60 -						
	Non College	79.3	80.3	78.7	1.2	-2.0
	College	86.5	86.1	86.2	-0.4	0.1
All						
	Non College	65.6	66.2	63.6	0.9	-3.9
	College	73.5	77.0	74.4	4.7	-3.4

Note: The data source is the March CPS supplement. Age and education level of a household are defined by those of the householder.