Too Poor to Retire? House Prices and Retirement[☆]

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Abstract

This paper finds that the employment rate for old home owners (but not for renters) increases more (decreases less) in the MSA where house price declines more in the house price crisis 2008. It argues that the wealth effect of house prices on retirement can account for this fact. The paper builds up a calibrated incomplete-market life-cycle partial-equilibrium model with risky housing consumption and endogenous retirement. It finds that after a 28 percent unexpected house price decline, the home owners aged 55-64 will reduce their non-durable consumption by 11.6 percent and delay their retirement by 5.8 months. The counterfactual experiment quantifies three channels (resizing effect, bequest motive, and collateral borrowing) through which house prices can affect retirement. The structural model also quantifies the endogenous retirement as self-insurance for the old homeowners against house price risk. The joint response of retirement and non-durable consumption implied by the structural model is consistent with the consumption and retirement elasticity of house prices found in the empirical studies using Health and Retirement Survey data, i.e., home owners' retirement probability drops by 1.7 percentage points and their non-durable consumption drops by 2.9 percent when house price declines by 10 percent. Therefore, the structure model sets up a reasonable reference line for the empirical studies.

Keywords: housing wealth effect, endogenous retirement, self-insurance
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1. Introduction

House price has dropped by more than 30 percent in the 2008 recession, which implies huge wealth losses for home owners. In the meantime, households aged 50-64 have the largest drop in non-durable consumption but smallest drop in employment rate among all working-age groups.[1]

Popular wisdom says that old households are too poor to retire when house price declines. My paper takes that argument seriously. I find that in the 2008 recession, there is no significant correlation between the drops in the regional employment rate for old home renters and the falls in regional house price. However, the employment rate of the old home owners drops less in the area where house price drops more. Figure 1 plots the 1-year changes in HP-filtered employment rate for homeowners and renters against the 1-year changes in house prices for 20 Metropolitan Statistic Areas (MSAs) in 2008. It finds a significant negative correlation between the two statistics for home owners but not for renters. The simple OLS regression for homeowners has a slope -12.0 and R squared 0.38. The interpretation is that a 10 percent decline in house prices is associated with a 1.2 percent increase the employment rate of home owners aged 55-70.

Motivated by those facts, this paper builds up an incomplete-market life-cycle model with risky housing asset and endogenous retirement to estimate the impact of house price shocks on retirement and non-durable consumption of old home owners. The model predicts that the old households will reduce their consumption and self-insure against negative housing wealth shocks through delayed retirement. Benchmark model simulation shows that after an unexpected 28 percent decline in house price, households aged 55-64 reduce their non-durable consumption by 11.6 percent and delay their retirement by 5.8 months on average.

In the model, households have non-separable preference over non-durable consumption, leisure, and housing consumption. More importantly, households can choose the timing of retirement as well as other consumption subject to income risk, house price risk, and mortality risk. The decline in house price immediately reduces the total networth of home owners. This wealth effect tends to reduce households non-durable consumption, housing services, and leisure consumption. When house is cheaper, households also wants to substitute non-durable consumption and leisure consumption for housing consumption. Combing the two effects altogether, the house price decline will make home owners consume less non-durable goods and leisure, which takes the form of delayed retirement. This mechanism relies on the ability to freely adjust the size of houses, which implies that households can upgrade or downgrade their houses after the house price shock[2]. After the adjustment in house sizes, the capital gain or loss due to fluctuating house prices is

[1] Hurd and Rohwedder (2010) finds that the two-year decline in non-durable consumption for older population aged 50-64 over 2007-2009 is 8.6 percent, compared to the average decline of 1 percent over 2001-2007. They also find that old workers revise their retirement expectation to delay retirement.

[2] Because housing transaction is costly, there have been debates on whether housing, like other liquid assets, is being used by old households to finance consumption. The home ownership rate in the US remains stable until age 70s and declines significantly afterwards (Yang, 2009). The adjustment to housing can take place along intensive margin as well. Banks et al. (2007) finds that U.S. households downsize their houses in terms of reductions in the number of rooms per dwelling and the value of the home, keeping the home ownership rate unaltered. Hryshko et al. (2010) finds that housing asset helps to cushion the consumption drops of home owners in the presence of negative labor market shocks.

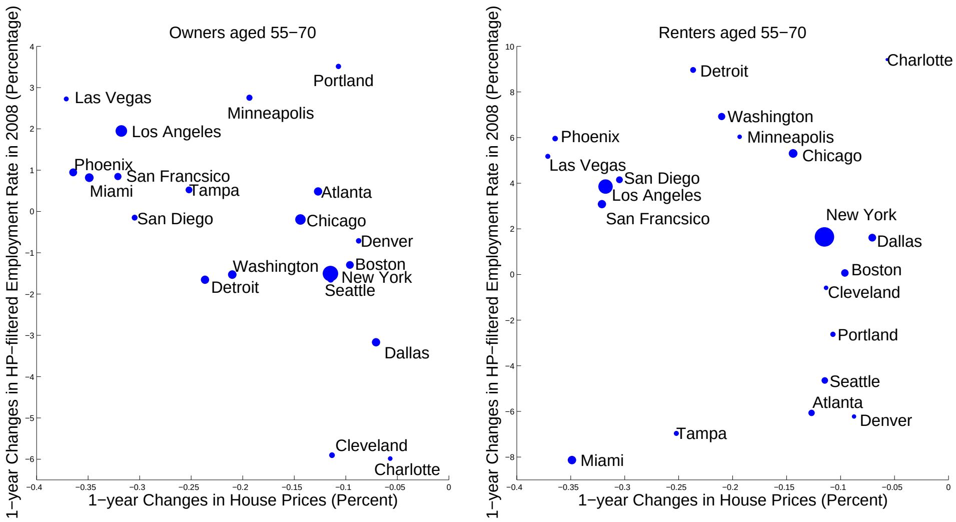

Figure 1: **1-year Changes in House Price and 1-year Changes in Employment Rate of 20 MSAs in 2008.** The Employment Rate is defined as the total number of employed households aged 55-70 divided by the total population aged 55-70. Each MSA is identified by CBSA code. See Appendix B.8 for detailed geographic definition. The monthly Employment Rate is detrended by HP-filter with smoothing parameters 129,600, as recommended by Ravn and Uhlig (2002). House prices for 20 MSAs are from S&P500/Case-Shiller Index. I take yearly average of HP-filtered employment-population rate and log house prices and then compute the 1-year difference. The size of the dot denotes the population weight of home owners and renters in each MSA.

realized, which in turns affects the reservation wage and the probability of retirement. I call this first channel the resizing effect.

Even if households can not adjust the size of their houses, house price can also influence households consumption and retirement decision through other two channels. The second one is called the collateral borrowing channel. Housing not only provides services flows, but also serves as the most important collateral for households. When households suffers from wealth loss, they want to borrow more against housing asset to smooth consumption. This provides incentive for the indebted households to work longer to pay back their mortgages. The collateral borrowing channel also works when house price increases. Old home owners who are asset rich but income poor may also take reverse mortgage loan to cash out housing value.[3] Therefore, rising house price brings more available resource to home owners and reduces their incentive to work.

The third channel is the bequest motive.[4] Households with warm-glow bequest motive

[3] Old home owners aged above 62 can use reverse mortgage to cash out their home value and don't have to pay back the loan until they die or move out of the house. Shan (2011) documents that the Home Equity Conversion Mortgage (HECM is the majority of reverse mortgage loan in the US) has an annual growth rate of 38 percent during 2003-2007. She also estimates that one percentage increase in the annual real house price appreciation is correlated with 3.4 percentage point increase in the HECM loan origination growth rate.

[4] Nardi (2004) finds that introducing bequest motive can explain the high concentration of wealth and large amounts of wealth held by the richest households during very old age in the data.

care about the adequacy of total net worth when they die. Other things being equal, home owners experiencing adverse house price shock tends to work longer in order to buffer the negative effect of house price on the value of accidental bequest. Even if one lives in the same house, the liquidation house value after his death will still affect the retirement decision when he is alive.

In order to verify the model prediction is consistent with the data, I compare the consumption and retirement elasticity of house price implied by the structural model with empirical findings using Health and Retirement Survey 1992-2008 and Current Population Survey 1989-2011. The empirical studies finds that a 10 percent decline in local house price will reduce the mean retirement probability for home owners aged 50-70 by 1.7-1.9 percent which is consistent with the prediction by the theoretical model. It also finds that a 10 percent decline in house price will reduce the non-durable consumption of home owners aged 50-70 by 2.3 percent, which is smaller than the prediction by the theoretical model.

Then I use the structural model to quantify the impact of house prices on retirement and consumption. It finds that after a one-time unexpected 28-percent house price decline, households aged 55-64 will reduce the non-durable consumption by 11.8 percent and retire nearly 6 months earlier than they would have done if house price had not declined. The structural model also quantifies the effectiveness of the endogenous retirement as self-insurance for home owners against house price risk. It finds that after the one-time unexpected 28 percent house price decline, the drops in non-durable consumption for the home owners aged 55-64 with endogenous retirement is 14 percent smaller than the drops in the consumption of the home owners with exogenous retirement.

Early literature about wealth effect focus on its impact on households non-durable consumption.[5] Recent studies by Case et al. (2001) and Campbell and Cocco (2007) look at one important component of household wealth, the housing asset.[6] They find that consumption of old homeowners is most responsive to house prices. However, these studies ignore the endogenous retirement, which turns out be an important way of self-insurance against house price risk for the near-retirement age households according to my research.

A growing literature is trying to estimate the wealth effect on labor supply and retirement, most of which are empirical studies. Early researches use household level data to estimate the stock market boom on the retirement decision. These studies confirm the anecdotal story that the bear market force old households to stay in the labor

[5] Holtz-Eakin et al. (1993) and Imbens et al. (2001) use exogenous wealth variations, such as inheritances or lottery winnings, to identify the wealth effect on consumption. The virtue of this method is to avoid the endogeneity problem of wealth accumulation. Other studies, including Parker (2000) and Juster et al. (2004), estimate the marginal propensity to spend out of household wealth using micro survey data. Estimates by those authors range between 3 percent and 8 percent.

[6] Case et al. (2001) use aggregate data to find a 10 percent increase in housing wealth increases aggregate consumption by 0.4 percent for the US and roughly 1.1 percent for international panel. Meanwhile, they find only insignificant effect of rising financial wealth on aggregate consumption. Using the UK households data, Campbell and Cocco (2007) investigate the response of household consumption to house price by constructing a pseudo panel. They find the largest effect of house prices on consumption for old home owners and smallest effect for young renters. In their benchmark regression, a 1 percent increase in housing value increase the non-durable consumption of the old homeowner by around 1.22 percent, which accounts for 8 percent of the increase in housing value.

force.[7] However, the findings about housing wealth effect on retirement are mixed. Farnham and Sevak (2007) finds that a 10 percent increase in housing wealth will reduce the expected retirement age by 3.5 months to 5 months. Coile and Levine (2009) finds no evidence that old workers respond to fluctuating housing market. More recently, French and Benson (2011) argues that the overall labor force participation rate would be 0.7 percentage points lower were it not for the declines in the values of stocks and houses over the 2006-2010 period. In this paper, I will complement the literature by looking at the evidence of wealth effect on both retirement and non-durable consumption *jointly* using panel data from Health and Retirement Study.

In terms of structural model, most previous papers emphasize the role of social security, private pension, health insurance, earning shocks, and taxation in determining retirement (French, 2005; Ljungqvist and Sargent, 2010; Prescott et al., 2009). From a different perspective, this paper analyzes the impact of wealth changes on retirement. My model is close to studies by Bottazzi et al. (2007), Farhi and Panageas (2007), Yogo (2009), Imrohoroglu and Kitao (2010), and Hryshko et al. (2010). However, none of these authors look at the effect of house prices on retirement.

The rest of the paper is organized as follows. Section 2 presents an incomplete-market life-cycle model with housing and endogenous retirement, which is used to perform some counterfactual experiments. Section 3 describes the data sets, estimation strategy, and empirical evidence. It also compares the estimated consumption and retirement elasticity of house prices with the model implied elasticities. Section 4 concludes.

2. The Benchmark Model

In this section, I will build up a structural model that is suitable for answering the following questions quantitatively. What is the impact of house prices on households non-durable consumption and retirement? What are the possible channels through which house prices can affect consumption and retirement? How effectively can endogenous retirement cushion house price risks as a self-insurance tool?

The natural candidate model is the incomplete-market life-cycle model, with extensions to allow for housing consumption and retirement decision. I will first use the calibrated model to quantify the effect of house prices on retirement through different channels. Then I compare the housing wealth effect on non-durable consumption with endogenous retirement with a second economy where households cannot schedule their retirement. By doing this, I am able to quantify the role of endogenous retirement as self-insurance against house price risks.

[7] Cheng and French (2000) show that the run-up in the stock market in 1990s, which has brought greater than $50,000 gains to more than 15 percent of individuals aged 55 and above, decreases the participation rate for people older than 50 by 3.2 percent. Sevak (2002) exploit the Health and retirement study data to find an increase of $50,000 wealth shock will lead to a 1.9 percent increase in retirement probability among individuals aged between 55 and 60. Coronado and Perozek (2003) uses the same data set and finds that households who held corporate equity immediately prior to the bull market of the 1990s retired 7 months earlier than other respondents on average. Gustman et al. (2009) finds that recent stock market decline lead the early boomers to postpone retirement by 1.5 months on average. Chai et al. (2011) build up a structural model with stocks and endogenously labor supply to study the effect of stock price crisis on households consumption and retirement.

2.1. Demographics

The model economy is inhabited by J overlapping generations. Each generation consists of one unit measure of households. Households have a uncertain life span and live up to the maximum age J. The conditional survival probability from age j to $j+1$ is s_j, $j \in [50, J)$;s_J=0.

As the model abstracts from population growth, the fraction of newborns at the stationary distribution of population is

$$\mu_1 = \frac{1}{1 + \sum_{j=1}^{J-1} \pi_j} \tag{1}$$

where $\pi_j \equiv \prod_{i=1}^{j} s_i$ is the unconditional survival probability for age j. The fraction of age j cohort is determined recursively by

$$\mu_{j+1} = s_j \mu_j \tag{2}$$

2.2. Preferences and Endowments

Households derive utility from non-durable consumption goods c_j , housing services h_{j+1}, leisure $1 - n_j$. Households also have warm-glow bequest utility $u^B(x_{j+1})$. Each household is endowed with one unit of labor endowment. Labor supply n_j is indivisible.[8] The household provides one unit of labor when at work and zero when retired. The household's utility function can be written as

$$E_0 \sum_{j=1}^{J} \beta^j \left[\pi_j u(c_j, h_{j+1}, n_j) + (\pi_j - \pi_{j+1}) u^B(x_{j+1})\right] \tag{3}$$

where x_{j+1} is the amount of accidental bequest, which is also the total networth at the beginning of period j+1 if one survives.

Labor income is risky. Let j^r be the endogenous retirement age. The stochastic process for the before-tax wage is assumed to be

$$\ln w_j = e_j + z_j + \epsilon_j \tag{4}$$

$$z_j = \rho_z z_{j-1} + \eta_j \tag{5}$$

for all $j = 1, \ldots, j^r - 1$. It consists of three parts. e_j is the deterministic age-specific labor efficiency unit. η_j is the persistent shock to wage and ϵ_j is the transitory shock to wage. Both shocks are independently and identically normally distributed with mean 0 and variance σ_η^2, σ_ϵ^2 respectively. Households pay the payroll tax τ when at work. Labor income after tax is

$$y_j = (1 - \tau) w_j \tag{6}$$

[8]The indivisibility assumption is justified by the facts that most variations in aggregate hours are attributed to extensive margin rather than intensive margin, especially for the near-retirement households (Prescott et al., 2009). A more relaxed assumption could be that old households can only look for a part-time job after retirement that pay much less than the full-time job before the retirement.

The model also abstracts from home-production. After retirement, households with age qualified for social security are able to collect social security benefit $b(z_{j^r-1}, j^r)$ each year, which is a function of persistent income shock before retirement and the retirement age.

$$y_j = b(z_{j^r-1}, j^r) \tag{7}$$

for all $j = j^r, \ldots, J$.

2.3. Assets Market

There is no annuity market in the model. The only financial asset is the risk free bond with gross interest rate R. The only risky asset in the economy is the housing. The house price follows a AR(1) process

$$\ln p_j = \rho_p \ln p_{j-1} + \zeta_j \tag{8}$$

where ζ_j is independently and identically distributed with mean 0 and variance σ_ζ^2. Housing depreciates at a rate of δ_h, which also includes the maintenance cost. Housing asset is fully divisible. In the benchmark model, I assume that the adjustment to housing size does not incur any transaction cost. Therefore, all households choose to become home owners.[9]

Housing not only provides services flows for housing consumption, but also serves as collateral. Households can only borrow using housing as collateral. The down-payment ratio is λ, i.e., the households can borrow up to $1 - \lambda$ fraction of total housing value. For simplicity, the loan rate is assumed to be the same as interest rate. Households can adjust the credit balance without any cost. I rule out default on mortgage in the model, which implies that households have to pay back their debt when borrowing constraint is binding.

2.4. Households' Problem

Let V^W denote the value function of the households who was working last period and has the option either to work or to retire at current period. Let V^R denote the value function of the households who has retired at current period. Following Farhi and Panageas (2007), I assume retirement is an irreversible choice. Therefore, households solves a discrete version of the optimal stopping problem.

The working households are heterogeneous in $\Theta_j^W = \{x_j, p_j, z_j, z_{j-1}, \epsilon_j, j\}$, which denotes total wealth at the beginning of period j, house price, current persistent income shock, last period persistent income shock, transitory income shock, and age respectively.[10] The retired households are heterogeneous in the following dimensions $\Theta_j^R = \{x_j, p_j, z_{j^r-1}, j^r, j\}$, where j^r is the endogenous retirement age.

The timing of the economy is the following. At the beginning of period, households are endowed with total net worth x_j at given house price level p_j. For the working

[9] Without transaction cost, rental price will be a fraction of house price. Given the same riskiness of rental housing and owner-occupied housing and the collateral value of owner-occupied housing, all households will choose to own a house rather than to rent.

[10] Because there is no transaction cost in the benchmark model, I am able to combine "savings" and "housing stocks" into one state variable, the total net worth.

households, their income shocks z_j and ϵ_j are randomly drawn. Households then decide whether to work or not. If they continue to work, they receive labor income and pay taxes. If they choose to retire, they receive retirement benefit $b\left(z_{j^r-1}, j^r\right)$ which depends on the current age and last period persistent shock. Then households choose the housing consumption, non-durable consumption, and savings. By the end of age j, households receive interest from savings account. At the beginning of age j+1, the mortality risk and house price next period are revealed. If one dies, the total amount of financial asset and housing asset are left as accidental bequest. If one survives, he starts the next period with total net worth at new house price level.

The optimization problem for households can be formulated recursively as follows:

Before the retirement, the working households solve the problem

$$V^W\left(\Theta_j^W\right) = \max_{n_j\in\{0,1\}} \left\{ \begin{array}{c} (1-n_j) \max\limits_{c_j,h_{j+1}} \left\{u\left(c_j,h_{j+1},0\right)+\beta E_j\left[s_j V^R\left(\Theta_{j+1}^R\right)+\left(1-s_j\right)u^B\left(\Theta_{j+1}^R\right)\right]\right\} \\ +n_j \max\limits_{c_j,h_{j+1}} \left\{u\left(c_j,h_{j+1},1\right)+\beta E_j\left[s_j V^W\left(\Theta_{j+1}^W\right)+\left(1-s_j\right)u^B\left(\Theta_{j+1}^W\right)\right]\right\} \end{array} \right\} \tag{9}$$

subject to

$$x_{j+1} = R\left(x_j + (1-\tau)\,w_j - c_j - p_j h_{j+1}\right) + p_{j+1}h_{j+1}\left(1-\delta_h\right) \tag{10}$$

$$x_j + (1-\tau)\,w_j - c_j \geq \lambda p_j h_{j+1} \tag{11}$$

$$c_j > 0 \tag{12}$$

$$h_{j+1} > 0 \tag{13}$$

$$x_{j+1} > 0 \tag{14}$$

where n_j is a binary variable for retirement/work decision. Equation (10) is the budget constraint for the working households who enter the age j with total net worth x_j. (11) is the borrowing constraint, which means the net worth at the end of this period cannot be larger than λ fraction of current housing value. (14) is the bequest constraint. Note that because of house price risk next period, the borrowing constraint (11) does not necessarily imply that households cannot leave negative bequest. The endogenous retirement age j^r is defined as

$$j^r \equiv \min\left\{j \mid n_j = 0, 1 \leq j \leq J\right\} \tag{15}$$

Once become retired, the households cannot choose to go back to work. The household's value function is given by

$$V^R\left(\Theta_j^R\right) = \max_{c_j,h_{j+1}} \left\{u\left(c_j,h_{j+1},0\right)+\beta E_j\left[s_j V^R\left(\Theta_{j+1}^R\right)+\left(1-s_j\right)u^B\left(\Theta_{j+1}^R\right)\right]\right\} \tag{16}$$

subject to (17), (18), (12), (13) and (14).

$$x_{j+1} = R\left(x_j + b\left(z_{j^r-1}, j^r\right) - c_j - p_j h_{j+1}\right) + p_{j+1}h_{j+1}\left(1-\delta_h\right) \tag{17}$$

$$x_j + b\left(z_{j^r-1}, j^r\right) - c_j \geq \lambda p_j h_{j+1} \tag{18}$$

2.5. Characterization of Partial Equilibrium

When the borrowing constraint is not binding, the first order optimality conditions for c_j and h_{j+1} can be partly characterized by Euler equations. I use the same notation for the policy function of both retired households and working households. Hopefully this would not cause any confusion here.[11]

$$u_c(j) = \beta s_j R E_j \left[u_c(j+1)\right] + \beta(1-s_j) R E_j \left[u_x^B(j+1)\right] \tag{19}$$

$$\begin{aligned} u_h(j) = {} & \beta s_j E_j \left[u_c(j+1)\left(Rp_j - (1-\delta_h)p_{j+1}\right)\right] \\ & + \beta(1-s_j) E_j \left[u_x^B(j+1)\left(Rp_j - (1-\delta_h)p_{j+1}\right)\right] \end{aligned} \tag{20}$$

where $u_c(j)$ stands for $u_c(c_j, h_{j+1}, n_j)$ and $u_h(j)$ stands for $u_h(c_j, h_{j+1}, n_j)$.

From (19), one can see that decrease in the consumption today will also increase the marginal utility from leaving a bequest, weighted by the probability of death. If $s_j = 1$, there is no uncertain life span and (19) becomes the standard consumption Euler equation.

Equation (20) is the housing Euler equation (no arbitrage condition for housing). It says the user cost of owner-occupied housing is the sum of foregone consumption and bequest next period.

When borrowing constraint is binding, the only first order condition becomes

$$\begin{aligned} u_h(j) = {} & \beta(1-s_j) E_j \left[u_x^B(j+1)\left((1-\lambda)Rp_j - (1-\delta_h)p_{j+1}\right)\right] + u_c(j)\lambda p_j \\ & + \beta s_j E_j \left[u_c(j+1)\left((1-\lambda)Rp_j - (1-\delta_h)p_{j+1}\right)\right] \end{aligned} \tag{21}$$

and the optimal consumption is determined by

$$c_j = x_j + y_j - \lambda p_j h_{j+1} \tag{22}$$

Now the user cost of housing has an additional component $u_c(j)\lambda p_j$, which corresponds to the cost of binding constraint on current consumption. This cost is positively correlated with down-payment ratio. When there is no borrowing constraint,i.e., $\lambda = 0$, then we go back to the equation (20).

2.6. Algorithm

I solve the life-cycle model backwards from the end of life cycle. I combine the Newton-Raphson method with Simulated Annealing to solve the nonlinear system of Euler equations. Due the discrete nature of retirement problem, value functions have to be stored for each possible choice combination. The conditional expectation is computed by Gaussian Quadrature. I approximate the stochastic process for house price and persistent income shocks with a 7-state Markov Chain using Rouwen-Hurst's method summarized in Kopecky and Suen (2010). The transitory income shock is simply approximated by 2-state Markov Chain.

[11] The retirement decision is a binary variable, therefore, the intra-temporal optimality condition for n_j doesn't exit. The policy function for labor is determined by comparing the continuation value for a worker and a retiree.

Table 1: Households Asset Portfolios By Age Group

Variables[a]	50	55	60	65	70	75	80	85
Real Asset[b]	291.3	356.8	364.8	291.1	297.9	270.9	176.6	159.5
Net worth[c]	489.5	570.6	680.8	582.8	571.7	487.7	342.6	295.2
Real/Net worth(%)	59.4	59.7	52.7	49.2	51.0	54.6	51.7	55.1
Normalized Net worth[d]	6.80	7.93	9.46	8.10	7.94	6.78	4.76	4.10

[a] Data is from Survey of Consumer Finance 1998. All statistics are mean value weighted by the sampling weight. Asset values are in 1998 thousand dollars. Age group i, i=50,55,60,65,70,75,80, include households aged i-2 to i+2. Age Group 85 include households older than 83

[b] The real asset is defined as total non-financial asset (including vehicles, primary residence, secondary residence, net equity in non-residential real estate, businesses, and Other misc. nonfinancial assets) minus debt secured by primary residence (mortgages, home equity loans, and debt secured by other residential property.

[c] The total net worth is the sum of real asset and financial asset. Financial asset include all types of transaction account, certificates of deposit, directly held pooled investment funds , savings bonds, directly held stocks, directly held bonds, cash value of whole life insurance, other managed assets, quasi-liquid retirement accounts, and other financial assets less any other lines of credit, credit card balances after last payment, installment loans , and other debt

[d] The total net worth is normalized by the before-tax average wage and salaries of working households at age 50, which is 70,567 in 1998 dollars

2.7. Calibration

The model economy starts at age 50 and ends at age 90. Households are allowed to work up to age 70. I take the initial joint distribution of total wealth and labor income for home owners at the age 50 from the 1998 Survey of Consumer Finance data (see Figure B.8).[12] Because Survey of Consumer Finance is a cross-sectional data, I cannot separate the persistent shock from transitory shock. I first randomly draw the value of persistent shocks at age 50 and attribute the residual income as transitory. Alternatively, I can randomly draw the value of transitory shocks at age 50 and treat the residual income as persistent shocks. The two methods do not change the estimate of housing wealth effect much, but affect the cross-sectional distribution of income risk over life-cycle. Using the first method will deliver a increasing cross-sectional income variance while the second one gives a slightly declining one.[13] Therefore, I choose the first method in the paper.

I normalize the age specific efficiency units taken from Hansen (1993) such that the average labor income at age 50 is 1. The logarithm value of efficiency unit e_j are plotted in Figure B.7. The age-specific survival probabilities are taken from the 2005 life table for white males in the United States.

The household's utility function takes the form

$$u\left(c_j, h_{j+1}, n_j\right) = \frac{\left(\left[c_j\left(1-\theta n_j\right)\right]^{\omega} h_{j+1}^{(1-\omega)}\right)^{1-\sigma}}{1-\sigma} \tag{23}$$

[12] I use the initial distribution for households aged between 48 and 52 in the data to increase the sample size. This gives me 419 households in 1998. Then I use the sampling weight to draw the simulated sample.

[13] This is because the second method implies an initial persistent shocks that is far away from the the long run stationary distribution of persistent shocks

Table 2: Parameters Calibrated in the Benchmark Model

Calibration inside the model				
Parameters		Value	Target Moments	Value
Discount Factor	β	0.962	Net worth of age 50-70	8.05
Consumption Weight	ω	0.77	Share of Net Real Asset of age 50-70	0.555
Bequest Strength	ϕ	10.3	Net worth of HHs older than 83	4.10
Fixed cost of working	θ	0.84	Cumulative Retirement Rate of age group 63	0.662
Relative Risk Aversion	σ	1.12	Average Consumption Drop Upon Retirement	-17%
Calibration outside the model				
Parameters		Value		
Interest Rate	R	1.02		
EIS Between c and h	ξ	1.00	Fernandez-Villaverde and Krueger (2004)	
Maximum Age	J	90		
Minimum Age		50		
Efficiency Unit	e_j	Figure B.7	Hansen (1993)	
Persistency of House Price	ρ_p	0.976	Nagaraja et al. (2009)	
Std. of House Price	σ_p	0.0748	Nagaraja et al. (2009)	
Persistency of Income	ρ_z	0.973	Heathcote et al. (2010)	
Std. of Persistent Shocks	σ_η	0.148	Heathcote et al. (2010)	
Std. of Transitory Shocks	σ_ϵ	0.278	Heathcote et al. (2010)	
Depreciation Rate	δ_h	0.005		
Down Payment Ratio	λ	0.200		
Social Security	b		See Text	
Payroll Tax	τ	0.100	See Text	

When n_j is a binary indicator. It equals 1 if households choose to be working. θ is the fixed cost associated with working. The higher it is, the earlier households choose to retire. Following Fernandez-Villaverde and Krueger (2004), I set the elasticity of substitution between consumption and housing services ξ to be 1. The parameter ω controls the share of housing services in the total consumption expenditure.

Following Cocco (2005) and Campbell and Cocco (2007), I assume the warm-glow bequest motive, which takes the following form

$$u_B = \phi \frac{x_j^{1-\sigma}}{1-\sigma} \tag{24}$$

It only depends on the total value of household's net worth. In other words, housing asset and financial asset are perfect substitutes in the bequest utility function, which is consist with the facts that relatively poor households leave bequest in terms of housing and the relatively rich households leave bequest in terms of financial asset. The other interpretation for the warm-glow bequest motive is the utility from living in the nursing home. Households can use their financial wealth or liquid their housing asset to pay the nursing home cost in their late life, which is an important expense in later life.[14] ϕ measures the bequest strength. Higher ϕ means more assets are left at the end of life.

[14] Kopecky and Koreshkova (2010) finds that 12 percent of aggregate savings is accumulated to finance and self-insure against old-age health expenses given the absence of complete public health care for the elderly, and that nursing home expenses play an important role in the savings of the wealthy and on aggregate.

The gross risk free interest rate is assumed to be 1.02. Nagaraja et al. (2009) estimates the house price process for 20 metropolitan areas using FHFA quarterly house price index 1985-2004. Their model consists of a fixed time effect, a random ZIP code effect, and an autoregressive component. The autoregressive coefficients range from 0.9819 to 0.9975. The variance of persistent shocks is between 8.83e-4 to 2.5e-3 . When translate into yearly frequency, this gives $\rho_p \in [0.9295, 0.9901]$, $\sigma_p \in [0.0592, 0.0997]$. In the benchmark model, I set the $\rho_p = 0.976$ and $\sigma_p = 0.0748$, which corresponds to the median value of estimates in 19 MSAs. The housing depreciation rate δ_h is set to be 0.005 and the housing down payment ratio λ is set to be 0.20.

The stochastic process from income risk is taken from Heathcote et al. (2010). I set the persistency of income shock $\rho_z = 0.973$, the standard variance of persistent shock $\sigma_\eta = 0.148$, and the standard variance of transitory shock $\sigma_\epsilon = 0.278$.[15] The payroll tax for social security is set to 0.10.[16]

The social security payment function $b(z_{j^r-1}, j^r)$ is based on the Average Indexed Monthly Earnings (AIME), which is the average labor income over one's 35 highest earnings years. In the model, I calibrate AIME to be

$$AIME(z_{j^r-1}, j^r) = \frac{(1-\tau)\exp(z_{j^r-1})}{35} \sum_{k=j^r-35}^{j^r-1} \exp(e_k) \tag{25}$$

AIME is converted into a Primary Insurance Amount (PIA) using the following formula where all dollars amount is in 1998 value (French and Jones, 2011).

$$PIA = \begin{cases} 0.9 \times AIME & \text{if} \quad AIME < \$5,724 \\ \$5,151.6 + 0.32 \times (AIME - 5,724) & \text{if} \quad \$5,724 \leq AIME < \$34,500 \\ \$14,359.9 + 0.15 \times (AIME - 34,500) & \text{if} \quad AIME \geq \$34,500 \end{cases}$$

Social Security benefits $b(z_{j^r-1}, j^r)$ also depends on the age at which individual retires. It will equal to the PIA if individual retires at age 65. For every year before age 65 that individual first draws benefits, benefits are reduced by 6.67 % and for every year (up to age 70) that benefit receipt is delayed, benefits increase by 8 %.[17] The total amount of PIA is capped above at $ 102,000.

The share of consumption in the utility function ω, the discount rate β, fixed benefit from retirement θ, the bequest strength ϕ, and the Relative Risk Aversion parameter σ are calibrated jointly to match the following five moments: the average share of net housing value in total net worth for householders age 50-70, the normalized net worth of households aged 50-70 , the average cumulative retirement-population rate of households for age group 63, the normalized net worth for households aged above 83, and the average drop in non-durable consumption upon retirement -.17 (Aguiar and Hurst, 2005). The average wealth profile is from the SCF 1998 data. The cumulative retirement-population rate is taken from the HRS 1998 data. These give $\omega = .77$, $\beta = .962$, $\theta = 0.84$, $\phi = 10.3$, and $\sigma = 1.12$. Table 2 summarizes all calibrated parameters.

[15] The persistent shock and transitory shock is set to the their value in year 1998

[16] Social Security payroll-tax rate in the US is 15.3 percent. Since my focus is the retirement benefit, I subtract the part of the tax rate due to Medicare and Disability Insurance.

[17] The credit for delayed retirement is 8% for the cohort born in 1948, which is the cohort I simulate.

The relative risk aversion parameter σ is larger than the elasticity of substitution between consumption and housing services. Note that this implies that housing consumption and non-durable consumption are substitutes.

2.8. Life Cycle Profile

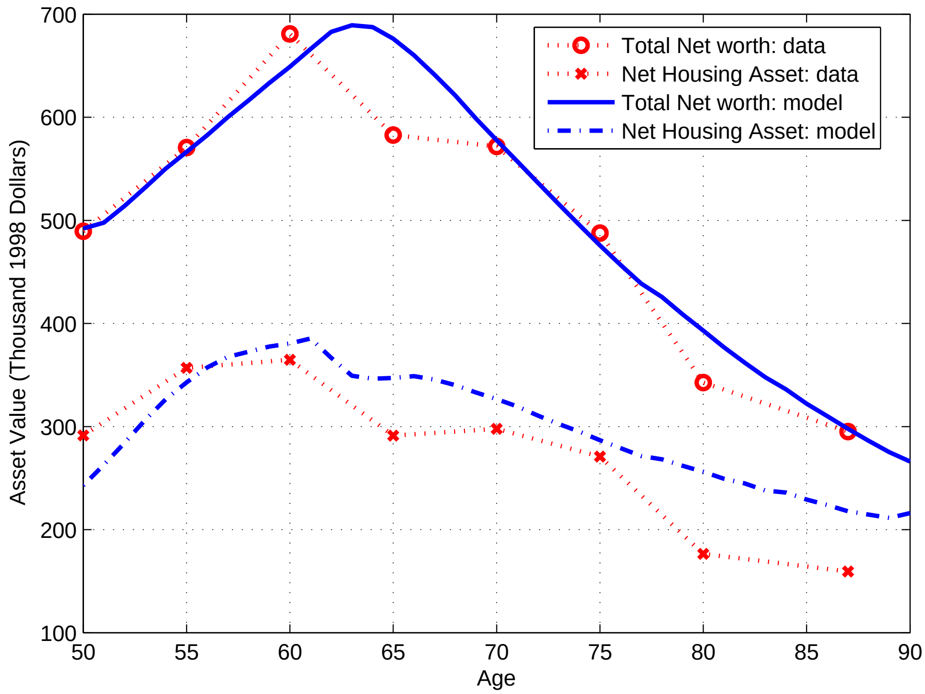

Figure 2: Life Cycle Profile of Wealth Accumulation and Portfolio Choice

Figure 2 plots the average total networth and net housing value over 50-90. For each house price sequence withdrawn, I simulate a cohort of 10,000 households with different realizations of income shocks from age 50 to age 70 (the full retirement age is 71 in the model). I repeat this procedure for 1000 different house price sequences and then average all cohorts to get a life-cycle profile for total net worth and net housing value, both of which have hump-shaped profile.[18] The share of net housing value falls rapidly after age 75 in the data, but it moves downwards slowly in the model. This may be related to shifting taste for housing in the later life in the data.

Figure 3 plots the accumulative retirement-population rate from simulated data. The cumulative retirement-population rate for home owners in the model exhibits a spike at age 62. This is due to fact that households cannot receive any social security payment before age 62 in the model. My model abstracts from health risk. Incorporating it in the model will force part of households to retire earlier and match more closely to the cumulative retirement-population rate before 62 in the data.

[18]The net housing value is defined as the value of housing stock minus mortgage debt in my model.

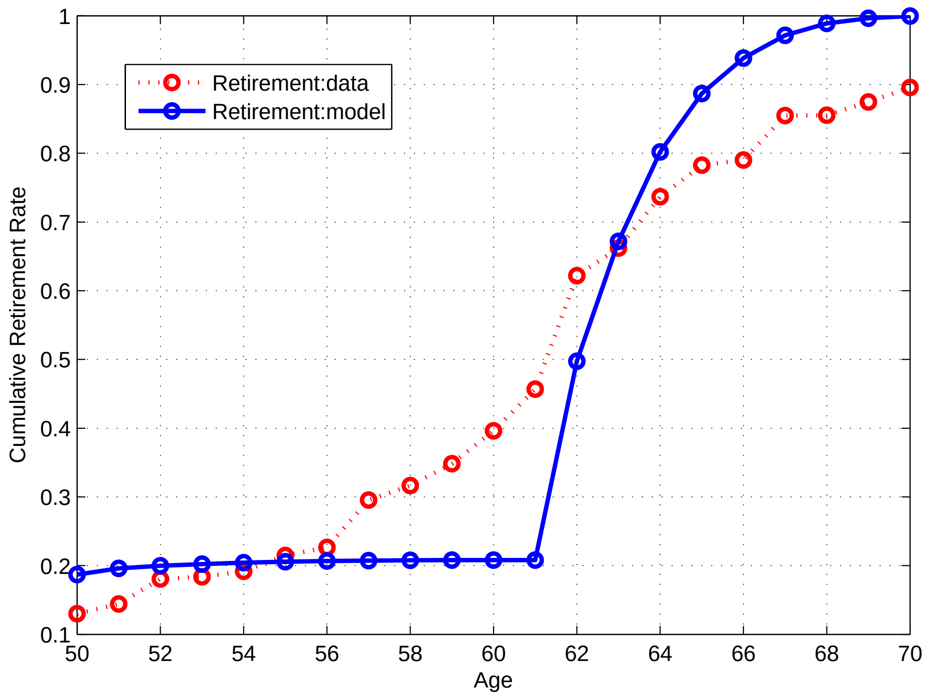

Figure 3: Cumulative Retirement-population Rate

Table 3: Elasticity of Non-durable Consumption to House Prices: Simulated Data

Dependent Variable: $\Delta\log$ (Non-durable Consumption)	Benchmark Model
$\Delta\log$ (Non-Capital Income)	.12
$\Delta\log$ (House Price)	.47
Age Dummies	Yes

2.9. Elasticity of Non-durable Consumption to House Prices

There are many empirical literature aiming to estimate the housing wealth effect on consumption. It is useful to compare the model implied elasticity of non-durable consumption to house prices with the those studies. I first construct a households panel, which consist of 1,000,000 households living in 200 MSAs. Each MSA has its own house prices withdrawn from the same stochastic process. House Prices across different MSAs are independently distributed. Then I estimate the following fixed effect panel regression

$$\Delta\log\left(c_{a,t}^{i}\right) = \alpha^{i} + \Delta\log\left(y_{a,t}^{i}\right) + \Delta\log\left(p_{t}\right) + I_{a} + \epsilon_{t}^{i} \tag{26}$$

where $y_{a,t}^{i}$ is the non-capital income for households i with age a at time t, which equals to wage income if households is working and equal to pension income if households is retired. I_a is the dummy for age. $\Delta\log\left(c_{a,t}^{i}\right)$ is the 1-year consumption growth rate and $\Delta\log\left(p_t\right)$ is the 1-year house price growth rate.

The regression results are shown in Table 3. The coefficient before house price growth

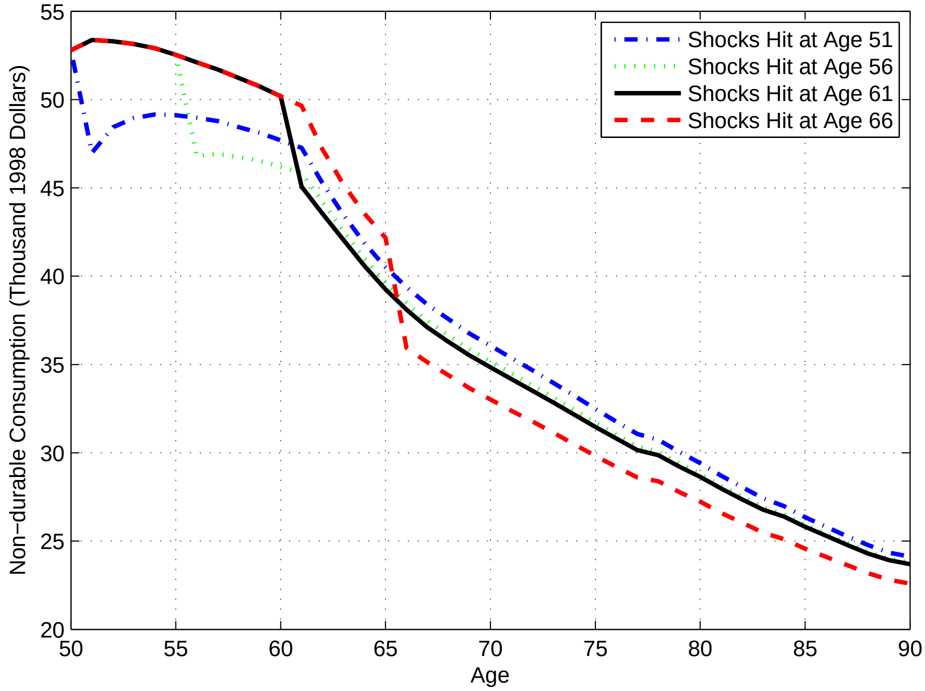

Figure 4: Consumption Profile After Negative House Price Shocks (Endogenous Retirement)

rate is .47, it is interpreted as a 10 percent decline in house prices will reduce the non-durable consumption of home owners aged 50-70 by 4.7 percent. This estimates is larger than the 2.9 percent point estimate in Hryshko et al. (2010), but smaller than the estimate by Campbell and Cocco (2007).[19]

The above linear regression assume that consumption elasticity is the same for all age groups. In order to identify the heterogenous responses for different age groups, I do the following experiment. Suppose the economy is in the stationary equilibrium. House price unexpected decreases by 27.7 percent.[20]I simulate the economy onwards after the price shock. I compute the consumption profile for each cohort and plot them in the Figure 4. I plot the consumption response for households that are hit at age 51, 56, 61, and 66 respectively. It can be seen from the graph that households non-durable consumption drops right after the negative house price shocks. After than the households non-durable consumption slowly recovers, but is still permanently lower than they would have consumed if house price hadn't dropped. Those who experience a negative house price shocks later in life on average have a lower non-durable consumption level than

[19]When I restrict the sample to households aged 50-64 only, as Hryshko et al. (2010) did in the paper, the point estimate of elasticity of consumption to house prices is 0.40.

[20]Consider this as a one-time shock and the house price still follows the same stochastic process after the unexpected shock. The number 27.7 percent comes from the Markov approximation to house price process. The minimum distance between two grid points is 27.7 percent. Clearly, I can get finer grids by increasing the number of grid points. Since the house price drops by nearly 30 percent in the 2008 recession, I use this exercise as a simulation about the current crisis.

Table 4: Regression Results for the Simulated Panel Data

Dependent Variable: Retirement Dummy	Benchmark	No Bequest	Zero Borrowing	Infinite Cost
Lagged Non-Capital Income (1000$ in 1998)	-1.73e-3	-1.6e-3	-1.6e-3	-1.7e-3
House Price^{BP}	.20	.17	.16	.05
Age Dummies	Yes	Yes	Yes	Yes

households who experience it at younger age.

How large is that effect for average households in the US? The average net house value is 326,000 dollars, the average consumption drop from the model is 5,911 dollars. Therefore, for each dollar loss in housing wealth, households non-durable consumption immediately drops by 2 cents. This estimate is the same as the results in Carroll et al. (2011).

2.10. Elasticity of Retirement to House Prices

In order to estimate the elasticity of retirement to house prices, I estimate the following linear probability model with fixed effect

$$retirement^i_{a,t} = \alpha^i + y^i_{a,t} + p_t + I_a + \epsilon^i_t \tag{27}$$

where $retirement^i_t$ is an indicator function for retiree.

The regression results is shown in Table 4. The coefficient before house prices is .20, which means a 10 percent decline in house prices will reduce the retirement probability for households aged 50-70 by 2 percentage point.

The linear probability regression model assumes that the response of retirement probability to house price is the same for all age groups. In order to show the heterogenous retirement response, I do the similar experiment again. Suppose the model econoemy is at stationary equilibrium. Then it is shocked by a one-time unexpected -27.7 percent house price shock. I simulate the economy onwards and compute the average retirement age for different cohorts after the shock, which is the dotted line in Figure 5. The solid horizontal line in Figure 5 is the average retirement age in absence of the unexpected one-time house price drop. Keep in mind that all cohorts start with the same initial joint distribution of total asset and labor income. The only difference between them is the date when the one-time unexpected house price shock hits.

The average retirement age for different cohorts is hump-shaped. Among all the cohorts that suffer from one-time unexpected negative house price shock, the cohort that is hit at age 62 has the largest increase in the average retirement age. The cohorts that are hit at age 55-64 on average retire 5.75 months later than they would have done if house price had not unexpectedly declined. The result is smaller than the estimates by Farnham and Sevak (2007), which finds that a 10 percent increase in housing wealth will reduce the expected retirement age by 3.5 months to 5 months.

When shock hits at age younger than 62, the response in retirement age becomes smaller. This is because the relatively young households have a longer working career and their age-specific efficiency unit is still rising. Hence, they have plenty of time to make up the wealth loss and delay retirement slightly. If the shock hit at the age close to the full retirement age, the increase in the retirement age is also smaller. This is because the majority of the households have already retired at the date when shock hit. For

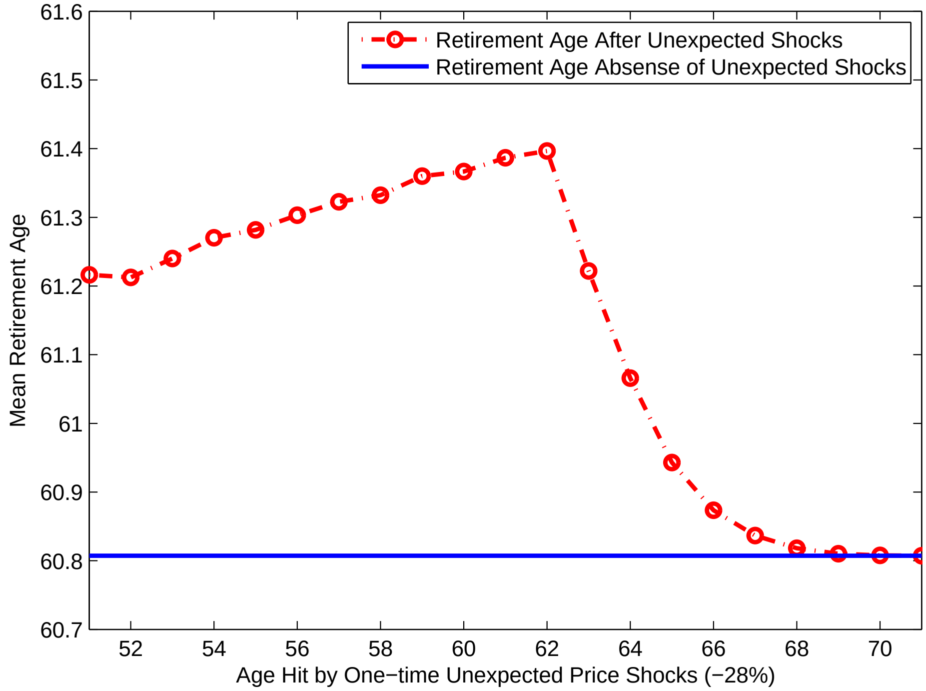

Figure 5: Mean Retirement Age after Negative House Price Shocks

those who are still in the labor force when shock hit, their remaining working career is shorter. Therefore, households do not have much flexibility to adjust their retirement. Note that the full retirement age in my simulation is age 70. Therefore, the unexpected house price shock at age 71 will not affect the retirement age at all.

2.11. Retirement As Self-insurance Against House Price Risks

From the incomplete-market life-cycle studies, we know that the labor adjustment is an important channel for households to self-insure against income shocks. In this section, I will study the retirement as self-insurance against house price shocks.[21]

In order to demonstrate the role of endogenous retirement in cushioning the house price risk, I build up a second structural model with exogenous retirement, where all households retire at the age 66.[22] The second model economy has the same social security system as in the benchmark model. I calibrate the consumption weight in the utility ω, the bequest strength ϕ, the discount factor β, and relative risk aversion σ to match four moments in the data: the average share of net housing value in total net worth for householders age 50-70, normalized net worth of households aged 50-70, the normalized

[21] It is worth mentioning that Hryshko et al. (2010) identifies house as a risk-sharing tool for consumption. They find that home owner tends to have less drops in food consumption than a renter when both of them experience a bad shock in the labor market.

[22] I also include the initial retiree at age 50 in the data and assume they stay in retirement until the end of life.

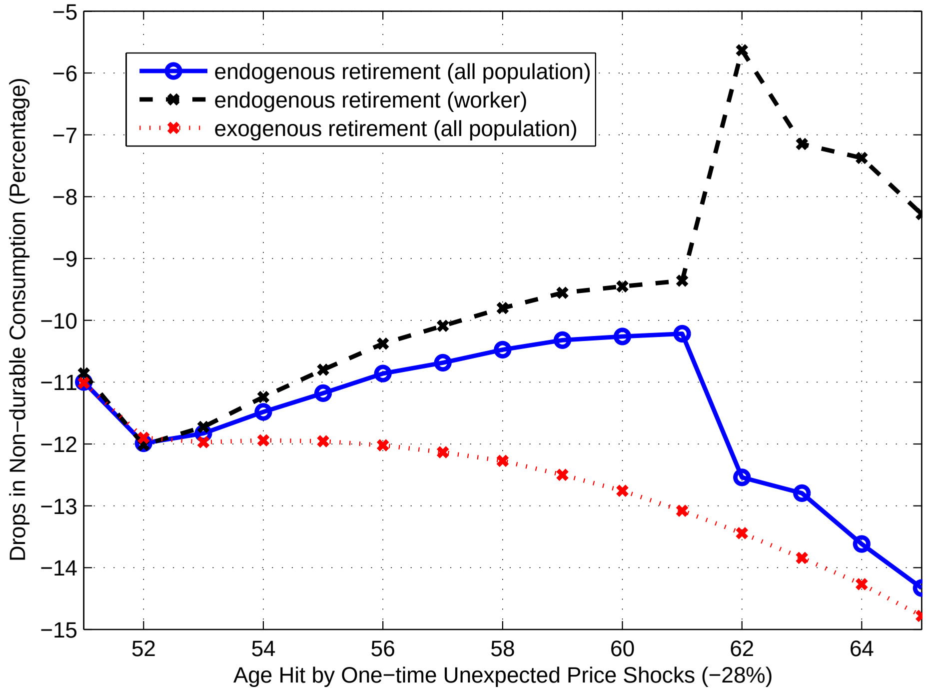

Figure 6: Instant Drops in Consumption After Negative House Price Shocks

net worth for households aged above 83, and the average consumption drop at retirement. These give $\omega = .810$, $\beta = .967$, $\phi = 6.0$, and $\sigma = 1.13$.

Figure 6 shows the instant consumption drop for different age groups after an unexpected -28% house price shocks in the endogenous retirement model (the solid line) and in the exogenous retirement model (the dotted line).

Two findings are worth mentioning. First, the average consumption response in the exogenous retirement model shows that old households on average suffer larger loss in the non-durable consumption than younger households, this is because younger households have longer working period left to recover from wealth loss. This is intuitive. For the old households close to full retirement age, this one-time unexpected house price shock is more like a permeant shock to them as they have little flexibility to adjust their retirement schedule.

Second, households in the endogenous retirement model on average have smaller drops in non-durable consumption than the households in the exogenous retirement model. The intuition is simple: the fall in house prices makes owners delay retirement in order to buffer negative wealth effect. It turns out that the average drop in non-durable consumption for the home owners aged 55-64 with the endogenous retirement is 14 percent smaller than the average drop for the same age group with exogenous retirement. For households aged 55-64, The average non-durable consumption drop in the endogenous retirement model is 11.5 percent and the average drop in the exogenous retirement model is 13.2 percent. This confirms the idea that endogenous retirement can cushion the negative house prices shocks on home owners' non-durable consumption.

The sudden drops at 62 in the endogenous retirement model is mainly driven by the consumption drop at retirement. The slow decline after age 63 for the economy with endogenous retirement is due the composition effect, i.e., more and more households become retired in the model. The dashed line is the consumption response of households conditional on being working in the endogenous retirement model. Conditional being working, the average consumption drop for households aged 55-64 in the endogenous retirement model is only 8.7 percent. The drops in the consumption is smaller for the old and larger for the young. This is mainly due to the self-selection into workers. Those with high income shocks decide to stay in the labor force and suffer less from the wealth shocks.

This exercise suggests that the endogenous retirement is important aspect when estimating the wealth effect on consumption for the near-retirement households. Neglecting this tends to overestimate the housing wealth effect on the consumption of old working households.

2.12. Model Mechanisms and Counterfactual Experiments

In this section, I first explain how house price can affect the non-durable consumption and retirement using an infinite horizon model. Then I will compare my benchmark model to the infinite horizon model and explain what are the implications coming from different model assumptions. Suppose the infinite horizon model model has the following features

A1 infinitely lived households

A2 fully predicted house price

A3 no borrowing constraint

A4 perfect housing market with no adjustment cost

A5 CRRA preference with Cobb-Douglas aggregation on consumption and housing services

Here, the assumption *A1* should not be interpreted literally. It can also be understood as a dynasty model where parents care about the utility of their children and choose whether to work or not. The assumption *A4* implies that the rental housing is perfect substitute to owner-occupied housing.

Under the assumptions *A2*-*A5*, the Cobb-Douglas utility implies a constant ratio between non-durable consumption and housing expenditure.[23] This is because the substitution effect and wealth effect of house price on non-durable consumption cancel out under Cobb-Douglas preference. The house prices will not affect the current consumption

[23] The ratio may remain constant even if the house price follows a stochastic process. One sufficient condition for that is to assume the returns on house price can be fully replicated by stock returns. The intuition is that housing serves as both consumption good and investment good. If its returns can be replicated by stocks, then housing asset can be treated as normal consumption goods. The constant ratio between consumption and housing value then comes from the properties of constant elasticity of substitution between housing and consumption.

or housing expenditure given the same total net worth at the beginning of this period (See proof in the appendix). In other words, after the total net worth is controlled, the current movement in house price will not affect non-durable consumption.

However, we usually ask how does house price affect consumption without control for total wealth. To clarify ideas, suppose the budget constraint can be written as follows

$$c + a' + ph' = ph + (1 + r)\,a \tag{28}$$

where c and h' is the non-durable consumption and housing stock in the current period respectively. r is the risk-free interest rate and p is the current house price. h is the housing stock last period (for simplicity, assume zero depreciation rate). Without loss of generality, suppose the housing stock produces the same amount of housing services.

Under assumption *A1-A5*, house price will not affect non-durable consumption if $h = h'$.[24] Generally speaking, $h \neq h'$. This is because households want to "rebalance" the consumption portfolio each period to make sure the ratio of non-durable consumption to housing expenditure is constant over time. Suppose one starts period with housing stock h and today's house price p is higher than yesterday's p^{-1} (the price for the housing service is also higher than yesterday's). If he chooses the same consumption and house size as yesterday's, then the consumption-housing-expenditure ratio is declining. To rebalance his portfolio, he wants to sell the houses and increase non-durable consumption.

To address the issue of endogenous retirement, I include the fixed cost of working. Now the utility function is no longer homogenous. An increase in the total wealth will reduce the marginal return to work. Therefore, households are less likely to work when house price increases.[25]

In this paper, I keep the assumption *A5* and modify the assumption *A1-A4*. More precisely, I break the assumption *A1* by introducing warm-glow bequest motive. The rationale for this assumption is discussed in the calibration part. House price is risky in the model, which changes the assumption *A2*. Therefore, the expectation about the future house price growth will matter. I break the assumption *A3* by assuming households can only borrow against the value of their houses. I will later introduce adjustment cost to housing asset, which violates the assumption *A4*.

The reminder of the section describes the three counterfactual experiments. By doing this, I quantify the housing wealth effect on retirement through three different channels: the bequest motive, collateral constraint, and the resizing effect.

2.12.1. Experiment A: No Bequest Motive

The first experiment is to quantify the effect of warm-glow bequest motive. I remove the bequest motive by setting the bequest strength ϕ to zero. I recalibrate the model to match three moments: the average share of net housing value in total net worth for householders age 50-70, the normalized net worth of households aged 50-70 , the average

[24] However, if assumptions *A1-A5* are not satisfied, then house price can still affect consumption and retirement even if $h = h'$. In the counterfactual experiment with infinite adjustment to housing, I shows that the housing wealth effect is still positive.

[25] If I study the effect of house price on retirement controlling for the total net worth, then the households are actually more (rather than less) likely to work when house price increases. This is because with higher house price and same initial wealth, households are worse off since their wealth in real value is smaller.

cumulative retirement-population rate of households for age group 63. Column "No Bequest" in Table 4 summarizes the regression results. The housing wealth effect equals .17, which is 3 percentage points smaller than the wealth effect in the benchmark model.

Households with warm-glow bequest motive care about the adequacy of total net worth when they die. Other things being equal, home owners experiencing adverse house price shock tends to work longer in order to buffer the negative effect of house price on the value of accidental bequest. The removal of bequest motive shut down this mechanism and tends to reduce the retirement response to house price shocks.

However, the drops in housing wealth effect after the removal of bequest motivate may be smaller than one would expect. One reason is that a counteracting force is functioning. The removal of bequest motive induces one to accumulate less wealth in the his late life. Because housing can be used as collateral, it is more valuable to the poor households than to the rich households. Therefore, the housing asset now accounts for a larger fraction of total net worth over life-cycle than in the benchmark case, which tends to increase the responsiveness of retirement to house prices.

There is a subtle difference between the warm-glow bequest motive and altruism.[26] If the altruism is assumed instead, then we go back to the infinite horizon model. I have proved that the house price fluctuations will not affect households' non-durable consumption and housing expenditure given all households have the same total net worth and fully predicted house price. This also implies the same amount of unintentional bequest. However, this argument will no longer be true in the case of warm-glow bequest motive. Households with warm-glow bequest motive care about the value of bequest but not the composition of bequest. In this case, households have different choices over non-durable consumption and saving under different house prices even if their total net worth at the beginning of period are the same. In this sense, introducing warm-glow bequest instead of altruism tends to increase the housing wealth effect.

2.12.2. Experiment B: Zero Borrowing Constraint

In the benchmark model, the average mortgage debt stays high at age 50 and then declines. Over the life cycle, households downsize houses and pay back mortgage gradually. After the retirement, the speed of decumulating debt is slower than in the working period. Households still hold some mortgage debt in late life. In fact, the mortgage leverage ratio is decreasing before retirement and increasing after retirement. This is because households in the model optimally use housing to finance their old-age consumption by taking reverse mortgage.

To study the effect of collateral constraint, I assume that households cannot borrow at all. This is done by simply setting the down-payment ratio λ to 100 percent. I recalibrate the model to match the average share of net housing value in total net worth for householders age 50-70, the normalized net worth of households aged 50-70 , the average cumulative retirement-population rate of households for age group 63, the normalized net worth for households aged above 83. The results are shown in column "Zero Borrowing" of Table 4. The housing wealth effect on retirement is .16, which is 4 percentage points less than the benchmark model.

[26] One can think of the bequest utility of altruism as $u_B = \phi \frac{\left(c_j^{\omega} h_{j+1}^{(1-\omega)}\right)^{1-\sigma}}{1-\sigma}$

Again, the drops in housing wealth effect may be smaller than one would expect. This is because two counter-acting forces are at work. On one hand, the 100 percent down-payment ratio reduces the incentive to hold housing asset as collateral. Under the zero borrowing constraint, households hold less housing in the total wealth than they do in the benchmark model. This in turn reduces the housing wealth effect on retirement and non-duable consumption.

On the other hand, the zero borrowing constraint limits the ability to self-insure against income risk and house price risk. In the case of negative house prices shocks, households want to increase the mortgage debt to housing value ratio in order to smooth consumption. The zero borrowing constraint prevents them from doing this and forces them to delay retirement. This counteracting force mitigate the drop in the responsiveness of retirement under zero borrowing constraint.

2.12.3. Experiment C: Infinite Adjustment Cost

The third experiment investigates how house price can affect retirement through house resizing. To get a lower bound on the resizing effect, I assume infinite adjustment cost, i.e., households cannot buy or sell their houses. One can think of the true world lies somewhere between the economy with infinite adjustment cost and the frictionless benchmark model.

Since housing adjustment is costly, the housing stock becomes one state variable. In the simulation, I use the empirical joint distribution of net housing value, wage income, and total net worth from home owners aged 48-52 in the Survey of Consumer Finance 1998 data. The resizing channel turns out to be the most important one for the housing wealth effect on retirement. After removal of resizing channel, a 10 percent decrease in house price will only reduce the average retirement-population rate in the sample by only 0.5 percent. This magnitude is only 20 percent of the housing wealth effect in the frictionless benchmark model.

The reason why housing wealth effect does not disappear completely in the infinite adjustment cost case is the following. First, households have bequest motive. When the adjustment cost is infinite, households choose to leave housing asset as a bequest instead of saving financial asset. Even if one lives in the same house, the liquidation house value after his death will still affect the retirement decision when he is alive. Second, the collateral borrowing channel allows households to consume out of their housing asset by taking reverse mortgage debt when they still live in them.

3. Empirical Evidence

3.1. Data

The empirical part is based on two US household survey: the Health and Retirement Study (HRS) and the Current Population Survey (CPS). The HRS is a national, biennial panel survey of individuals over age 50 and their spouses. It includes detailed information about demographics, income, wealth, health status, job status and history, and pension plans etc. In this paper, I use the RAND (2011) version of HRS data 1992-2008. The CPS is a monthly U.S. household survey conducted jointly by the U.S. Census Bureau and the Bureau of Labor Statistics from 1940s. It contains labor force status, wages, hours, and detailed geographic and demographic information. I use the basic CPS data 1989-2011 from NBER.

In order to exploit the time variation in house price across different regions and time variation in stock price, I use the house price index for 9 census divisions (CDs) from Federal Housing Finance Agency and S&P/Case-Shiller house price index for 20 metropolitan statistical areas (MSAs).[27]

Many empirical studies about wealth effect on labor supply treat retirement as a binary decision(Sevak, 2002; Farnham and Sevak, 2007; Coile and Levine, 2007, 2009). Households choose to retire if the discounted future value of being a retiree is larger than the value of being a worker. Since the value function for each individual is unobservable, the regression model simply assumes that it can be written as a linear combination of observable variables. Under different assumptions about distribution of error terms, the problem can be formulated as binary choice model. In this paper, I estimate a linear probability model for both HRS and CPS data.

3.2. HRS Data

The analyzed sample consists of respondents aged between 50 and 70 with positive household net worth during 1992-2008. The sample includes the entire five cohorts in HRS, that is the initial HRS cohort, the AHEAD (Assets and Health Dynamics Among the Oldest Old) cohort, the CODA (Children of Depression) cohort, the War Baby cohort, and the early Baby Boomer Cohort. The average number of households in a single wave is around 10,000.

Before I use the structural model to perform any counterfactual experiment, I want to make sure it can deliver the same retirement response to house prices as we have seen in the data. To do this, I first estimate a fixed-effect linear-probability model using simulated panel data. When constructing the panel, I take the joint distribution of total net worth and labor income for home owners at age 50 directly from empirical data. The simulated panel consists of households aged 50-70. There are 200 "MSAs" in the panel, with 200 different house price sequences drawn from the stationary distribution. There are 5,000 households in each simulated MSA. To be consistent with the empirical analysis, I also apply the Band-pass filter to the model generated house price series.[28] The results for the simulated panel data is given in column 3, Table **??**.

The regression model is formulated as follows:

$$Retirement_t^i = \alpha^i + \beta_t^T \mathbf{X}_t^i + \epsilon_t^i \tag{29}$$

where $Retirement_t^i$ is a binary variable. It equals 1 if the respondent i is retired at time t and 0 otherwise.

[27] Both indices are based on repeat transactions on the same physical property units in order to control for differences in the quality of the houses comprising the sample used for statistical estimation. The Case-Shiller house price index is more volatile than FHFA house price index. The census divisions are East North Central, East South Central, Middle Atlantic, Mountain, New England, Pacific, South Atlantic, West North Central, and West South Central. See Table B.8 in the appendix for detailed definitions of 20 MSAs

[28] Since my simulated data is in annual sequence, I apply the Band-pass filter using parameters 2 and 8, with a lead-lag length set to 3 as recommended in Baxter and King (1999).

Table 5: Regression Results for the HRS data

Dependent Variable: Retirement Dummy	(1)	(2)	(3)
	All	All	Home Owners
House Price^{BP}	.13***	.17***	.19***
	(2.6)	(3.1)	(3.1)
Renter	2.4e-3	2.2e-3	—
	(.26)	(.24)	
Renter×Census-Division House Price^{BP}	-.19	-.19	—
	(−1.3)	(−1.3)	
Stock Price^{BP}	.049***	.084***	.089***
	(2.9)	(3.4)	(3.1)
Non-Stock Owner	3.8e-3	3.6e-3	6.5e-3
	(.82)	(.77)	(1.2)
Non-Stock Owner×Stock Price^{BP}	-.14***	-.13***	-.10***
	(−5.5)	(−5.3)	(−3.3)
Lagged Labor Earnings (1000$ in 1998)	-1.5e-3***	-1.5e-3***	-1.3e-3***
	(−3.2)	(−3.2)	(−2.7)
Self-employed	-.21***	-.21***	-.20***
	(−18.9)	(−19.0)	(−14.9)
Health Status	7.3e-3***	7.3e-3***	6.7e-3***
	(3.2)	(3.2)	(2.5)
Government Provided Health Insurance	.085***	.084***	.083***
	(11.1)	(11.1)	(9.1)
Employer Provided Health Insurance	-.18***	-.18***	-.18***
	(−28.6)	(−29.0)	(−24.9)
Unemployed in the Last Wave	.056***	.056***	.047**
	(3.6)	(3.5)	(2.3)
Census-Division Unemployment Rate	—	5.7e-3*	6.4e-3*
		(1.8)	(1.7)
Census Divisions and Age Dummies	Yes	Yes	Yes
Overall R^2	.32	.32	.35
Number of Observations	71,801	71,801	50,310
Number of Households	17,651	17,651	12,200

In the Rand HRS data, the labor force status is divided into seven states: work full time, work part time, unemployed, partly retired, fully retired, disabled, not in the labor force. Here, I define retirement as a combination of three status: partly retired, full retired, and not in the labor force (excluding the disabled). The average retirement-population rate for respondents aged 50-70 is 48 percent. There is a second definition of retirement, the self-reported retirement. I also use the second definition as robustness check. The results are given by Table B.9 in the appendix.

$\mathbf{X}_t^i$ is a vector of observable variables including the respondent's labor earnings last year, the interaction term between home ownership dummy and house price index, the interaction term between stock ownership dummy and stocks price index, social demographic and geographical variables, the self-reported health status, a full set of dummies for census divisions and age, and whether the respondent is covered by government-provided or employer-covered health insurance plan. α^i is the individual unobserved characteristic, which remains constant over time but may be correlated with observable variables $\mathbf{X}_t^i$.

In HRS, questions about the respondents and their spouses' labor earnings are retrospective. According to the definition of RAND (2011), the respondent' labor earnings is the sum of his/her wage income, bonuses, overtime pay, commissions, tips, 2nd job or military reserve earnings, professional practice, and trade income. For simplicity, I treat the labor earnings as income from the year previous to the survey year.[29] The labor earning is deflated by the annual CPI index.

The home ownership dummy is an indicator of *renter*. It equals 0 if the respondent reports a positive gross value of his/her primary residence. It equals 1 if the value of primary residence is zero. Similarly, the stock ownership dummy is an indicator of *non-stock owner*. It equals 0 if the respondent has any stocks, mutual funds, investment trusts, individual retirement account, or defined contribution plan on any previous job.[30] It is a binary variable, which equals 1 if households own any form of stocks. I drop the observations for which either home value or stock value is missing. For households with respondent aged between 50 and 70, the weighted average stock ownership and home ownership is 46 percent and 83 percent respectively.

I use the monthly house price index from Federal Housing Finance Agency for 9 census divisions. The index is based on sales price data, rather than appraisal data. The stock prices are from S&P500 index. In the main results, I include the yearly-averaged BP-filtered log monthly price index.[31] All indices are deflated using CPI index. As a robustness check, I also report regression results in Table B.9 using the yearly-averaged HP-filtered log monthly price index and the linear-detrended yearly-averaged log price index.[32]

Table 5 shows the estimates of fixed effect model only, where the unobserved heterogeneity is assumed to be correlated with other explanatory variables. The t-statistics are given in the parenthesis and standard errors are clustered at household level. The Breusch and Pagan Lagrangian multiplier test for random effects reject the absence of individual effect. The Hausman specification test for all specifications gives p-value less than 1 percent. Therefore, the null hypothesis that there is no significant difference between the random effect model and fixed effect model is rejected, and the fixed effect model gives consistent estimates while the random effect model does not.

The main effect of house price is .13 in the specification 1. Remember that the reference group here is the home owners. Therefore, it means 10 percent increase in house price above the long-term trend is associated with 1.3 percent increase in the retirement probability. The renter dummy is not significantly different from zero, suggesting there

[29] Generally, Wave 1 questions ask about 1991 income, Wave 2H asks about 1993 income, and Wave 2A and from Wave 3 forward, about income last calendar year, based on the Financial Respondent's interview year. In Waves 2A, 3H, 4, and 5 forward not all interviews are completely conducted in the same year.

[30] Here I simply assume that all assets in the individual retirement account and defined contribution plan are invested in the stocks market. In HRS, the information on the type of pension plan is missing if the respondent has already retired. I define the retiree's pension plan status according to the information during the previous wave of survey when he/she is still working.

[31] In order to take out both the long term trend in price and too high frequency movement in the price index, I use a Band-pass filter with parameters 18 and 96 to preserve the components of the cycle with frequency between 1.5 and 8 years. For the house price data, the earliest monthly repeated sales data for 9 census divisions is available from 1991m1. I choose the lead-lag length of the filter to be 36, as recommended by Baxter and King (1999). This forces me to drop the 1992 wave of HRS because the BP-filtered house price index is only available from 1993.

[32] The HP-filtered log monthly price index are using smoothing parameter 129,600, as recommended by Ravn and Uhlig (2002). The linear-detrended price series are from the OLS regression residuals with log house prices as explanatory variables and year as the only regressor.

is no significant difference in retirement probability between the home owner and the renter after controlling for the unobserved fixed effect. The net effect of house price on the renters' retirement probability is the sum of main effect and the interaction effect, which is -.6 percent ($.13 - .19 = -.06$). The house wealth effect on the renters is insignificant, with p-value .63.

The main effect of stock price is .049 in the specification 1. The reference group for the stock wealth effect is the stock owners. It means 10 percent increase in stock price above the trend is associated with .49 percent increase in the stock owners' retirement probability. The net effect of stock price on non-stock owners is -.09 ($-.14+.049 = .091$). The effect is significantly different from zero. The possible reason is that the stock price is correlated with the economic fundamentals which also affect non-stock owners' willingness to work.

In order to control for the economic prospective, I include the census-division specific aggregate unemployment rate in specification 2. The coefficient before unemployment rate is .0057, which means 1 percentage point rise in unemployment rate is associated with .57 percent increase in the retirement-population rate. This is consistent with the idea that tight labor market tends to increases the retirement probability of the old households.

There is concern about the endogeneity of home ownerships and stock ownerships, e.g., some unobserved individual characteristic that accounts for both the ownerships and retirement decisions. However, as long as these unobserved characteristics is not time varying, the fixed effect model takes care of it. The specification 3 looks at subsample of home owners who haven't change their ownerships within the sample period and who haven't moved across census divisions. The results from home owners sub-sample give the similar estimate about housing wealth effect and a little bit higher stock wealth effect on retirement than the full sample. This suggests that these results are to some degree robust to the selection of home owners.

How large is the wealth effect? The mean gross house value of primary residence in 2006 for the home owners aged 50-70 is around 273,000 dollars. The mean asset value of stocks (excluding the defined contribution plan) for the stock owners aged 50-70 is nearly 176,000 dollars. Take housing wealth effect for example. From 2006 to 2008, the BP-filtered house price in the Pacific region drops nearly 17 percent below the long-term trend, nearly 46,410 dollars decline in housing wealth. The will creates 2.4 percent decline in the retirement probability according to the regressions.

There are other determinants of retirement, which are also interesting to look at. The coefficient before lagged labor earnings last year is negative, which is not surprising since labor earnings is the opportunity cost of retirement. It means that 10,000 dollars (in 1998 dollars) increase in households annual labor earnings will reduce the retirement probability in the subsequent year by 1.5 percent.

The coefficient before the indicator of being unemployed last wave is .056. Households who experienced unemployed in the last wave (two years ago) is 5.6 percent more likely to retire. Although it is impossible to find out whether the respondent keeps searching for the job after being unemployed, this evidence seems to be consistent with the discouraged worker effect.

Health status is also an important factor. The health index ranges from 1 to 5, with the most healthy status indexed by 1. For one extra level increase in health indicator, the retirement probability increases by 0.73 percent. For a person with most excellent health, his retirement probability is nearly 3 percent smaller than the person with poorest health. The coverage of health insurance also plays an important role in the retirement planning. The retirement probability of the worker covered by employer provided health insurance plans is 18 percent smaller than their non-insured counterparts. On the other hand, government provided health insurance, like Medicare and Medicaid, increases respondent's retirement probability. This is partly because Medicaid is only available for those aged above 65.

Recall that the structural model has an estimated elasticity of retirement to house prices equal to .172 on retirement probability of home owners aged 50-70. The wealth effect is comparable to the estimates from HRS regression. Now I am looking into the estimation about elasticity of consumption to house prices using the HRS data.

The HRS data is not designed for study of households consumption. However, it has a supplement called the Consumption and Activities Mail Survey (CAMS) from 2001. It is a paper-and-pencil survey that is collected biennially in odd-numbered years. One of its primary objectives is to measure total household spending over the previous 12 months. In September 2001, the first CAMS survey was mailed to 5,000 households selected at random from households that participated in the HRS 2000 core survey. I use the entire five waves of the CAMS data 2001-2009. The questions on consumption record individual consumption last month or last 12 months. The Rand CAMS contains the cleaned annualized consumption data. Since the survey usually starts in September in odd-number years, I will simply treat the consumption data as values for the year 2001, 2003, 2005, 2007, and 2009. In the HRS, the questions on income are retrospective. Households are asked about their last year's income. Since survey is conducted in even-number years, I merge the income data from Rand HRS data 2002-2010 to the CAMS 2001-2009 sample.

I only look at HRS household respondents aged 50-70 who are also covered in the CAMS survey the following year. Due to the sample attrition problem, there are only less than 3000 observations in 2009. Table 6 shows the fixed effect panel regression which also allows for AR(1) error terms. The dependent variable is the 2-year changes in log non-durable households consumption.[33] The explanatory variables include the 2-year changes in log house price at census-division level and its interaction term with home ownerships. I also include the 2-year changes in log S&P500 stock price and its interactions with stock ownerships.

The elasticity of consumption to house prices is .26, which means 10 percent growth in house prices increases the growth rate of non-durable consumption of homeowners aged 50-70 by 2.6 percentage points. The stock wealth effect is .17, which says that 10 percent growth in stock prices increases the average growth rate of non-durable consumption by 1.8 percentage points. When I restrict the sample to homeowners only, the house wealth effect do not change much. However, the interaction term between stock price growth and stock ownerships become positive. The coefficient before the changes in log households non-capital income is .023, which says the growth rate of non-durable consumption increases by 0.23 percentage point if the growth rate of non-capital income increases by 10 percentage point. The empirical estimates about the consumption elas-

[33]According the Rand Version of CAMS data, the non-durable consumptions include the home/renter insurance, vehicle insurance, health insurance, trips and vacations, gift, rent, electricity, water, home repairs, clothing and apparel, personal care products, drugs, tickets, sport equipment etc.

Table 6: Comparison between HRS data and Simulated Data

Dependent Variable: Δc	All	Homeowners
ΔNon-capital Income (1000$ in 1998)	.023*	.033**
	(1.8)	(2.2)
ΔHouse Price	.26**	.23*
	(2.0)	(1.7)
Renter	-.14*	—
	(−1.7)	
Renter×ΔHouse Price	-.13	—
	(−.58)	
ΔStock Price	.17**	.20**
	(2.0)	(2.2)
Non-Stock Owner	-.01	-.01
	(−.30)	(−.31)
Non-Stock Owner×ΔStock Price	-.03	.01
	(−0.40)	(.17)
Age Dummies	Yes	Yes

ticity is smaller than the estimate from the structural model. According to the previous counterfactual experiment, this is largely due the frictionless housing market assumption in the benchmark model.

3.3. CPS data

In this section, I provide the evidence of housing wealth effect on retirement using the monthly CPS data 1989-2011.[34] The analyzed sample consists of householders aged between 50 and 70. Some periods in the sample (May 1995, June 1995, and July 1995) are dropped because of the missing geographic information. The advantage of this data set is its large sample size. The data set contains detailed geographic identifiers on the monthly basis, which allows me to investigate the wealth effect of local house price changes. I focus on the sub-sample of households who are living in the 20 largest metropolitan statistics areas (MSAs), for which the Case-Shiller house price index is available. However, the drawback of the data set is the cross sectional structure. I cannot control the unobserved individual characteristics using fixed effect model. Moreover, it doesn't contain any information on stock ownership or pension plan. The new regression model is written as follows:

$$Retirement_t^i = \alpha + \beta_t^T \mathbf{X}_t^i + \epsilon_t^i \tag{30}$$

The binary variable $Retirement_t^i$ equals 1 if individual i retires at time t and 0 otherwise. After 1994, the redesign of CPS questionnaire lists the retirement status as a separate item in CPS labor force status. Before 1994, retirement cannot be identified using the labor force status alone. I combine the labor force status with the major labor activity last week (item 19) to identify the retirement status. I define a person to be retired if and only if her major activity last week is reported as retirement and her labor force status in CPS is coded as being "not in the labor force". The difference in the

[34]The sample period starts at 1989 because the housing tenure question was not asked before 1982 and the monthly house price index for different MSAs is only available from 1987.

sample design creates a structural difference in retirement-population rate between the two periods. I include a regime dummy for the post-1994 period in the regression to control for this change.[35] All observations are weighted by the final sampling weight in the regression.

$\mathbf{X}_t^i$ contains the interaction term between home ownership dummy and house price index, the demographic and geographic variables (gender, race, marital status, college degree, number of persons in the family), and different sets of dummies (age, MSA, and month interviewed in the sample).

In the monthly CPS, there is a question about the total household income in past 12 months, which is recorded as categorical variable. I simply impute the value of household income using the cell mean and include this variable in the regression.[36] I drop observations with households annual income larger than 2,500 dollars (in current value), which account for less than 1 percent of the whole sample.

Home ownership dummy is an indicator of the *renter*. It equals 0 if the respondent owns the residence. It equals 1 if the respondent is a renter. I use the interaction term between home ownership and BP-filtered MSA-specific monthly log Case-Shiller house price index to identify the housing wealth effect.[37] Table B.10 in the appendix also provides the regression results using linear-detrended log price index and HP-filtered monthly log price index. All price indices are deflated by the monthly CPI. The identification of stock wealth effect is impossible in the CPS because there is no question about stock ownerships.[38]

Table 7 shows the regression results for the CPS data from pooled OLS regression. The t-statistics are given in the parenthesis and all standard errors are clustered at MSA level. The main effect of house price is .19 in the specification 1. The reference group here is home owners. It means 10 percent increase in housing price above the trend will increase the retirement probability for home owners by 1.9 percent. The renter dummy is significant at 1 percent level. It says the renters are 6.2 percent less likely to retire than homeowners. The net effect of house price on renter is .05, with p-value .62.

I include the MSA-specific unemployment rate for households aged above 16 in specification 2 in order to control for the economic prospective. After controlling the MSA-specific unemployment rate, the estimates for house price do not change. The coefficient before the unemployment rate is not significantly different from zero.

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[35]The regression coefficient before the regime dummy is .05, which means the post-1994 period have a retirement-population rate that is 5 percentage point higher than the pre-1994 period.

[36]The total households income is defined as the total income of all family members during the past 12 months. This includes income from jobs, net income from business, farm or rent, pensions, dividends, interest, social security payments and any other money income received by members of this Family who are 15 years of age or older. Ideally, one wants to include the labor income in the regression. However, only those who are going to leave the sample next month (known as the ongoing rotation group) in monthly CPS are asked the detailed question about individual earnings. This group accounts for only less than 25 percent of the whole sample. I choose not to use this subsample because it would keep very little observations for some MSAs.

[37]The Band-pass filter uses parameters 18 and 96 to preserve the components of the cycle with frequency between 1.5 and 8 years. The lead-lag length of the filter is set to be 36.

[38]In a separate exercise (results not shown here), I proxy the stock ownerships using *college degree*. I include the interaction term between the non-college group and the BP-filtered log S&P500 index to see whether stocks price affect this education group in a different way. I haven't found any stock wealth effect using this proxy method.

Table 7: Regression Results for the CPS data

Dependent Variable: Retirement Dummy	(1)	(2)	(3)
	All	All	Home Owners
MSA House Price^{BP}	.19***	.19***	.17***
	(3.4)	(3.2)	(3.1)
Renter	-.067***	-.067***	—
	(−15.7)	(−15.4)	
Renter×MSA House Price^{BP}	-.14	-.14	—
	(−.93)	(−.93)	
Lagged Family Income (1000$ in 1998)	-1.7e-3***	-1.7e-3***	-1.7e-3***
	(−12.0)	(−12.0)	(−11.4)
Self-employed	-.17***	-.17***	-.17***
	(−33.3)	(−31.5)	(−30.6)
MSA Unemployment Rate	—	-8.0e-5	1.3e-4
		(−.07)	(.12)
Race, Marital Status, Gender, No. of Persons, Age dummies	Yes	Yes	Yes
Year ≥1994, Month-in-sample, College Degree, MSA Dummies	Yes	Yes	Yes
R^2	0.35	0.33	0.35
Number of Observations	522,372	522,372	432,236

Specification 3 restricts the sample to home owners only. The housing wealth effect on home owners drops by 3 percentage points. It suggests that some unobserved individual characteristics that account for both the home ownerships and retirement decisions are not controlled. Because of the cross-sectional structure of the CPS data, one need to be more cautious in interpreting the housing wealth effect estimated from CPS data.

The coefficient before family income is almost identical to the one estimated from HRS regression. It says that 10,000 dollars (in 1998 dollars) increase in households income will reduce the retirement probability of householder by 1.7 percent. The impact of self-employment on retirement is also similar. The self-employed households are 17 percent less likely to retire than wage and salary workers.

4. Conclusion

This paper complements previous studies on retirement by pointing out the importance of housing wealth effect and stock wealth effect on retirement and consumption decision for the old population.

It builds up an incomplete-market life-cycle partial-equilibrium model, in which households choose housing consumption and timing of retirement subject to exogenous labor income risk, house price risk, and mortality risk. Calibrated to match the U.S. data, the model's predictions about retirement are consistent with empirical evidence. Counterfactual experiments indicate that households respond to house price shocks through three channels: resizing effect, bequest motive, and collateral borrowing. Using the structural model, the paper argues the endogenous retirement is quantitatively important channel for self-insurance against house- and stock-price shocks.

The U.S. households are gradually shifting their portfolios towards riskier assets because of the recent development in the financial market, e.g., the increasing participation rate in the defined contribution plan and the boom in home ownerships from mid-1990s.[39]

[39] Most increase in DC plans takes place within private sectors. Costo (2006) documents that the

Therefore, the near-retirement households are faced with great volatility in total wealth if the portfolios are heavily concentrated in housing assets and stocks.[40] It is particular important to understand the key factors that influence the timing of retirement when the Post-World War II baby boomers are preparing to retire. The government should take wealth effect into consideration when making policy such as taxation, the early retirement age, and pension reform.

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coverage of DC plans in private sectors has outpaced the coverage of DB plans since 1992. The difference between the two coverage rates is 20 percent at year 2005. Chambers et al. (2009) shows the surge in the home ownerships after 1994.

[40] During last 20 years, the annualized returns to stocks and housing asset have been varying from -20 percent to 50 percent. The median households whose age is now between 57-62 hold 22.3 percent of their total net worth (including social security wealth) in housing market, 9.2 percent in stocks market at year 2006 (Gustman et al. (2009)). Since then, both stocks market and housing market have been declining by 30 percent, which is equal to 10 percent of their total wealth, nearly $53,700 in 2006 dollars. The loss is even larger than the median household income, which is $50,233 in 2007 according to the U.S. Census Bureau.

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Appendix A. Proof in Section 3.10

Rewrite the infinite horizon problem recursively

$$V(x,p,\eta,\varepsilon)=\max_{c,n,h'}\{u(c,h')-\theta n+\beta V'(x',p',\eta',\varepsilon')\} \tag{A.1}$$

subject to the constraint

$$x'=R(x+wn-c-ph')+p'h'(1-\delta_h) \tag{A.2}$$
$$c>0,h'>0,x'>0 \tag{A.3}$$

Insert A.2 into Bellman Equation and differentiate with respect to c and h'

$$V_c=\beta RE\left[V_x'(x',p',\eta',\varepsilon')\right] \tag{A.4}$$
$$V_{h'}=\beta RE\left[V_x'(x',p',\eta',\varepsilon')(p-(1-\delta)p'/R)\right] \tag{A.5}$$

Combine the two first order conditions

$$\frac{V_c}{V_{h'}}=\frac{1}{p-(1-\delta)p'/R} \tag{A.6}$$

Denote that $p^r=p-(1-\delta)p'/R$, which is in fact the rental price. This is because of zero adjustment cost and no borrowing constraint. Using that

$$u(c,h',n)=\frac{\left(c^{\omega}h'^{(1-\omega)}\right)^{1-\sigma}}{1-\sigma}-\theta n \tag{A.7}$$

Then the consumption-housing-expenditure ratio is given by

$$\frac{c}{p^r h'}=\frac{\omega}{1-\omega} \tag{A.8}$$

which is independent of house price shocks. The budget constraint A.2 is now equivalent to

$$x'=R(x+wn-c/\omega) \tag{A.9}$$

Therefore, households have the same consume and housing expenditure if their total net worth at beginning of period is the same.

Appendix B. Tables and Figures

Table B.8 shows the mapping from 20 MSAs used by Case-Shiller Index to the Geographic Identifiers in the CPS. The specific metropolitan identifiers in this table are based on the Office of Management and Budget's definition in several years.

Table B.9 and B.10 are the robustness check for shows the same regression as in Table 5 and 7. It uses different measure of house price shocks. Table B.9 also use an alternative definition of retirement in HRS

Figure B.7 it the normalized efficiency units taken from Hansen (1993). Figure B.8 plots the joint distribution of total net worth and wage income for homeowners aged 48-52 from Survey of Consumer Finance 1998.

Table B.8: Geographic Identifiers of 20 MSAs in the CPS data

MSA	HG_MSAC 1989M12-1993M12	GEMSA 1994M1-2004M4	GTCBSA 2004M5-2011M4
Phoenix-Mesa-Scottsdale, AZ	6200	6200	38060
Los Angeles-Long Beach-Santa Ana, CA	4480,5945	4480,5945	31100
San Diego-Carlsbad-San Marco, CA	7320	7320	41740
San Francisco-Oakland-Fremont, CA	7360,5775	7360,5775	41860
Denver-Aurora, CO	2080	2080	19740
Washington-Arlington-Alexandria, DC-VA-MD-WV	8840	8840	47900
Miami-Fort Lauderdale-Pompano Beach, FL	5000,2680,8960	5000,2680,8960	2.8
Tampa-St. Petersburg-Clearwater, FL	8280	8280	45300
Atlanta-Sandy Springs-Marietta, GA	520	520	12060
Chicago-Naperville-Joliet, IL	1600	1600	16980
Boston-Cambridge-Quincy, MA-NH	1120,1200,4160	1120,1200,2600,4160	71650
	4560,5350,7090	4560,5400,4760,6450	
Detroit-Warren-Livonia, MI	2160	2160	19820
Minneapolis-St. Paul-Bloomington, MN-WI	5120	5120	33460
Charlotte-Gastonia-Concord, NC-SC	1520	1520	16740
Las Vegas-Paradise, NV	4120	4120	29820
New York City Area	0875,1160,1930,3640	1160,1930,2281,3640,5015	35620,45940
	5190,5380,5600,5640	5190,5380,5600,5480,5640	71950,75700
	5760,5950,8040	5660,8040,8480,8880	
Cleveland-Elyria-Mentor, OH	1680,4440	1680	17460
Portland-Vancouver-Beaverton, OR-WA	6440,8725	6440	38900
Dallas-Fort Worth-Arlington, TX	1920,2800	1920,2800	19100
Seattle-Tacoma-Bellevue, WA	7600,8200	7600,8200	42660

Table B.9: Regression Results for the HRS data: robustness check

Dependent Variable: Retirement Dummy	(1)	(2)	(3)	(4)	(5)
	Retirement Recoded		Self-reported Retirement		
House Price^{HP}	.18***	—	—	—	.076
	(3.8)				(1.5)
House price^{Linear}	—	.076 ***	—	.080 ***	—
		(3.8)		(3.8)	
House Price^{BP}	—	—	.030	—	—
			(.46)		
Renter	1.6e-3	1.8e-3	7.4e-3	8.1e-3	6.8e-3
	(.20)	(.20)	(.79)	(.86)	(.73)
Renter×Census-Division House price^{HP}	-.27**	—	—	—	-.29**
	(−1.9)				(−2.2)
Renter×Census-Division House price^{Linear}	—	-.031	—	-.097 *	—
		(−.57)		(−1.86)	
Renter×Census-Division House Price^{BP}	—	—	-.30**	—	—
			(−2.0)		
Stock Price^{HP}	.088***	—	—	—	.042
	(3.4)				(1.6)
Stock Price^{Linear}	—	.072***	—	.089***	—
		(5.2)		(6.1)	
Stock Price^{BP}	—	—	.015	—	—
			(.59)		
Non-stock Owner	1.7e-3	1.5e-2***	.011**	.0130***	.011**
	(.37)	(2.8)	(2.3)	(3.02)	(2.2)
Non-Stock Owner×Stock Price^{HP}	-.11***	—	—	—	-.033
	(−4.6)				(−1.3)
Non-Stock Owner×Stock Price^{Linear}	—	-.058***	—	-.022*	—
		(−5.0)		(−1.8)	
Non-Stock Owner×Stock Price^{BP}	—	—	-.043	—	—
			(−1.5)		
Labor Earnings (1000$ in 1998)	-1.5e-3***	-1.5e-3***	-1.3e-3***	-1.3e-3***	-1.3e-3***
	(−3.2)	(−3.2)	(−2.9)	(−2.9)	(−2.9)
Self-employed	-.21***	-.21***	-.091***	-.09***	-.091***
	(−19.0)	(−19.0)	(−8.2)	(−8.1)	(−8.2)
Health Status	7.3e-3***	7.1e-3***	.014***	.0134***	.014***
	(3.2)	(3.1)	(5.5)	(5.5)	(5.5)
Government Provided Health Insurance	.085***	.084***	.15***	.15***	.15***
	(11.1)	(11.1)	(18.7)	(18.6)	(18.7)
Employer Provided Health Insurance	-.19***	-.19***	-.17***	-.17***	-.17***
	(−28.5)	(−28.5)	(−25.8)	(−26)	(−26.3)
Unemployed in the Last Wave	.057***	.057***	.009	.01	.009
	(3.6)	(3.6)	(.60)	(.61)	(.59)
Census-Division Unemployment Rate	.008**	.015***	-.002	.019***	.0017
	(2.4)	(4.0)	-.64	(4.9)	(.47)
CD and Age Dummies, Fixed Effects	Yes	Yes	Yes	Yes	Yes
Overall R^2	.32	.32	.36	.38	.36
Number of Observations	71,801	71,801	60,485	60,485	60,485
Number of Households	17,651	17,651	16,508	16,508	16,508

Table B.10: Regression Results for the CPS data: robustness check

Dependent Variable: Retirement Dummy	(1)	(2)	(3)	(4)
	All	Home Owners	All	Home Owners
MSA House Price$^{\text{Linear}}$	.030*	.030*	—	—
	(1.8)	(1.8)		
MSA House Price$^{\text{HP}}$	—	—	.10**	.091**
			(2.3)	(2.2)
Renter	-.063 ***	—	-.063 ***	—
	(−17.3)		(−17.7)	
Renter×MSA House Price$^{\text{Linear}}$	-.016	—	—	—
	(−.50)			
Renter×MSA House Price$^{\text{HP}}$	—	—	-.045	—
			(−.36)	
Lagged Family Income (1000$ in 1998)	-1.7e-3***	-1.7e-3***	-1.7e-3***	-1.7e-3***
	(−13.0)	(−12.1)	(−12.9)	(−12.1)
Self-employed	-.17***	-.18***	-.17***	-.18***
	(−29.5)	(−30.1)	(−29.4)	(−30.1)
MSA Unemployment Rate	3.3e-4	8.0e-4	2.2e-4	5.3e-4
	(.40)	(.76)	(.31)	(.63)
Race, Marital Status, Gender, No. of Persons, Age dummies	Yes	Yes	Yes	Yes
Year≥1994, Month-in-sample, College Degree, MSA Dummies	Yes	Yes	Yes	Yes
R^2	0.35	0.34	0.35	0.34
Number of Observations	641,405	531,468	641,405	531,468

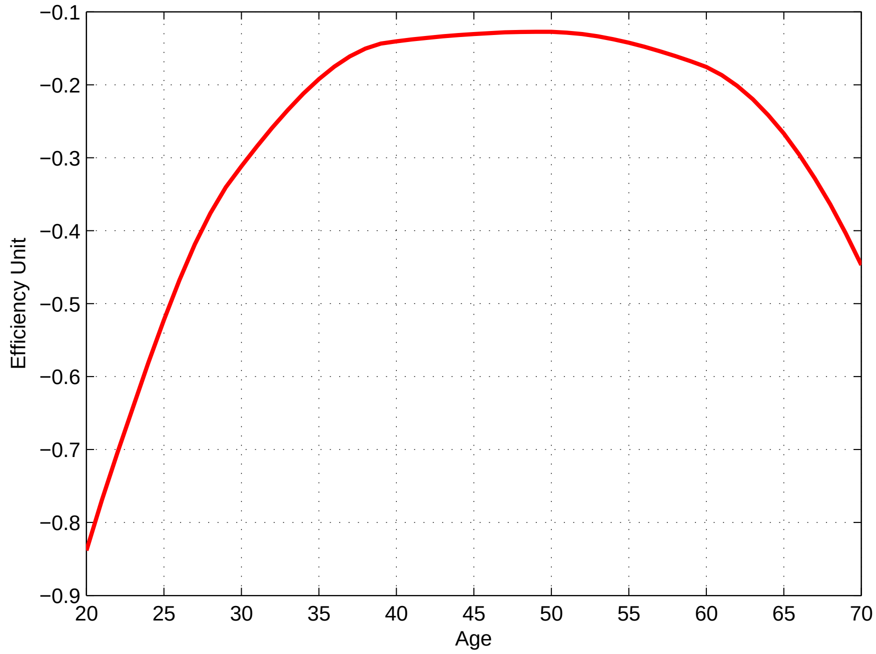

Figure B.7: Logarithm of Efficiency Unit

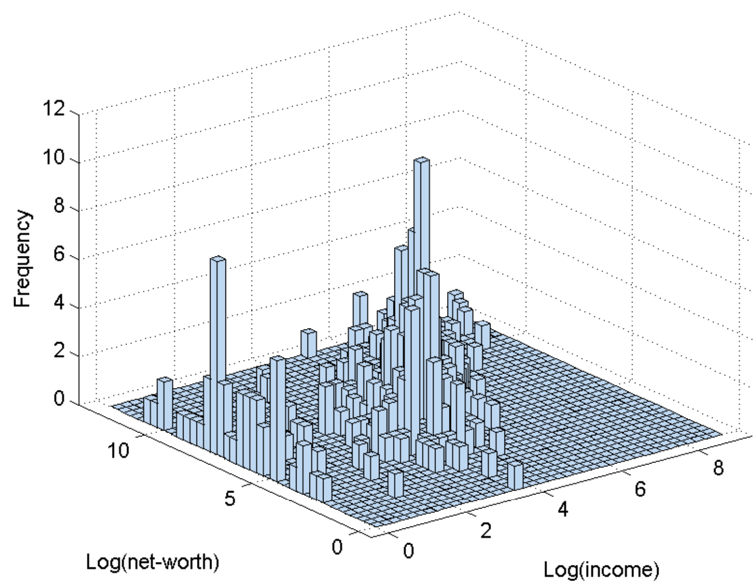

Figure B.8: Joint Distribution of Net worth and Earnings at Age 50