Too Poor to Retire? Housing Prices and Retirement*

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Abstract

This paper documents two facts. First, the near-retirement households among all working-age groups in the U.S. experienced larger drops in consumption and greater increases in labor force participation during the financial crisis of 2007 to 2009. Second, the retirement probability for the near-retirement home-owners (but not for renters) decreases more in those areas where house prices also decline more. This paper argues that the wealth effect of house prices on retirement can account for this fact. It creates a calibrated incomplete-market life-cycle partial-equilibrium model with risky housing assets and endogenous retirement. It first verifies that the joint response of retirement and non-durable consumption implied by the structural model is consistent with the empirical findings using data from the Health and Retirement Study 1992 to 2012. It then shows that after a one-time unexpected 27.7 percent house price decline, the near-retirement home-owners aged 55-64 will reduce their non-durable consumption by 4.7 percent and increases their LFP by 0.96 percentage points immediately and delay their retirement by 3 months in the long run. The model also quantifies endogenous retirement as self-insurance for the elderly homeowners against house price risk.

Keywords: Housing wealth effect, Endogenous retirement, Self-insurance

JEL: E21, E24, J26, R21

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1 Introduction

The impact of the 2007 to 2009 financial crisis on household consumption and labor supply differs across age groups. Table 1 shows the average annual growth rate of nondurable consumption during the pre-crisis period of 2002 to 2007, the crisis period of 2007 to 2009, and the post-crisis period of 2009 and 2014. Both the young age group (age 16 to 24) and the near-retirement age group (age 55 to 64) had the largest drop in consumption during the crisis period. Table 2 exhibits the average annual changes of labor force participation rates during the same period. All age groups except for the near-retirement age group experienced a decline in the labor force participation rate during the crisis period. Surprisingly, the labor force participation rate of the near-retirement age group increased at a higher rate during the crisis period than in the pre-crisis period.

Conventional wisdom says that the households of the elderly are too poor to retire due to falling asset prices during the financial crisis, e.g., the S&P Case-Shiller house price index for the U.S. dropped by 30 percent between 2006 and 2009.[1] Because of the high fraction of housing wealth in total household wealth as well as the high home-ownership rate during later life, the households of the elderly are particular vulnerable to house price shocks.

This paper takes this argument seriously and analyzes all waves from the Health and Retirement Study 1992 to 2012, a nationally representative panel survey of individuals 50 and over. Further, it studies how house prices affect the joint behaviors of retirement and consumption. By exploiting the geographic and time variations in house prices, it finds that the decline in regional house prices is positively correlated with the drop in retirement probability and the consumption of home-owners aged 50 to 65. Such a positive correlation is absent for renters in this same age group.

Motivated by the empirical results, this paper takes the off-the-shelf 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 older home-owners. In the model, households derive utilities from non-durable consumption, leisure, and housing services. More importantly, households can choose the timing of retirement subject to uninsurable labor income risk, house price risk, health risk, and mortality risk. Calibrated to the US data, the structural model delivers predictions that are consistent with the empirical study. The regression using the Health and Retirement Study 1992-2012 finds that a 10 percent decline

[1] Hurd and Rohwedder (2010)also finds that the elderly revised their retirement expectations to delay retirement during the 2007 to 2009 period. Goda, Shoven and Slavov (2011) documents similar evidence on delayed retirement plans of elderly households during 2006 to 2008.

Table 1: **Average annual growth rate of non-durable consumption for households aged 16-64**. The consumption growth rates are denoted in percentage points. Consumption data are from Consumer Expenditure Survey (CE) and deflated by CPI. The nondurables consist of food consumption, alcohol beverages, utilities, household operations, apparel, public transportation, gas and motor oil, entertainment, personal care products, tobacco products and smoking supplies, and miscellaneous expenditures. The age of head is the defined as the age of the reference person in the households. The standard error is computed based on CE standard error table and put in the parentheses. Data source: CE database from BLS.

Time period	Age of households head				
	16-24	25-34	35-44	45-54	55-64
2002-2007	1.50	0.72	2.04	1.60	1.46
	(0.89)	(0.42)	(0.42)	(0.52)	(0.64)
2007-2009	-4.61	-1.62	-1.73	-1.86	-3.37
	(2.85)	(1.16)	(1.13)	(1.41)	(1.49)
2009-2014	-1.12	-0.97	-0.80	-0.10	-0.41
	(1.19)	(1.16)	(0.51)	(0.58)	(0.53)

Table 2: **Average annual changes of labor force participation for individuals aged 16-64**. The labor force participation rate is defined as the total labor force divided by the total population in each age group. Data source: BLS published time series LNS11324887, LNS11300089, LNS11300091, LNS11300093, and LNU01300095.

Time period	Age of individuals				
	16-24	25-34	35-44	45-54	55-64
2002-2007	0.77	-0.07	-0.08	-0.02	0.38
2007-2009	-1.29	-0.31	-0.02	-0.15	0.56
2009-2014	-0.37	-0.30	-0.31	-0.41	-0.16

in local house prices will reduce the mean retirement probability for home-owners aged 50 to 65 by 0.72 percent and reduce the non-durable consumption of home-owners aged 50 to 65 by 2.5 percent, results that align very well with the structural model. Numerical simulation also shows that after the house prices drop by 27.7 percent, a magnitude close to that experienced during the financial crisis of 2007 to 2009, households aged 50-65 reduced their non-durable consumption by 4.7 percent and increases their LFP by 0.96 percentage points immediately and delay their retirement by 3 months in the long run.

The decline in house prices immediately reduces the total wealth of home-owners. This wealth effect tends to reduce households consumption of non-durables, housing services, and leisure. When a house is not worth as much, households also want to substitute consumption of non-durables and leisure for housing. Combining the two effects, the house price decline will cause homeowners to consume fewer non-durable goods and engage in fewer leisure activities, which takes the form of delayed retirement. This mechanism relies mostly on the ability to freely adjust the size of the house, which implies that households can upgrade or downgrade their houses after the house price shock.[2] After the adjustment in house size, the capital gain or loss due to fluctuating house prices is realized, which, in turn, affects the reservation wage and the probability of retirement. I call this first channel the re-sizing effect.

Even if households cannot adjust the size of their houses, house price can influence household consumption and retirement decisions through the other two channels. The second channel is called the collateral borrowing channel. Housing not only provides service flows, but it also serves as the most important collateral for households. When households suffer from wealth loss, they want to borrow against housing assets to smooth consumption. This provides incentives for the indebted households to work longer to pay back their mortgages. The collateral borrowing channel also works when house prices increase as older homeowners who are asset rich but income poor may also take reverse mortgage loans to cash out their housing value.[3] Therefore, rising house prices bring more available resources to home-owners

[2]Because housing transactions are costly, there have been debates on whether housing, like other liquid assets, is being used by older households to finance consumption. The home-ownership rate in the US remains stable until age 70 and then declines significantly afterwards(Yang, 2009). 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, Jos Luengo-Prado and Sørensen (2010) finds that housing assets help to cushion the consumption drops of home-owners in the presence of negative labor market shocks.

[3]Home-owners aged above 62 can use reverse mortgage to cash out their home value and do not have to pay back the loan until they die or move out of the house. Shan (2011) documents that the Home Equity Conversion Mortgage (the majority of reverse mortgage loan in the US are HECM) grew by 38 percent annually between 2003 and 2007. She also estimates that one percentage increase in the annual real

and reduce their incentive to work.

The third channel is the bequest motive.[4] Households care about the adequacy of their total bequest after they die. Other things being equal, home-owners experiencing adverse house price shocks tend to work longer to buffer the negative effect of house prices on the value of the bequest. Even if one lives in the same house, the liquidation value of that house after his death affects his retirement decision when he is alive.

I examine the importance of these three channels through counterfactual experiments. The structural model also quantifies the effectiveness of endogenous retirement as self-insurance for home-owners against house price risk. It finds that after the one-time unexpected 27.7 percent house price decline, the drops in non-durable consumption for home-owners aged 55 to 64 with endogenous retirement is 34 percent smaller than the drops in the consumption of home-owners with exogenous retirement.

Early literature regarding wealth effects focuses on the impact of wealth on households non-durable consumption.[5] Recent studies by Case, Quigley and Shiller. (2001) and Campbell and Cocco (2007) examine only one important component of household wealth, the housing asset.[6] They find that consumption of older home-owners is most responsive to house prices. Mian, Rao and Sufi (2013) investigates the consumption consequences of the 2006-2009 housing collapse and estimates a large elasticity of consumption with respect to housing net worth of 0.6 to 0.8. They find that the average marginal propensity to consume out of housing wealth is 5-7 cents with substantial heterogeneity across ZIP codes. The housing wealth effect can have large welfare implications. Glover et al. (2011) constructs a stochastic

house price appreciation is correlated with a 3.4 percentage points increase in the HECM loan origination growth rate.

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

[5]Holtz-Eakin, Joulfaian and Rosen (1993) and Imbens, Rubin and Sacerdote (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, Quigley and Shiller. (2001) uses aggregate data to find a 10 percent increase in housing wealth increases aggregate consumption by 0.4 percent in the US and by roughly 1.1 percent for the international panel. Meanwhile, they find only insignificant effects of rising financial wealth on aggregate consumption. Using the UK household data, Campbell and Cocco (2007) investigates the response of household consumption to house price by constructing a pseudo panel. They find the largest effect of house prices on consumption for older home-owners and smallest effect for younger renters. In their benchmark regression, a 1 percent increase in housing value increases the non-durable consumption of the elderly homeowner by approximately 1.22 percent, which accounts for 8 percent of the increase in housing value.

overlapping-generations general equilibrium model in which households are subject to aggregate shocks that affect both wages and asset prices, and find that a model recession translates into a large welfare loss of around 10% of lifetime consumption for households aged 70 and over. However, these studies ignore endogenous retirement, which turns out be an important form of self-insurance against house price risk for the near-retirement age households according to my research.

A growing literature, most of which consists of empirical studies, is trying to estimate the wealth effect on labor supply and retirement. Early researches use household level data to estimate the effect of the stock market boom on the retirement decision. These studies confirm the anecdotal story that the bear market force older households to remain in the labor force.[7] However, the findings regarding housing wealth effects 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 older workers respond to a 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 to 2010 period. In this paper, I will complement the literature by examining the evidence of the housing wealth effect on both retirement and non-durable consumption using panel data from the health and retirement study.

In terms of a structural model, most previous papers emphasize the role of social security, private pensions, health insurance, earning shocks, and taxation in determining retirement (French, 2005; Ljungqvist and Sargent, 2010; Prescott, Rogerson and Wallenius, 2009). From a different perspective, this paper analyzes the impact of wealth changes on retirement. My model is similar to the studies of Yogo (2009); Glover et al. (2011); Telyukova and Nakajima (2010); Hryshko, Jos Luengo-Prado and Sørensen (2010); Bottazzi, Low and Wakefield (2007); Farhi and Panageas (2007); Imrohoroglu and Kitao (2010). However, none of these authors consider the effect of house prices on retirement.

[7]Cheng and French (2000) show that the run-up in the stock market in the 1990s, which has brought greater than $50,000 gains to more than 15 percent of the individuals aged 55 and above, decreases the participation rate for people older than 50 by 3.2 percent. Sevak (2002) exploits the Health and Retirement Study data to find an increase of $50,000 wealth shocks 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, on average, retired 7 months earlier than other respondents. Gustman, Steinmeier and Tabatabai (2009) finds that the recent stock market decline led the early boomers to postpone retirement, on average, by 1.5 months. Chai et al. (2011) creates a structural model with stocks and an endogenously labor supply to study the effects of the stock price crisis on household consumption and retirement.

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

2 Empirical Evidence

2.1 Data

The empirical findings are based on the U.S. Health and Retirement Study (HRS). 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 pension plans etc. I use the RAND (2015) version of HRS data 1992-2012 to study retirement behavior.

However, the core HRS data does not contain information on consumption. In order to study the consumption behavior, I use a HRS supplement, the Consumption and Activities Mail Survey (CAMS) 2001-2011. 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. The questions on consumption record individual consumption in the 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, 2009, and 2011. I merge the income data from Rand HRS data 2002-2012 to the CAMS 2001-2011 sample.

To exploit the time variations in home prices across different regions, I use the home price indices for 9 census divisions from Federal Housing Finance Agency. The 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 census divisions are East North Central, East South Central, Middle Atlantic, Mountain, New England, Pacific, South Atlantic, West North Central, and West South Central.[8]

[8]In the public data, detailed geographic information such as metropolitan statistic areas are not available.

I restrict the sample based on the following standards. First, I look at the HRS respondents aged between 50 and 65 between 1992 and 2012. Second, I only include married respondents to keep the family composition stable. Third, I keep only respondents with positive total household net worth. In the end, there are 43,881 observations in the retirement regression and 4,579 observations in the consumption regression.

2.2 Home Prices and Retirement

The regression model is formulated as follows:

$$R_t^i = \alpha^i + \mathbf{Z}_t + P_t \times H_t^i + \mathbf{X}_t^i + \epsilon_t^i \tag{1}$$

R_t^i is a binary variable. It equals 1 if the respondent i reports she/he has fully/partly retired at time t and 0 otherwise. α^i is the individual unobserved characteristics, which may be correlated with other explanatory variables. $\mathbf{Z}_t$ is a vector of observable aggregate economic factors, including year dummy, census-division unemployment rates, census division dummy, etc. To control the trend of labor force participation, I also add the linear time trend interacted with census division dummy. P_t denotes logarithm of census-division home prices deflated by CPI index. I use the monthly home price index from Federal Housing Finance Agency for 9 census divisions. I match the monthly census-division home prices to the HRS respondents based on the month they finished the survey and the census divisions they lived in. Because the assignment of the interview date is considered to be exogenous (Goda, Shoven and Slavov, 2011), this procedure tries to address the concerns that home prices may not be fully exogenous.[9] Home prices are log value deflated by CPI index. H_t^i is an indicator of renter for respondent i at time t. This interaction term exploits the regional variations in home prices and variations in home-ownership in order to identify the housing wealth effect on retirement. $\mathbf{X}_t^i$ includes labor earnings in the last calender year, type of health insurance plan, and other social demographic variables, such as age, age^2, age^3, health status dummy, education, race, self-employment status, etc.

The first two columns in Table 3 report the regression coefficients of fixed-effect linear probability model. The last two columns report the regression results of random-effect linear probability model.[10] Columns 1 and 3 examine the whole

[9] Results remain robust if yearly housing prices are used instead. See the Appendix for more robustness check.

[10] The model can also be estimated using fixed-effect Logit model. The linear and non-linear models give the same qualitative predictions. The results can be found in the earlier version of the paper and

Table 3: **Regression results on retirement decision**. The variable renter is a binary dummy. The reference group is the homeowners.

Dependent var.: Retirement dummy	FE	FE	RE	RE
Sample coverage	All HH	Homeowner	All HH	Homeowner
Log(House price)	0.073**	0.072**	0.070**	0.075**
	(2.1)	(2.0)	(2.2)	(2.2)
Renter	1.00***	—	0.64***	—
	(3.8)		(3.0)	
Log(House price)×Renter	-0.22***	—	-0.16***	—
	(-3.3)		(-2.6)	
Earnings last year(Thousands $)	-0.0013***	-0.0013***	-0.0016***	-0.0016***
	(-9.5)	(-9.4)	(-12.0)	(-12.0)
Year/C-D dummy	Yes	Yes	Yes	Yes
No. of Obs.	43,881	40,789	43,881	40,789

sample while columns 2 and 4 focus on homeowners only. T-statistics are given in parenthesis and standard errors are clustered at individual level.

The main effect of home price is 0.073 in column 1, which means that 10 percent increase in home price is associated with 0.73 percentage points increase in the retirement probability of home owners. The coefficient before the renter dummy is positive and significant, which implies that renters are more likely to retire than home owners.[11] On one hand, renters tend to have less wealth, which reduces the likelihood of retirement due to wealth effect. On the other hand, renters tend to be less healthy and less educated, which increases the likelihood of retirement. The regression tells us the net effect is positive. The net effect of home price on the renters' retirement probability is the sum of main effect and the interaction effect, which is -0.15. One possible explanation is that rising home prices positively correlate with rental prices, which has a negative wealth effect on the renters.

The possibility exists that home prices only capture the growth rate of the local economy. In order to control for this, I include the year fixed effect and census-division unemployment rate in all the specifications.

Higher labor income in the last year leads to less retirement.[12] Holding other variables constant, A 10,000 dollar increase in the labor income reduces the odds of

are omitted here for simplicity.

[11]Renter dummy 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.

[12]According to the definition of RAND (2015), the respondent's 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. The labor earning is deflated by the annual CPI index and measured in 2006 thousand dollars.

retirement by 1.3 percentage points.

There is concern about the endogeneity of home ownerships, e.g., some unobserved individual characteristic that accounts for both the ownerships and retirement decisions. However, as long as these unobserved characteristics are not time varying, the fixed effect model takes care of it. The column 2 shows the regression results using homeowners only, which gives the similar estimate about housing wealth effect. This suggests that these results are to some degree robust to the selection of homeowners.[13]

The US has experienced a unprecedented housing price decline during the 2007-2009 subprime crisis. I am interested in estimating the housing wealth effect during the crisis period and compare it with the rest of the sample period. To do this, I specify the regression model that allows the retirement response of households to differ from other episodes. The results are reported in Table 4. Both the fixed effect model and the random effect model suggest that homeowners' retirement response to housing price shocks was stronger in the subprime crisis than in the other episodes. The Column 1 of Table 4 shows that a 10 percent increase in the housing prices is associated with a 1.8 percentage points increase in the retirement probability of home owners during the crisis, which is 1.1 percentage higher than the rest of the sample period.

I perform several robustness check in the Appendix. First, it allows the housing wealth effect to differ across census divisions during the subprime crisis 2007-2009. The idea is that different census divisions experienced different housing price decline during the crisis and the housing wealth effect may be nonlinear in housing prices. Second, it use yearly housing price data instead of monthly data. In the end, it also looks at the impact of housing prices on the amount of working hours, the expectation of retirement, and the value of housing asset, etc.

2.3 Home Prices and Consumption

This section examines the effect of home prices on household consumption. This topic has been discussed in Case, Quigley and Shiller. (2001); Campbell and Cocco (2007); Hryshko, Jos Luengo-Prado and Sørensen (2010); Mian, Rao and Sufi (2013).

[13]Other variables, such as, health status and health insurance coverage, also affect retirement decisions. Poor health encourages retirement. The health index ranges from 1 to 5, with the most healthy status indexed by 1. The effect of the health index on retirement probability is nonlinear. The odds of retirement for a person with most excellent health is 12 percentage points smaller than the person with poorest health. Retirement planning is closely related to the type of health insurance. The retirement probability of the worker covered by employer provided health insurance plans is 14 percent smaller than their non-insured counterparts. On the other hand, government provided health insurance, like Medicare and Medicaid, positively correlates with the respondent's retirement probability.

Table 4: **Regression results on retirement decision**. The variable renter and subprime are both binary dummies. The reference group is the home-owners that experienced the subprime crisis.

Dependent var.: Retirement dummy Sample coverage	FE All HH	FE Homeowner	RE All HH	RE Homeowner
Log(House price)	0.18***	0.17**	0.24***	0.23***
	(2.6)	(2.4)	(3.5)	(3.4)
Log(House price)×Owner×(Subprime=0)	-0.11*	-0.10*	-0.18***	-0.17***
	(-1.8)	(-1.65)	(-2.8)	(-2.6)
Log(House price)×Renter×(Subprime=1)	-0.47***	—	-0.57***	—
	(-2.8)		(-2.0)	
Log(House price)×Renter×(Subprime=0)	-0.34***	—	-0.33***	—
	(-4.3)		(-3.0)	
Earnings last year(Thousands $)	-0.0014***	-0.0013***	-0.0016***	-0.0016***
	(-9.5)	(-9.4)	(-12.0)	(-12.0)
Year/C-D dummy	Yes	Yes	Yes	Yes
No. of Obs.	43,881	40,789	43,881	40,789

None of them have used the HRS data. Here I only examine HRS household respondents aged 50-65 who satisfy sample selection criteria in the previous section and who are also covered in the CAMS survey in the following year. Due to the sample attrition problem, there are less than 400 respondents in our sample in 2011.

The regression model can be formulated as follows:

$$C_t^i = \alpha^i + \mathbf{Z}_t + P_t \times H_t^i + \mathbf{X}_t^i + \epsilon_t^i \tag{2}$$

where the C_t^i is the log non-durable households consumption deflated by the CPI index. According the Rand Version of CAMS data, the non-durable consumption include gifts, clothing, charitable contributions, dining out, medications and medical supplies, utilities, food and beverages, health insurance and services, telecommunications, tickets, trips and vacations, personal care items, furnishings, hobbies, sports, housekeeping services and supplies, and yard services and supplies.

α^i is the individual unobserved characteristics, which may be correlated with other explanatory variables. $\mathbf{Z}_t$ is a vector of observable aggregate economic factors, including year dummy, regional unemployment rates. P_t denotes logarithm of census-division home prices deflated by CPI index. H_t^i is an indicator of renter for respondent i at time t. This interaction term exploits the regional variations in home prices and variations in home ownership in order to identify the housing wealth effect on consumption. $\mathbf{X}_t^i$ includes log non-capital income , type of health insurance plan, and other social demographic variables, such as age, age^2, age^3,

Table 5: **Regression results on non-durable consumption**. The variable renter is a binary dummy. The reference group is the homeowners.

Dependent var.: Log(Non-durable consumption) Sample coverage	FE All HH	FE Homeowner	RE All HH	RE Homeowner
Log(House price)	0.28**	0.25**	0.35***	0.35***
	(2.4)	(2.0)	(3.0)	(2.9)
Log(House price)×Renter	-0.66***	—	-0.59***	—
	(-2.6)		(-2.6)	
Renter	2.6***	—	2.4***	—
	(3.1)		(3.0)	
Log(Non-capital income)	0.036***	0.027**	0.13***	0.11***
	(3.0)	(2.1)	(10.0)	(10.4)
Year/C-D dummy	Yes	Yes	Yes	Yes
No. of Obs.	4,579	4,056	4,579	4,056

health status dummy, education, race, etc.

The first two columns in Table 5 show the results of the fixed effect regression. The elasticity of consumption to home prices is 0.28, which means 10 percent growth in home prices increases the growth rate of non-durable consumption of homeowners aged 50-65 by 2.8 percentage points. When I restrict the sample to homeowners only, the housing wealth effect on consumption becomes smaller. The coefficient before the changes in log households' non-capital income is 0.036, which says the non-durable consumption increases by 3.6 percent if non-capital income increases by 100 percent. As a robustness check, I also show the results from random effect estimation in the last two columns in Table 5. Most coefficients do not differ much except that the consumption elasticity of non-capital income becomes larger.

I could also look at the housing wealth effect on consumption by splitting the sample period into two, the subprime crisis period and the rest. The results are shown in Table 6. The consumption elasticity of homeowners in the subprime crisis period does not differ statistically from the one in the rest of the sample period.

Instead of estimating consumption elasticity with respect to housing prices, I can also estimate the marginal propensity of consumption out of housing wealth, as in Mian, Rao and Sufi (2013). The results are given in the appendix, where I try to compare our results to Mian, Rao and Sufi (2013) in a similar setup. Our estimates of the MPC is between 3.9 cents per dollar to 4.5 cents per dollar, which is close to the lower bound of Mian, Rao and Sufi (2013).

Table 6: **Regression results on non-durable consumption**. The variable renter and subprime are both binary dummies. The reference group is the homeowners that experienced the subprime crisis.

Dependent var.: Log(Non-durable consumption)	FE	FE	RE	RE
Sample coverage	All HH	Homeowner	All HH	Homeowner
Log(House price)	0.28*	0.22	0.35**	0.28**
	(1.9)	(1.5)	(2.5)	(2.0)
Log(House price)×Owner×(Subprime=0)	0.006	0.074	0.008	0.070
	(0.04)	(0.43)	(0.05)	(0.41)
Log(House price)×Renter×(Subprime=1)	-0.86**	—	-0.89***	—
	(-2.0)		(-2.6)	
Log(House price)×Renter×(Subprime=0)	-0.41	—	-0.37	—
	(-1.2)		(-1.2)	
Log(Non-capital income)	0.036***	0.027**	0.12***	0.11***
	(3.0)	(2.2)	(10.0)	(8.8)
Year/C-D dummy	Yes	Yes	Yes	Yes
No. of Obs.	4,579	4,056	4,579	4,056

3 Structural Model

In this section, I build up an incomplete-market life-cycle model with housing assets and endogenous retirement. First, I verify that the housing wealth effect on retirement and consumption predicted by the model are consistent with the empirical findings. Second, I use counterfactual experiments to quantify three channels through which housing prices affect retirement. Third, I measure the importance of self-insurance through the endogenous retirement.

3.1 Demographics

Households have a minimum age 50 and a maximum life span J. They face uninsurable health risk and mortality risk. The health status at age j is denoted by m_j, which takes two values, $m_j = 0$ if health is good and $m_j = 1$ if health is bad. Next year's health status depends on current health status and age, with conditional probability $Pr\left(m_{j+1}|m_j, j\right)$. Mortality rates depends on age and health status. The conditional survival probability from age j to $j+1$ is $s_j\left(m_j\right)$, $50 \leq j \leq J$.

3.2 Endowment

Labor income risk is uninsurable. Let j^r denote the endogenous retirement age. The wage rate of the working households consists of three parts: the deterministic age-specific labor efficiency unit e_j, the persistent shock $z_{i,j}$, and the transitory shock $\epsilon_{i,j}$.

$$\ln w_{i,j} = e_j + z_{i,j} + \epsilon_{i,j} \tag{3}$$

$$z_{i,j} = \rho_z z_{i,j-1} + \eta_{i,j} \tag{4}$$

where $\eta_{i,j}$ and $\epsilon_{i,j}$ are i.i.n.d. with mean 0 and variances σ_η^2 and σ_ϵ^2 respectively. Let τ denote the payroll tax rate. The after-tax labor income $y_{i,j}$ is $(1-\tau)\, w_{i,j} n_{i,j}$, $50 \le j \le j^r - 1$.

After retirement, households are able to collect social security benefits under certain circumstances. The social security benefits b depend on Average Indexed Monthly Earnings, or AIME, which is average earnings in the 35 highest earning years. They also depend on the endogenous retirement age. The earliest age to receive social security benefits is age 62. For every year before the normal retirement age the individual applies for benefits, benefits are adjusted downwards. For every year after normal retirement age (up to age 70) that benefit application is delayed, benefits are adjusted upwards. Therefore, the labor income of retirees $y_{i,j}$ is equal to $b\,(AIME_{i,j}, j^r)$, $j = j^r \le j \le J$.

The AIME is computed by the following formula

$$AIME_{i,j} = \begin{cases} AIME_{i,j-1} + \frac{1}{35}\max\left(0, w_{i,j}n_{i,j} - AIME_{i,j-1}\right), & j \ge 60 \\ AIME_{i,j-1} + \frac{1}{35} w_{i,j}n_{i,j}, & j < 60 \end{cases} \tag{5}$$

3.3 Asset 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 is the housing asset. Its price follows an AR(1) process

$$\ln p_t = \rho_p \ln p_{t-1} + \zeta_t \tag{6}$$

where ζ_t is i.i.n.d. with mean 0 and variance σ_ζ^2. Housing depreciates at a rate of δ_h.

Households cannot borrow against labor income. They can only borrow up to $1-\lambda$ fraction of current housing value, where λ denotes the down-payment ratio. For simplicity, I assume that the mortgage loan has the same interest rate as risk-free bond. Credit balance can be adjusted without any cost.

Housing assets are fully divisible. The transaction of housing asset will incur the adjustment cost $tr(h_{i,j}, h_{i,j+1})$, which is proportional to the housing value.

$$tr(h_{i,j}, h_{i,j+1}) = \begin{cases} \tau_s p_{j+1} h_{i,j}, & h_{i,j} \neq h_{i,j+1} \\ 0, & h_{i,j} = h_{i,j+1} \end{cases} \tag{7}$$

3.4 Households' Problem

Let V^W denote the value function of the working households who have the option to quit the labor force at current period. Let V^R denote the value function of the households who have retired at current period. Following Farhi and Panageas (2007), I assume retirement is an irreversible choice. Therefore, households solve an optimal stopping problem. I make this assumption for two reasons. First, the proportion of old retirees that re-enter the labor market is small. According to the HRS data, only 3 percent of retirees aged between 60 and 70 go back to work two years later. Second, there is measurement error with retirement status. Alternatively, I can allow retirees to re-enter the labor market with entry cost and assume that I observe their labor market participation with measurement error.

Let $\Theta^W_{i,j} \equiv \{h_j, x_{i,j}, p_j, z_{i,j}, \epsilon_{i,j}, m_j, AIME_{i,j}, j\}$ denote the state variables of the working households. It contains the housing stocks h_j, total wealth $x_{i,j}$ at the beginning of period j, house price p_j , persistent income shock $z_{i,j}$, transitory income shock $\epsilon_{i,j}$, health status m_j, $AIME_{i,j}$, and age j. The state variables of the retired households are given by $\Theta^R_{i,j} \equiv \{h_j, x_{i,j}, p_j, m_j, AIME_{i,j}, j\}$.

The timing of the economy is the following. At the beginning of period, households start with total household net worth $x_{i,j}$ and home price p_j. The working households decide whether to retire or not after their income shocks are randomly drawn. If households continue to work, they receive labor income and pay taxes. If households choose to retire, they receive social security benefits. After the labor supply decision is made, households choose the non-durable consumption, hours worked, the housing assets, and the risk-free bond. At the beginning of age j+1, health risk, mortality risk and home price next period are revealed. Households receive interest payment from the risk-free bond. If one dies, his total assets are left as a bequest. If one survives, he starts the next period with total net worth $x_{i,j+1}$.

The optimization problem for households can be formulated recursively as follows. Before the retirement, the working households solve the problem

$$V^{W}\left(\Theta_{i,j}^{W}\right) = \tag{8}$$

$$\max\left\{\begin{array}{c} V^{R}\left(\Theta_{i,j}^{R}\right), \\ \max\limits_{c_{i,j},h_{i,j+1},n_{i,j}} \left\{u\left(c_{i,j},h_{i,j+1},n_{i,j}\right) + \beta E_j\left[s_j V^{W}\left(\Theta_{i,j+1}^{W}\right) + \left(1-s_j\right)u^{B}\left(\Theta_{i,j+1}^{W}\right)\right]\right\}\end{array}\right\}$$

subject to

$$\begin{aligned}
x_{i,j+1} &= R\left(x_{i,j} + (1-\tau)\, w_{i,j} n_{i,j} - tr\left(h_j, h_{j+1}\right) - c_{i,j} - p_j h_{i,j+1}\right) + p_{j+1} h_{i,j+1}\left(1-\delta_h\right) && (9)\\
c_{i,j} &\leq x_{i,j} + (1-\tau)\, w_{i,j} n_{i,j} - tr\left(h_j, h_{j+1}\right) - \lambda p_j h_{i,j+1} && (10)\\
c_{i,j} &\geq 0 && (11)\\
h_{i,j+1} &\geq 0 && (12)\\
x_{i,j+1} &\geq 0 && (13)\\
n_{i,j} &\in (0,1) && (14)
\end{aligned}$$

Equation 9 is the budget constraint for the working households who enter the age j with total net worth $x_{i,j}$. Equation 10 is the borrowing constraint. Equation 13 is the bequest constraint, which rules out that households leave negative bequest. The endogenous retirement age j^r is defined as $j^r \equiv \min\left\{j \mid n_{i,j} = 0, 50 \leq j \leq J\right\}$

Households cannot choose to go back to work after retirement. Therefore, the retiree's value function is given by

$$V^{R}\left(\Theta_{i,j}^{R}\right) = \max_{c_{i,j},h_{i,j+1}} \left\{u\left(c_{i,j},h_{i,j+1},0\right) + \beta E_j\left[s_j V^{R}\left(\Theta_{i,j+1}^{R}\right) + \left(1-s_j\right)u^{B}\left(\Theta_{i,j+1}^{R}\right)\right]\right\} \tag{15}$$

subject to 11, 12, 13, 16, and 17.

$$\begin{aligned}
x_{i,j+1} &= R\left(x_{i,j} + b\left(AIME_{i,j}, j^r\right) - tr\left(h_j, h_{j+1}\right) - c_{i,j} - p_j h_{i,j+1}\right) + p_{j+1} h_{i,j+1}\left(1-\delta_h\right) && (16)\\
c_{i,j} &\leq x_{i,j} + b\left(AIME_{i,j}, j^r\right) - tr\left(h_j, h_{j+1}\right) - \lambda p_j h_{i,j+1} && (17)
\end{aligned}$$

3.5 Calibration

The maximum age J is set to 90. Households can choose to work until age 70. In all simulations in this paper, I take the initial joint distribution of total household net worth, health status, working status, and wage rate for home-owners aged 48-52 from the 2006 HRS data. I apply the same sample selection criteria as the one used

Table 7: **Distribution of the initial sample.**

Quartiles of Networth	Earnings (Thousands \$)	Net housing value (Thousands \$)	Networth (Thousands \$)	Poor Health (Percent)	Retirement (Percent)
1st Quartile	62.1	89.1	63.8	18.4	15.5
2nd Quartile	74.0	232.4	222.8	8.01	0.9
3rd Quartile	87.0	371.6	458.5	8.1	8.2
4th Quartile	75.4	709.0	1821.7	10.8	17.3

in the empirical studies. This gives us 220 individuals in 2006. I use the sampling weight to draw the random sample. The initial sample statistics are summarized in the following Table 7. I normalize the age-specific efficiency units taken from Hansen (1993) such that the average labor income at age 50 is 1.

Health status in the model takes two values. In the HRS data, the self-report of health has five categories. They are classified into two groups, the healthy group including health status from good health to excellent health and the unhealthy group including fair and poor health. The age-specific survival probabilities are computed using Bayes' Rule:

$$1 - s_j (m_j = k) = \frac{Pr(m_j = k | dealth_{j+1})}{Pr(m_j = k)} Pr(dealth_{j+1}), k = 0, 1 \tag{18}$$

where $Pr(m_j = k|dealth_{j+1})$ and $Pr(m_j = k)$ are computed using HRS and the death rate $Pr(dealth_{j+1})$ is taken from the 2005 life table for total population in the United States. The health process is also directly computed using HRS data. These exogenous variables are plotted in Figure 1.

The household's utility function $u(c_{i,j}, h_{i,j+1}, n_{i,j})$ takes the following form

$$\alpha\omega \log(c_{i,j}) + (1-\alpha)\omega \log\Big(1 - n_{i,j} - \theta_p I_{(n_{i,j}>0)} - \theta_m I_{(m_j=1)}\Big) + (1-\omega)\log(h_{i,j+1}) \tag{19}$$

where I follow Davis and Ortalo-Magne (2011) to assume a unitary elasticity between consumption and housing services.

The housing adjustment cost is given by $tr(h_{i,j}, h_{i,j+1}) = \tau_s p_{j+1} h_{i,j}$. Following Hryshko, Jos Luengo-Prado and Sørensen (2010), I set τ_s to be 6 percent. The annual real interest rate is 2 percent. Nagaraja, Brown and Zhao (2011) estimates the home price process for 20 metropolitan areas using FHFA quarterly home 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 $\rho_p \in [0.9295, 0.9901]$,$\sigma_p \in$

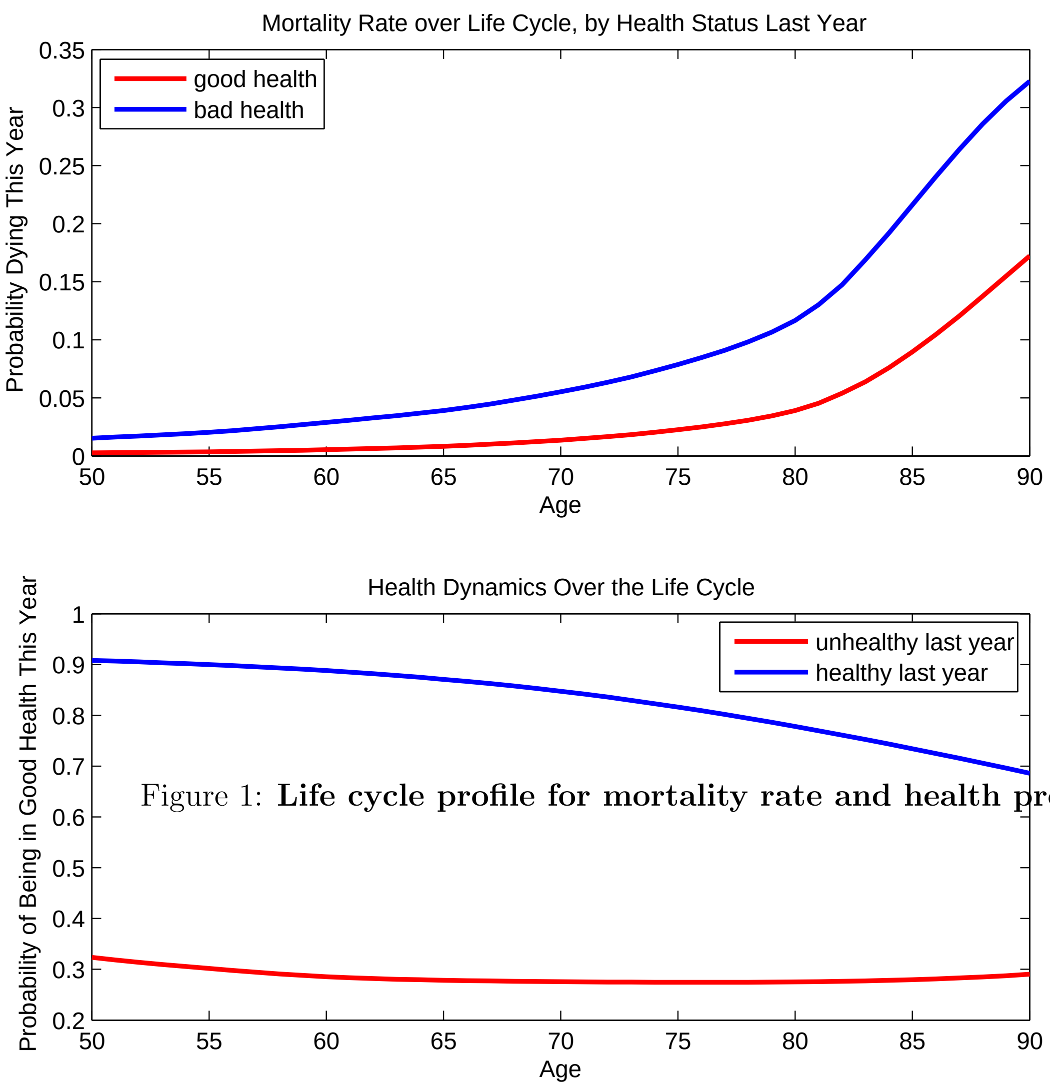

Figure 1: **Life cycle profile for mortality rate and health process.**

$[0.0592, 0.0997]$. In the benchmark model, I set $\rho_p = 0.976$,$\sigma_p = 0.0748$, which corresponds to the median value of estimates in 19 MSAs. The housing depreciation rate δ_h is set to be 1.5 percent and the housing down payment ratio λ is set to be 10 percent.

The bequest function is written as

$$u_B = \phi \log(x_{i,j} + \xi) \tag{20}$$

Following Cocco (2005), I assign the same power to the bequest as to the composite of durable and non-durable consumption. $\xi > 0$ is a parameter that determines the distribution of bequest. Following French (2005), I set it to be 5.84, which implies that households derive little utility if bequest is less than 50,000 dollars. The utility from leaving bequest only depends on the total value of household's net worth. In other words, housing assets and financial assets are perfect substitutes in the bequest utility function, which is consistent with the facts that relatively poor households leave bequests in terms of housing and the relatively rich households leave bequests in terms of financial assets. The other interpretation for the warm-glow bequest motive is the utility from living in a nursing home. Households can use either financial wealth or housing wealth to pay the nursing home cost in their late life, which is an important expense in later life.[14] All parameters in the utility are calibrated within the model.

The stochastic wage process is taken from Heathcote, Storesletten and Violante (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 $\sigma_\epsilon = 0.278$. The payroll tax for social security is set to be 0.10.[15]

In the HRS data, the information on AIME for each respondent is not available. I assume everyone enters the labor market at age 25 and supply same amount of hours until age 50. Using the calibrated wage process, I can simulate the joint distribution of AIME and labor income at age 50. I impute the AIME for each individual in the initial sample using the joint distribution of AIME and labor income at age 50. Each individual will receive a random draw for the AIME conditional on his/her labor income at 50 in the sample. AIME is converted into a Primary Insurance Amount (PIA) using the following formula where all dollars amount is in 2006 value.

[14] Kopecky and Suen (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.

[15] 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.

$$PIA = \begin{cases} 0.9 \times AIME & \text{if} \quad AIME < 7,872 \\ 7,084.8 + 0.32 \times (AIME - 7,872) & \text{if} \quad 7,872 \leq AIME < 47,460 \\ 19,753 + 0.15 \times (AIME - 47,460) & \text{if} \quad AIME \geq 47,460 \end{cases} \tag{21}$$

For the individuals born between 1939 and 1940, the normal retirement age (NRA) is between 65 and 4 months and 65 and 6 months. Therefore, I choose NRA to be 65. The social security benefits equal to the PIA if individual retires at NRA. For every year before NRA that individual first draws benefits, benefits are reduced by 6.67 percent and for every year (up to age 70) that benefit receipt is delayed, benefits increase by 7 percent.[16]

The consumption weight α, the housing weight $1-\omega$, the discount rate β, the bequest strength ϕ, the fixed cost of working θ_p, and the fixed cost of bad health θ_m are jointly calibrated to match the following 6 moments: the average net housing wealth of homeowners aged 65 and 80, the average net-worth of homeowners aged 65 and 80, the average cumulative retirement rate for homeowners aged 50-70 with good health and bad health. In the end, this gives $\alpha = 0.427$, $\omega = 0.874$, $\beta = 0.959$, $\theta_p = 0.239$, $\theta_m = 0.335$, and $\phi = 16.3$. Table 8 summarizes all calibrated parameters.

I solve the life-cycle model backwards from the end of life cycle using value function iteration. The conditional expectation is computed by Gaussian Quadrature. I approximate the stochastic process for home price and persistent income shocks with a 5-state Markov Chain using Rouwenhorst's method (Kopecky and Suen, 2010). The transitory income shock is simply approximated by 2-state Markov Chain. I choose 50 states for total net worth, 10 states for housing asset, 10 states for working hours, 10 states for AIME, and 2 states for health status.[17] The parameters are calibrated using simulated annealing method. I use multi-linear interpolation for value function on intermediate points.

Figure 2 plots the simulated profiles and true profiles.[18] The model simulates 5,000 households for each home price sequence drawn. It repeats this simulation for 200 different home price sequences and compute average retirement rate and wealth profile. The simulated net-worth profile fits the data very closely. The simulated

[16]The credit for delayed retirement is 7 percent for the cohort born between 1939 and 1940.

[17]I choose the number of those grid points by experiment. There is a trade-off between speed and accuracy. I find that adding more grid points will not significantly change our quantitative results.

[18]The raw cumulative retirement-population rate for home-owners by health status is computed from the HRS 2002-2006 data. The average net-worth and housing wealth for home-owners is estimated from the HRS 2006 using the sample weight. The housing wealth is defined as the sum of net value of primary residence, net value of secondary residence, net value of nonresidential real estate, and net value of all vehicles held by household. Lowess smoothing is used to get the asset profiles.

Table 8: **Parameters calibrated in the benchmark model**

	Calibration Inside the Model	
Parameters	Value	Source
β	0.959	See Text
α	0.427	See Text
ϕ	16.3	See Text
θ_p	0.239	See Text
θ_m	0.335	See Text
ω	0.874	See Text
	Calibration outside the model	
Parameters	Value	Source
R	1.02	
J	90	
ξ	5.84	French (2005)
$\{e_j\}_{j=25}^{70}$		Hansen (1993)
ρ_p	0.976	Nagaraja, Brown and Zhao (2011)
σ_p	0.0748	Nagaraja, Brown and Zhao (2011)
ρ_z	0.973	Heathcote, Storesletten and Violante (2010)
σ_η	0.148	Heathcote, Storesletten and Violante (2010)
σ_ϵ	0.278	Heathcote, Storesletten and Violante (2010)
δ_h	0.015	Cocco (2005)
λ	0.1	Cocco (2005)
τ_s	0.06	Hryshko, Jos Luengo-Prado and Sørensen (2010)
b		See Text
τ	0.1	See Text

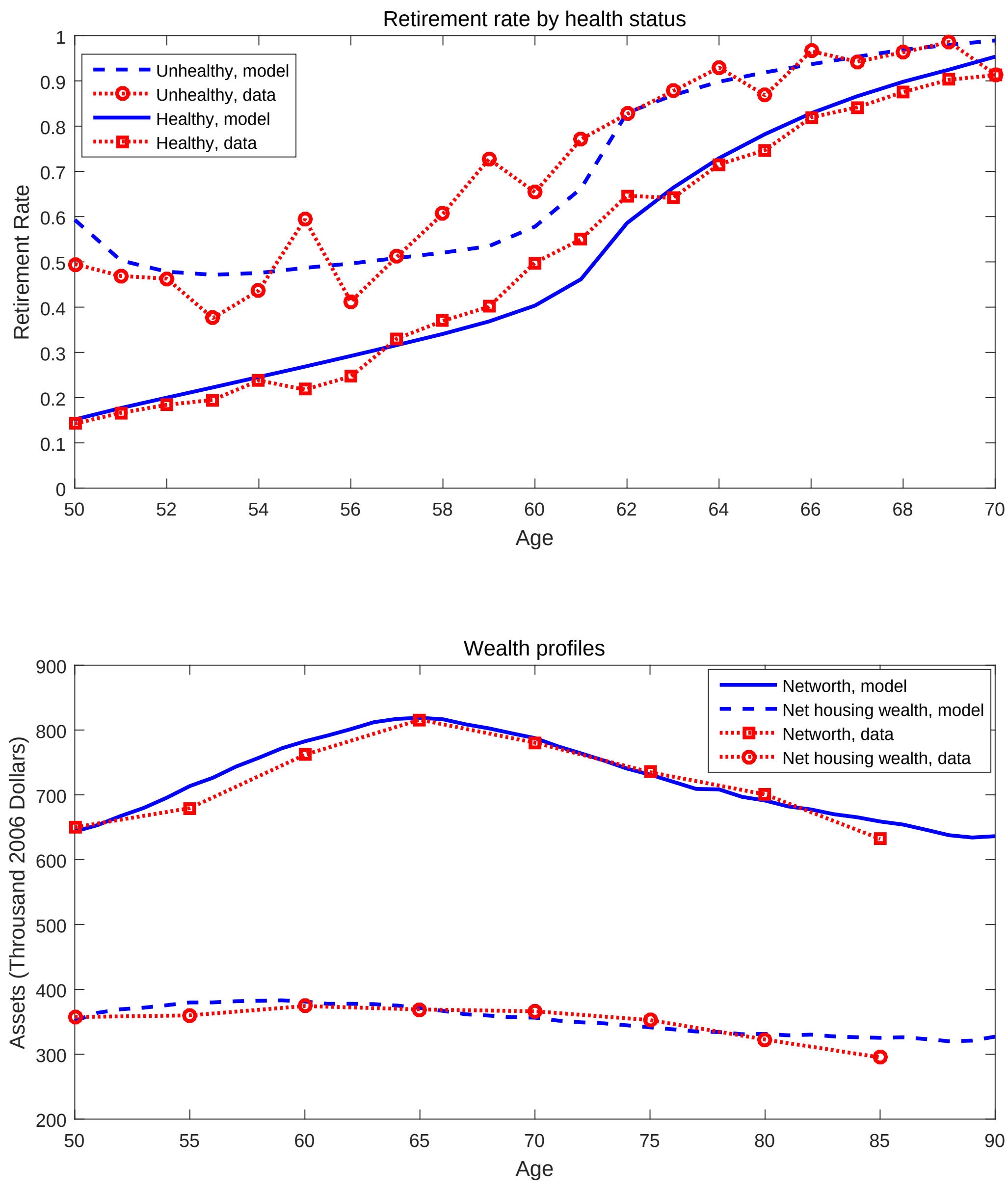

Figure 2: **Simulated retirement and asset profiles.**

Table 9: **Elasticity of retirement to house prices**

Dependent var.	Data	Model		
Retirement dummy	FE	Benchmark	Exp. A	Exp. B
Log(House price)	0.072^{**}	0.065^{***}	0.091^{***}	0.105^{***}
Non-capital income(Thousands $)	$-1.30e\text{-}3^{***}$	$-1.70e\text{-}3^{***}$	$-2.68e\text{-}3^{***}$	$-1.78e\text{-}3^{***}$

net housing wealth profile is flatter than the empirical data. The model also does well in matching the retirement rate of healthy and unhealthy households.[19]

3.6 Counterfactual Experiments

In this section, I first verify that the structural model predicts reasonable retirement and consumption response to housing price fluctuations. Then I conduct counterfactual experiments to study the impacts of bequest motive and housing adjustment cost on the retirement and consumption response.

I estimate the following reduced-form fixed-effect linear probability model using the panel data generated by the structural model.

$$R_t^i = \alpha^i + P_t + X_t^i + \epsilon_t^i \tag{22}$$

R_t^i is an indicator function for retiree. X_t^i includes the labor income and a cubic polynomial of age. When constructing the panel, I take the joint distribution of total net worth, wage income, and health status for home-owners aged 48-52 directly from the HRS 2006 data as the initial condition. The simulated panel consists of households aged 50-65, living in 50 different regions with 50 independent home price sequences drawn from the stationary distribution. There are 5,000 households in each simulated region. I estimate the equation 22 using the simulated households data and exhibit the results in Table 9. The coefficient before home prices is 0.065, which means a 10 percent decline in home prices will reduce the retirement probability for households aged 50-65 by 0.65 percentage points. The elasticity of retirement in the benchmark model is very close to the coefficient found in the empirical data, which is 0.072.

I also estimate the following reduced-form fixed-effect regression model on non-durable consumption.

[19]The retirement rate of unhealthy individuals drops in the early age (from 50 to 52). This is because some healthy individuals move into the unhealthy group but have a higher probability of working than the initial unhealthy individuals.

Table 10: **Elasticity of non-durable consumption to house prices**

Dependent var.	Data	Model		
Log(Non-durable consumption)	FE	Benchmark	Exp. A	Exp. B
Log(House price)	0.25**	0.19***	0.35***	0.27***
Log(Non-capital income)	0.027**	0.11***	0.14***	0.11***

$$C_t^i = \alpha^i + P_t + X_t^i + \epsilon_t^i \tag{23}$$

where X_t^i includes the log non-capital income, which equals to wage income if households is working and equal to social security income if households is retired. It also includes a cubic polynomial of age. C_t^i is the log non-durable consumption.

The regression results are shown in Table 10. The coefficient before log home price is 0.19. A 10 percent decline in home prices will reduce the non-durable consumption of home-owners aged 50-65 by 1.9 percent. The elasticity of consumption to house prices in the benchmark model is very close to the empirical estimate, which is 2.5 percent.

I consider two counterfactual experiments that will affect the housing wealth effect on retirement and consumption.[20] The first experiment (Experiment A) is to quantify the effect of warm-glow bequest motive. I investigate the role of bequest motive by setting the bequest strength ϕ to 0. Column A in Table 9 and Table 10 summarize the regression results. The housing wealth effect on both retirement and non-durable consumption becomes larger.

The removal of bequest motive induces one to accumulate less wealth in his later life. Because housing can be used as collateral, it is more valuable to the poor households than to the rich households. Therefore, the housing assets now account for a larger fraction of total net worth over life-cycle than in the benchmark case, which tends to increase the responsiveness of retirement and consumption to home prices.

However, there is a counteracting force. 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 home price shock tends to work longer or cut non-durable consumption in order to buffer the negative effect of home price on the value of accidental bequest. Therefore, the decline in bequest motive tends to reduce the retirement response to home price shocks. The numerical

[20] I also perform the counterfactual experiment that changes the down payment ratio to 100 percent. It has a very small impact on retirement or consumption elasticity with respect to housing prices. The retirement and consumption elasticity will become 0.061 and 0.17 respectively.

Table 11: **Heterogenous housing wealth effect on retirement**

Dependent var.	Homeowners grouped by quartiles of		
Retirement dummy	Initial net worth	Initial housing value	Initial earnings
1st Quartile	0.068	0.068	0.044
2nd Quartile	0.081	0.058	0.063
3rd Quartile	0.070	0.071	0.081
4th Quartile	0.040	0.061	0.079

Table 12: **Heterogenous housing wealth effect on consumption**

Dependent var.	Homeowners grouped by quartiles of		
Non-durable Consumption	Initial net worth	Initial housing value	Initial earnings
1st Quartile	0.11	0.14	0.21
2nd Quartile	0.22	0.22	0.20
3rd Quartile	0.22	0.20	0.16
4th Quartile	0.19	0.20	0.16

simulation shows that the counteracting force is not strong enough and the removal of bequest motive alone will amplify the housing wealth effect on retirement and consumption.

I conduct a second policy experiment that sets the housing transaction cost to zero (Experiment B) to study the role of housing adjustment cost. The consumption elasticity and retirement elasticity increase by 42 and 47 percent respectively.

So far, I have estimated the average consumption response and retirement response with respect to housing prices. Households in the model have great heterogeneity and may response differently to housing price shocks. I want to study the heterogeneous response conditional on homeowners' initial wealth, net housing wealth, and earnings at age 50. After generating the artificial households panel, I first group households into different quartiles based on their initial net worth, the initial net housing value, and the initial earnings at age 50. Then I perform the same regression (equation 22 and 23) on each subgroups. I only report the coefficient before log housing prices, which are shown in Table 11 and Table 12. It is clear that housing wealth effect is not monotonic as we move from the lowest quartile to the highest quartile.

3.7 The Short-term and the Long-term Effect of Housing Crisis

The reduced-form regressions using simulated panel data shows the predictive power of the structural model. Therefore, I can use the model as laboratory to study both the short-term and the long-term impact of housing crisis. Suppose the model economy starts from the stationary equilibrium in 2006 and is shocked by a one-time unexpected -27.7 percent home price shock, a magnitude close to that experienced during the financial crisis of 2007 to 2009.[21] In order to evaluate the short-term impact of housing crisis, I compute the instant changes in retirement rate and non-durable consumption for different age groups. To evaluate the long-term impact of housing crisis, I simulate the economy onwards and compute the changes in the average retirement age, the impulse response of retirement rate and non-durable consumption relative to the baseline scenario where no housing crisis happens.

The short term impact of the housing crisis on different age groups are shown in Figure 3. Keep in mind that all age groups start with the same initial joint distribution at age 50. The only difference among them is the date when the house price shock hits them, which is denoted by the x axis. I compare the model economy that experienced the one-time housing price decline with the stationary distribution of the model economy that experienced no such one-time shock. I compute the consumption and labor force participation rate difference (i.e, 100-retirement rate) between the two economies and plot the results in Figure 3.

The upper panel shows that older households experienced larger instant non-durable consumption drop than younger households. This is because the younger households have a longer working career and have more flexibility to delay retirement. The lower panel shows that the instant increase in the labor force participation rate is not a monotonic function of age. It is the age group who is close to age 62 have the largest instant increase in the labor force participation rate. This is because the younger households are still far away from the optimal retirement age and the older households have limited flexibility to adjust their retirement plan.

How do the model predictions fit the data? I compare the model predictions on average consumption drop and labor force participation rate increase for households aged 55-64 with the data(Table 1 and Table 2). Our model predicts that the homeowners aged 55-64 will reduce consumption by 4.7 percent and increase labor

[21]Consider this as a one-time shock and the home price still follows the same stochastic process after the unexpected shock. The number 27.7 percent comes from the Markov approximation to home 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 home price drops by nearly 30 percent in the 2008 recession, I use this exercise as a simulation about the current crisis.

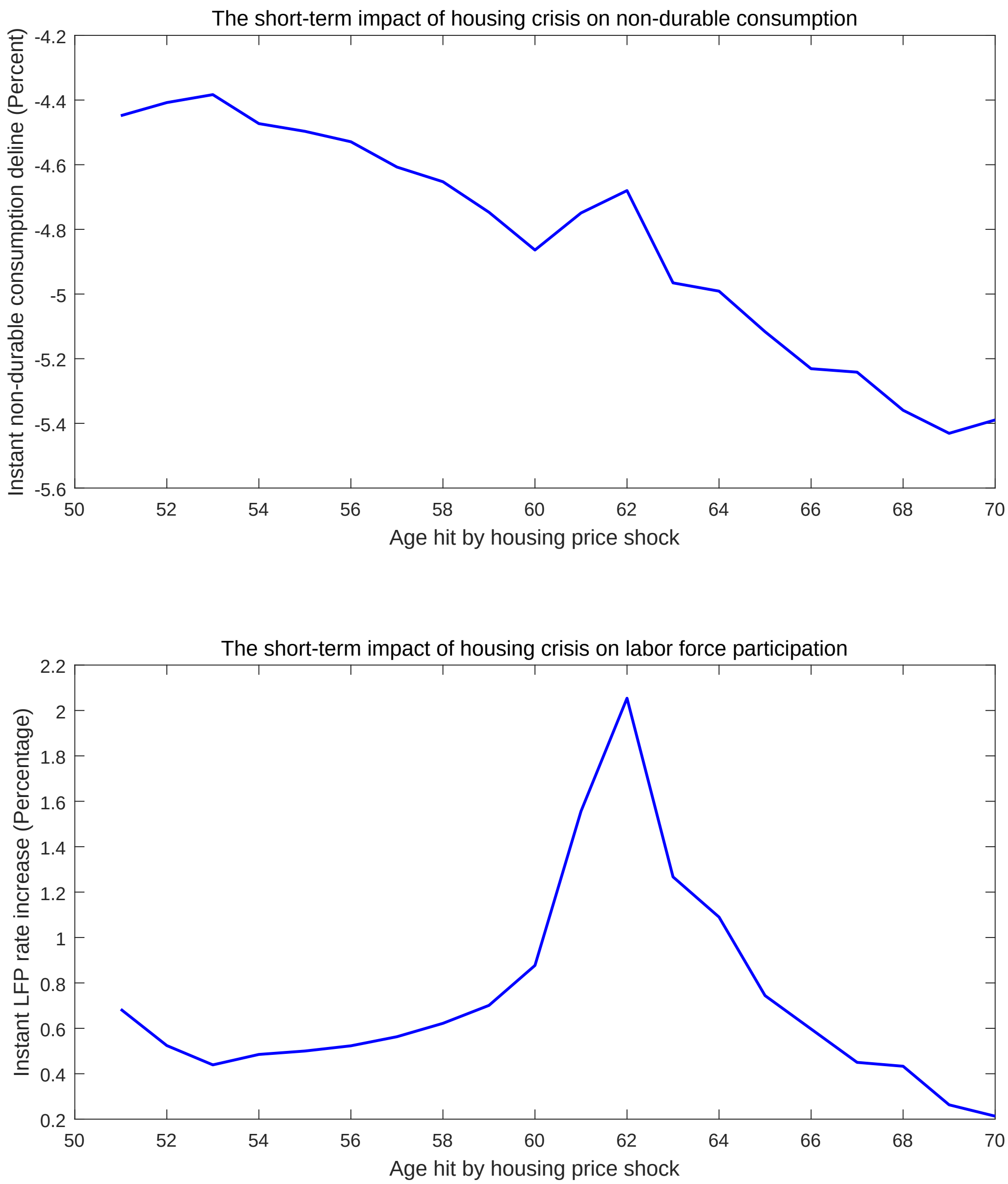

Figure 3: **The short-term impact of the housing crisis on consumption and retirement**

participation rate by 0.96 percentage points. Therefore, our model accounts for 70 percent of the actual consumption drop and 86 percent of the actual labor force participation rate increase in the data.[22]

To understand the long-term impact of the housing crisis, I simulate the model economy onwards and compute the impulse response of the non-durable consumption and the labor force participation rate for different age groups. As before, I compute the consumption and labor force participation rate difference (i.e, 100-retirement rate) between the two economies and plot the results in Figure 4. Each circle represents the starting age when housing price shock hits those homeowners. The "hair" graph shows the long-term response of consumption and retirement for homeowners hit by shocks at different ages.

The upper panel shows that the impact of housing crisis on the non-durable consumption is very persistent. Even for the homeowners hit by shocks at age 50, their consumption at age 70 is still 2.8 percent lower than the homeowners experiencing no housing crisis. The lower panel shows that homeowners hit by the housing price shocks at youngest age will have the largest increase in the labor participation rate over life cycle. Therefore, although the youngest cohort do not exhibit the largest instant increase in the labor force participation rate, their retirement behavior will be greatly affected several years later.

To summarize the long-term impact of housing crisis on the retirement behavior, I plot long-term impact of housing crisis on the average retirement age. Again, the baseline economy is the stationary distribution where no housing crisis happens. I compute the difference in the retirement age for different age groups between the crisis economy and the baseline economy. Consistent with our previous graph on the impulse response of labor force participation, the youngest age group will have the largest increase in the retirement age. For the age group 55-64, the average retirement age increases by 3.0 months. The quantitative effect may look small, however, many counterfactual experiment in the literature predicts the similar retirement response. For example, French (2005) finds that 20 percent reduction in the social security income will cause workers to delay exit from the labor force by only three months. French and Jones (2011) finds that raising the Medicare eligibility age from 65 to 67 leads individuals to work an additional 0.88 months over ages 60-69. In comparison, eliminating 2 years' worth of Social Security benefits

[22]This may overestimate the fit of the model because the statistics in Table 1 and 2 are computed using the full households sample, including renters. Given that the home ownership rate for households aged 55-64 is about 80 percent and the assumption that rental price does not change, then the model can explain about 56 percent of the actual consumption drop and 69 percent of the actual increase in the labor force participation rate.

increases years of work by 0.91 months.

3.8 Retirement as Self-insurance Against House Price Risks

In the incomplete market model literature, we know that the labor adjustment is an important channel for households to self-insure against income shocks.[23] In order to demonstrate the role of endogenous retirement in cushioning the home price risk, I build up a comparison model with exogenous retirement, where each household in the initial distribution retires at the same age as in the endogenous-retirement model. Therefore, both model economies exhibit the same retirement age distribution. Figure 6 shows the consumption growth rate for working households after an unexpected -27.7 percent home price shocks in the endogenous retirement model (the solid line) and in the exogenous retirement model (the dashed line).

First of all, the consumption growth rate is declining over time in both economies. This is mainly due to the life cycle features of rising mortality rate. Second, the consumption growth decline in the endogenous retirement model is always smaller than in the exogenous retirement model. It implies that homeowners aged 55-64 that are able to choose retirement age will on average experience 34 percent less drop in non-durable consumption than homeowners that are forced to retire at fixed age. However, retirement as a way of self-insurance becomes less effective for the very young households and the old households close to age 70. For young households, it is still too early to use retirement as self-insurance. For the old households, the room for delayed retirement is limited.

4 Conclusion

This paper complements previous studies on retirement by pointing out the importance of housing wealth effect on retirement and consumption decision for the elderly 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, home price risk, health 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 home price shocks mainly through two channels: re-sizing

[23]It is worth mentioning that Hryshko, Jos Luengo-Prado and Sørensen (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.

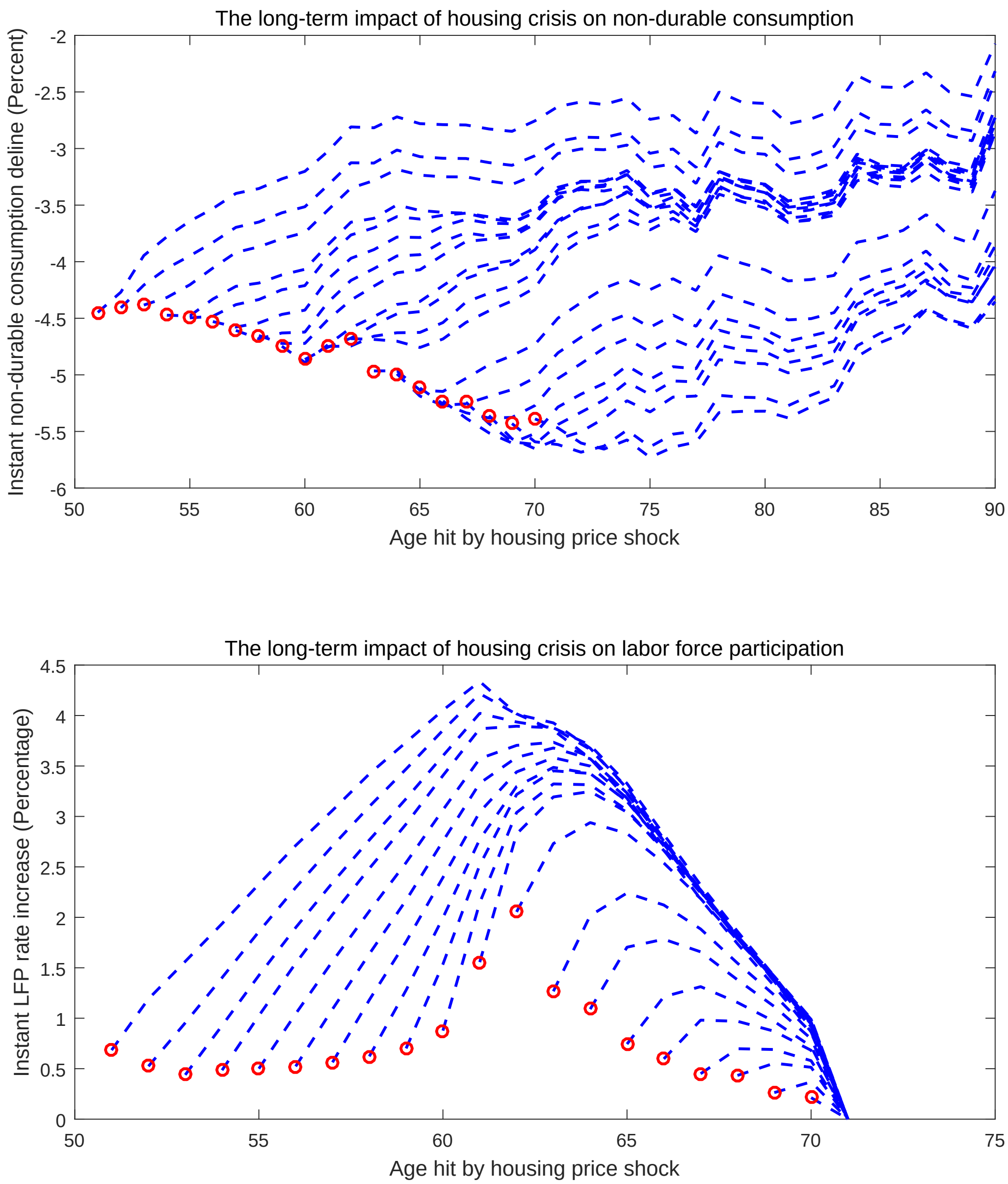

Figure 4: **The long-term impact of the housing crisis on consumption and retirement**

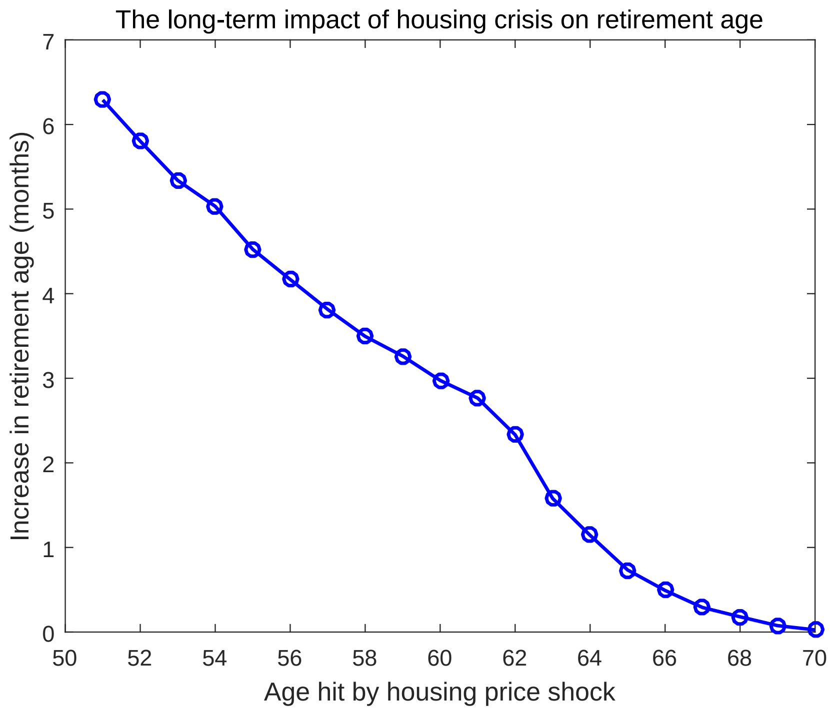

Figure 5: **The long-term impact of the housing crisis on retirement age**

effect and the bequest motive. Using the structural model, the paper argues the endogenous retirement is quantitatively important channel for self-insurance against house price shocks.

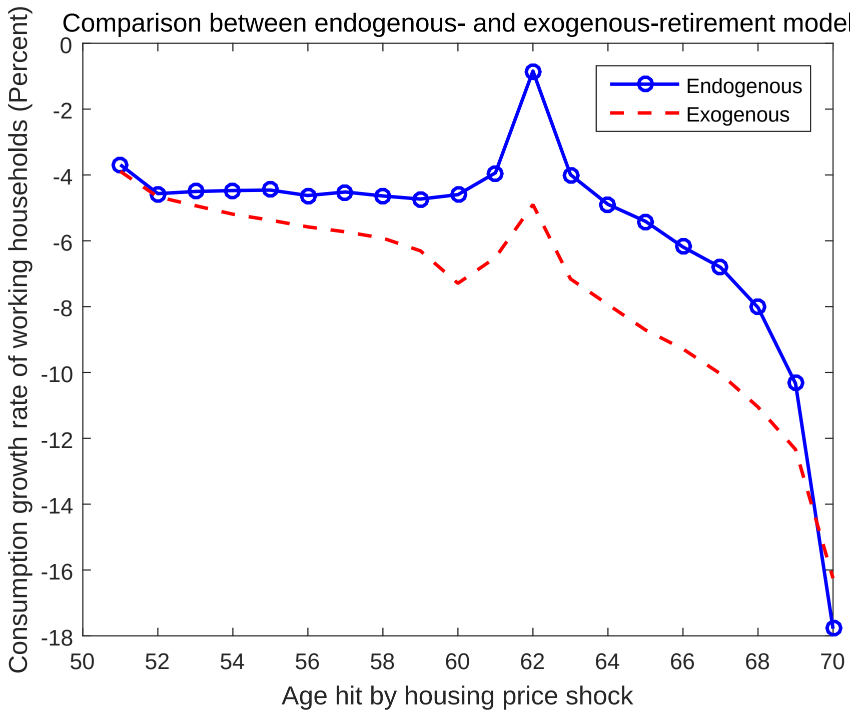

Figure 6: **Consumption insurance by endogenous retirement**. The annual consumption growth rate are computed using working households only.

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5 Appendix

5.1 Robustness Check

In this section, I perform several robustness check. First, I allow the housing wealth effect to differ across census divisions during the subprime crisis. It focuses on three census divisions (Pacific, Mountain, and the South Atlantic) that have the largest house price decline during the subprime crisis 2007-2009. Table 13 shows that the retirement response to house prices in the three census divisions is higher than in the other census divisions. In particular, the South Atlantic region has the largest retirement response to house price decline. This area also experienced the largest drop in housing prices in the recent subprime crisis (about -38 percent drop over two years).

Second, I allow the housing wealth effect on retirement to differ by health status. The results are reported in Table 14 where I separate the sample into two groups

Table 13: **The retirement response across census divisions.** For simplicity, this table focus on homeowners only. The average housing price decline for the Pacific, the Mountain, and the South Atlantic census division are -37.9 percent, -26.3 percent, and -23.2 percent, respectively during the 2007-2009 subprime crisis.

Dependent var.: Retirement dummy Sample coverage	FE Homeowner	RE Homeowner
Log(House price)	0.065*	0.065*
	(1.8)	(1.9)
Log(House price)×(Subprime=1)×Other region	0.06	0.06
	(0.5)	(0.5)
Log(House price)×(Subprime=1)×Pacific	0.11	0.64
	(0.19)	(1.13)
Log(House price)×(Subprime=1)×Mountain	0.14	0.34
	(0.42)	(1.0)
Log(House price)×(Subprime=1)×South Atlantic	0.58*	1.08***
	(1.71)	(3.3)
Earnings last year(Thousands $)	-0.0013***	-0.0013***
	(-9.4)	(-9.4)
Year/C-D dummy	Yes	Yes
No. of Obs.	40,789	40,789

based the health status of homeowners. I find a larger point estimate for homeowners with poor health, although the coefficient is not significantly different from zero at 10 percent confidence level. The retirement of homeowners with poor health also responds more to changes in households non-capital income. The structural model predicts a similar retirement elasticity with respect to housing prices.

Third, I estimate the housing wealth effect on retirement using the yearly average housing prices data. The results are shown in Table 15. The quantitative results are similar to Table 3 in the main text where I use monthly housing prices.

Fourth, I study the impact of housing prices on retirement expectations. The RAND (2015) contains information on the self-reported probability of working full-time after age 62, ranging from 0 to 100. About 80 percent of the respondent answered this question and the mean probability reported by respondents aged 50-61 is about 40 percent. Table 16 reports the impact of housing prices on the self-reported probability of working. It finds that a 10 percent increase in housing price is associated with 0.6 percentage point decline in the working probability of home owners. For the renters, the impact in the opposite. A 10 percent increase in housing is associated with 0.53 percentage point increase in working probability of renters.

Table 14: **The retirement response by health status.** For simplicity, this table reports results for homeowners only.

Dependent var.:	Data				Model	
Retirement dummy	FE	FE	RE	RE	FE	FE
Sample coverage	Good	Poor	Good	Poor	Good	Poor
Log(House price)	0.080**	0.104	0.073**	0.11	0.086***	0.12***
	(2.0)	(1.0)	(2.0)	(1.4)	(34.1)	(21.9)
Earnings last year	-1.2e-3***	-2.8e-3***	-1.5e-3***	-3.6e-3***	-1.9e-3***	-2.5e-3***
(Thousands $)	(-8.7)	(-3.5)	(-11.3)	(-5.9)	(-580.9)	(-142.3)
Year/C-D dummy	Yes	Yes	Yes	Yes	Yes	Yes
No. of Obs.	34,113	6,636	34,113	6,636	3,051,289	948,711

Table 15: **The retirement response to yearly housing prices.** This table estimates the impact of yearly housing prices on retirement decision. The yearly housing prices is the simple average of monthly real housing prices. It also includes the yearly census-division average unemployment rates, instead of monthly unemployment rate as regressor.

Dependent var.: Retirement dummy	FE	FE	RE	RE
Sample coverage	All HH	Homeowner	All HH	Homeowner
Log(Yearly House price)	0.088**	0.086**	0.069**	0.075**
	(2.4)	(2.2)	(2.0)	(2.1)
Renter	0.95***	—	0.62***	—
	(3.6)		(2.9)	
Log(Yearly House price)×Renter	-0.21***	—	-0.15***	—
	(-3.6)		(-3.2)	
Earnings last year(Thousands $)	-0.0013***	-0.0013***	-0.0016***	-0.0016***
	(-9.5)	(-9.4)	(-12.0)	(-12.0)
Year/C-D dummy	Yes	Yes	Yes	Yes
No. of Obs.	43,881	40,789	43,881	40,789

Table 16: **The impact of housing prices on the retirement Expectation.** The independent variables is the probability of working full-time after age 62, ranging from 0 to 100. The sample now only includes respondents aged 50-61. The previous sample selection standards still apply.

Dependent var.: Prob. of working after age 62 Sample coverage	FE All HH	FE Homeowner	RE All HH	RE Homeowner
Log(House price)	-6.0*	-5.23	-5.8**	-5.5*
	(-1.8)	(-1.5)	(-2.0)	(-1.9)
Renter	-48.9*	—	-11.5	—
	(-1.9)		(-0.56)	
Log(House price)×Renter	11.3*	—	3.9	—
	(1.9)		(0.84)	
Earnings last year(Thousands $)	0.02***	0.02***	0.05***	0.05***
	(4.1)	(3.7)	(8.9)	(8.3)
Year/C-D dummy	Yes	Yes	Yes	Yes
No. of Obs.	32,079	29,637	32,079	29,637

Fifth, I estimate the impact of housing prices on annual working hours. So far, I have investigated the impact of the housing prices on the retirement decision, which is the extensive margin of labor adjustment. Now I examine the impact of the housing prices on the amount of working hours, which is the intensive margin of labor adjustment. The dependent variable is the annual working hours at the main job of the respondents. I restrict our sample to full-time and part-time workers only and the regression results are shown in Table 17. I find that a 10 percent increase in the housing prices is associated with nearly 30 hours increase in the annual working hours of homeowners. Structural model predicts a smaller impact of housing prices on working hours. Simple calculation would suggest that the extensive margin is more important in explaining the aggregate hours fluctuations.

Sixth, I investigate homeowners' ability to adjust housing asset in the data and compare it with the model. The housing wealth effect depends on the ability of households to buy/sell their houses, which is strongly affected by the housing adjustment cost. Suppose the households cannot buy or sell their houses due to high adjustment cost when prices fluctuate, I should observe that the value of housing asset (not the net housing asset) should move at the same pace as regional housing prices. If households can sell their houses when prices go up and buy new houses when prices go down, then the value of housing asset would fluctuate less than the housing prices. Therefore, I estimate the impact of housing prices on the value of primary residence for homeowners. Table 18 show the results. I find that the coefficient before the housing value is significantly below 1, an evidence that households

Table 17: **The impact of housing prices on working hours.** The dependent variables is the annual working hours at the main job. The previous sample selection standards still apply.

Dependent var.: Hours	Data				Model	
	FE	FE	RE	RE	FE	RE
Sample Coverage	All HH	Homeowner	All HH	Homeowner	Homeowner	Homeowner
Log(House price)	-291*	-359**	-338**	-408***	-223***	-163***
	(-1.7)	(-2.1)	(-2.2)	(-2.6)	(-53)	(-50)
Renter	-6381***	—	-4600***	—	—	—
	(-5.0)		(-4.3)			
Log(House price)×Renter	1457**	—	1085**	—	—	—
	(2.2)		(4.5)			
Earnings last year	6.4***	6.6***	8.3***	8.6***	15.3***	15.5***
(Thousands $)	(10.7)	(11.3)	(12.9)	(13.4)	(1366)	(1463)
Year/C-D dummy	Yes	Yes	Yes	Yes	Yes	Yes
No. of Obs.	34,943	32,833	34,943	32,833	4,000,000	4,000,000

do change the size of their house in response to housing price fluctuations. Our structural model with housing adjustment cost can replicate the empirical results, with a smaller impact on the housing prices.

In the end, instead of estimating consumption elasticity with respect to housing prices, I can also estimate the impact of housing wealth changes on total households spending, as in Mian, Rao and Sufi (2013). Mian, Rao and Sufi (2013) estimates the impact of housing wealth changes on total households spending. Various specifications in Table IV in Mian, Rao and Sufi (2013) show that the MPC out of housing wealth is between 5.1 cents per dollar to 11.9 cents per dollar.

Table 18: **The impact of housing prices on the housing value.** The independent variables is the log real value of housing asset (primary residence). The sample now only includes homeowners. The previous sample selection standards still apply.

Dependent var.: Log(Housing Value)	Data		Model	
	FE	RE	FE	RE
Log(House price)	0.33***	0.28***	0.12***	0.06***
	(3.22)	(2.74)	(50.4)	(27.2)
Earnings last year(Thousands $)	3.96e-5	3.2e-4***	4.2e-4***	5.7e-4***
	(0.73)	(5.8)	(69.3)	(94.4)
Year/C-D dummy	Yes	Yes	Yes	Yes
No. of Obs.	47,933	47,933	4,000,000	4,000,000

Table 19: **Marginal propensity of spending out of housing wealth.** The sample only includes homeowners.

Dependent var.: Total Households Spending	Data		Model	
	FE	RE	FE	RE
Housing Wealth	0.039***	0.045***	0.030***	0.043***
	(4.6)	(8.7)	(774)	(2809.7)
Non-capital Income	0.04	0.11***	0.058***	0.061***
	(1.4)	(5.2)	(807)	(811)
Year/C-D dummy	Yes	Yes	Yes	Yes
No. of Obs.	1,046	1,046	4,000,000	4,000,000

I restrict the HRS sample period data to two years, 2007 and 2009. I look at impact of the value of total housing wealth (the sum of value of primary and secondary residence) on the total spending of homeowners. Following definitions in Mian, Rao and Sufi (2013), the total households spending include not only non-durable consumption but also the durable spending, which is comprised of the purchase price of five big ticket items: dishwashers, refrigerators, washer/dryers, computers and televisions. I further add automobile purchases, which is a component of transportation spending (not included in the durable spending) in RAND (2015). Results are shown in Table 19. The estimates of the MPC from HRS is between 3.9 cents per dollar to 4.5 cents per dollar, which are close to the lower bound of Mian, Rao and Sufi (2013).

The structural model does not have durable spending. Using the non-durable consumption instead, the structural model predicts a MPC lies between 3.0 and 4.3, which is also lower than the empirical estimates in Mian, Rao and Sufi (2013).

Following their definitions, the total households spending include not only non-durable consumption but also the durable spending, which is comprised of the purchase price of five big ticket items: dishwashers, refrigerators, washer/dryers, computers and televisions. It does not include automobile purchases, which is a component of transportation spending. I restrict the HRS data to two years, 2007 and 2009. I look at impact of the value of total housing wealth (the sum of value of primary and secondary residence) on the total spending of homeowners. Results are shown in Table 19. Our estimates of the MPC from HRS is between 3.9 cents per dollar to 4.5 cents per dollar, which is close to the lower bound of Mian, Rao and Sufi (2013). The structural model does not have durable spending. Using the non-durable consumption instead, the structural model predicts a MPC that lower than the empirical estimates.