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# Essays on Retirement Behavior during the Housing Boom and Bust

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Abstract

This study contains two chapters. The first uses the Prentice-Gloeckler-Meyer proportional hazard model with individual heterogeneity to investigate the effects of loss aversion concerning the housing market and the local foreclosure rate on retirement during the housing bust periods. The second chapter creates a dynamic programming life-cycle model with the housing wealth and uses the Method of Simulated Moments to systematically study the retirement and saving behavior during the housing boom and bust (the years 2000-2014).

Housing wealth is one of the biggest savings for elderly. It relates to the financial security of elderly after retirement. After the incredible growth of housing prices in the early 2000s, the housing market melted down at the end of the year 2007. A tremendous decline in property value caused a high uncertainty about the housing market. Even though elderly were not sure how severe the housing bust would be, they knew the highest value of home equity before the Great Recession. In the first chapter, we use this highest value at the year 2006 to measure the loss aversion concerning housing wealth. Higher housing equity at the year 2006 might experience more loss in the Great Recession. When there was a loss of housing wealth, it increased the uncertainty of financial resources in the future. Delaying retirement and working more years to increase savings are a reasonable plan to improve resources.

For the same amount of housing wealth loss, the effect is not the same if elderly live in a different area and a different housing market. The expectation of housing market performance is also not the same. We have high-quality data on local foreclosure rates from Equifax. It provides the number of foreclosures starting in the first week of July from year 2005 to 2012 on the zip-code level. We use the local foreclosure rate to approximate the expectation of the local housing market. Coefficients of both home equity at the year 2006 and local foreclosure rate (except the

year 2009) are significant and negative, meaning elderly with higher home equity at the year 2006 and elderly who live in an area with a higher foreclosure rate significantly delay their retirement.

In the second chapter, we create a dynamic programming life-cycle model based on French and Jones (2011). We still take into account the risks of wage, health status, mortality and medical cost in our models. Because we study the elderly after the year 2000, the 'Senior Citizens' Freedom to Work Act of 2000' that eliminates the Social Security earnings test after normal retirement age is applied. We use the re-entry state variable to control the labor force participation when there is no Social Security earnings test.

New models separate the housing wealth from total wealth in the original model and consider the housing wealth through two constraints: the baseline model has an unknown proportional housing wealth in the asset accumulation equation; the modified model has a home equity borrowing constraint. New models also take into account housing wealth change in the bequest motive component.

Both the baseline and modified models match the labor-force participation well and capture the high exit rate at the Medicare age. The coefficient of unknown proportional housing wealth in the baseline model indicates that elderly takes into account approximately 25 percent of their housing wealth in the asset accumulation, which, coincidently, is close to the average ratio of loan to value in the data. The modified model matches better than the baseline model in the asset quantile moments (saving behavior). Robust checks show the bequest coefficients significantly change if we do not separate housing wealth from total wealth. Surprisingly, change of bequest curvature is close to the mean of the housing wealth.

Three experiments are conducted in the second chapter. We experiment with two different housing wealth projections and one tighter borrowing constraint. The results indicate that loss of housing wealth and tight borrowing constraints delay retirement. Even though we use the long-term growth rate and obtain a similar mean of labor-force participation rate, the curves significantly shift to adjust the new expectation of housing wealth change.

# Essays on Retirement Behavior during the Housing Boom and Bust

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# Contents

# Chapter 1

## Introduction

Assessing how earnings, employer-provided pensions, and individual assets contribute to retirement income and wealth accumulation requires an understanding of how these sources of retirement income affect the retirement decisions of older workers.[1] Economists use duration analysis to estimate the effect of the socio-economic characteristics on the conditional probability of retirement (see, for example, Diamond and Hausman 1984; Gustman and Steinmeier 1986 and 2000; and Hurd 1990). However, an accurate assessment also requires an understanding of how the levels and future expectations of the different sources of retirement income have changed in the last several years.

The U.S. economy has experienced two major recessions in the last two decades. The first of these started in late 2000 following the Tech Bust. Firms laid off millions of employees as profits fell. While employment outcomes for older workers in fact remained favorable during the recession and recovery (see Munnell, Sass, Soto and Zhivan 2006; and Cooper 2008), the recession brought substantial declines in the value of their defined contribution plans and other non-housing equity assets. The S&P 500 index fell in 2003 to a value last seen in 1997. It had passed the 1500 benchmark in the year 2000 but next attained that level only in 2007. The declines in retirement assets led to delays in the decision to retire (see Cooper 2008).

Unlike the Tech Bust, the Housing Bust of 2007 brought with it not only a decline in financial asset values but also a decline in property values unprecedented in recent decades. By April 2008 equities were off 15.5 percent from their October 2007 highs, while housing prices

[1] Retirement can mean Social Security claiming age, self-reported retirement, or full or partial retirement (see Gustman and Steinmeier 2002). The econometric analysis below will be performed for a self-reported retirement definition.

were down by 10 percent or more nationally from the preceding year. By 2009 the Housing Bust had not only caused a decline in home values of 28 percent in the United States (see Reinhart and Rogoff 2009), it had also increased the uncertainty about the current and future values of a particular home. In a March 18, 2013 interview with the Daily Ticker, Robert Shiller of Yale University says "the future of the housing market is a great unknown." (See also Nakamura 2010.) Case, Shiller, and Thompson (2012) find that respondents in their survey seem to have a much unclear picture when the housing market is ambiguous. Short-run expectations are underreacted to the year-to-year changes in actual home prices. Older workers consider their home to be both a place to live in retirement and a store of wealth for bequests or in case of emergency. Anecdotal evidence (see, for example Levitz 2008) suggests that the general declines in home values that started in 2007 and the uncertainty about the value of housing delays the retirement of these workers. Older workers will want to work longer to accumulate additional wealth to replace lost housing value.

We use both the Prentice-Gloeckler or complementary log-log proportional hazard model (see Prentice and Gloeckler 1978) and the heterogeneity-corrected Prentice-Gloeckler-Meyer proportional hazard model (see Meyer 1990) to estimate the determinants of the time to first self-reported retirement of married males.[2] Restricting the sample to married males reduces heterogeneity due to including single males who are not involved in joint decision-making. By including a dummy indicating the retirement status of the female spouse in the covariate list of the male spouse, the estimated model takes into account coincidence in tastes for leisure, since

[2] The focus on first retirement excludes subsequent retirement after a re-entry into the labor force, the timing of which may have different determinants.

each spouse's utility depends on the retirement status of the other (see Gustman and Steinmeier 2000; and Hurd 1990).

The Health and Retirement Study (HRS) waves from 1992 through 2012 provide the data for the estimation. Demographic data and data on income, pensions, and housing and non-housing financial wealth form the basis of the covariate list. We use the restricted Social Security Administration data to obtain the zip code of the household's primary residence, which is then tied to the percentage of foreclosures started in the month of July for years after the Housing Bust, obtained from Equifax Credit Trends 4.0,. This local percentage of foreclosures is included as a hazard covariate.

The remainder of the paper is laid out as follows. Section 2 constitutes the literature review, while section 3 presents the econometric theory. Section 4 describes the data in greater detail. Section 5 presents the empirical results and section 6 concludes.

## Literature Review

Work by Diamond and Hausman (1984) is among the first important studies to examine the determinants of the retirement behavior of older men. They suggest that individual uncertainty concerning wealth accumulation, financial needs, health and job opportunities should be a central focus in using longitudinal data for this purpose. The statistical specification used by Diamond and Hausman is a Weibull duration model with a Gamma random effect, introduced into the economic literature by Lancaster 1979, to control for unobserved determinants of retirement.

There are distinct advantages to using a duration model instead of other statistical methods to study retirement. First, in most longitudinal data there will be a degree of censoring (the respondent will not have retired by the end of the sample period), which can easily be incorporated into the likelihood function for duration. Second, the fact that relevant regressors are likely to change over time can be handled in a straightforward manner in a hazard analysis.

Diamond and Hausman find that both private pensions and Social Security have strong positive effects on the retirement hazard of older men. The Social Security effect is strong when benefits first become available at age 62 and rises for workers over 62. Bad health has a significantly positive effect on the retirement hazard at all ages, no matter what financial incentives or disincentives are provided by private pensions and Social Security. They find little effect for variables related to education and marital status. At least in part, this may be due to the way these variables were specified. The highest degree attained was not controlled for directly; nor was the work status of a spouse. In the latter case, a spouse who works may provide additional financial security, at least until her retirement. Conversely, a spouse who has never worked or has previously retired (or is about to retire) may enhance the utility of retirement, since the additional leisure can be shared with a partner with similar interests. This reasoning clearly suggests a need to consider the joint retirement decision of the husband and the wife.

Perhaps the first important work concerning the joint retirement decision of married couples is by Hurd (1990). Hurd seeks to determine whether husbands and wives tend to retire the same time, and if so to provide an explanation for this tendency. He finds evidence of the co-ordination of retirement dates, both through preliminary analysis of the data as well as economic modeling. Hurd hypothesizes that the closeness of retirement dates could be due to either similarity of tastes caused by assortative mating, by economic variables, or by complementarity of leisure. He claims that each potential explanation has different implications for the response of retirement to policy changes. According to his empirical results, economic variables appear to explain very little of the closeness of retirement dates. He also rules out assortative mating as a potential explanation. The only hypothesis left is the complementarity of leisure. Unfortunately, Hurd feels that data limitations leave him with only a qualitative result. Hurd's methodology does not involve duration modeling.

Over the last 25 years two sets of researchers, working independently, have made significant contributions to the theory and empirical analysis of retirement behavior.

Gustman and Steinmeier focus on structural modeling and have relied primarily on the HRS for their data. Gustman and Steinmeier (1986) estimate a structural model of retirement choice that interacts lifetime preferences and incentives. Their results track actual retirement behavior closely, including peaks in the retirement rate at ages 62 and 65.

Gustman and Steinmeier (2000) develop a structural model of the joint retirement decision of married couples and estimate this model using panel data from the NLS for Mature Women. In the model utility depends on family lifetime consumption, the separate labor supply of the husband and the wife, as well as the age and health of each. The value that each spouse places on leisure is influenced by the retirement status of the other spouse. Because people who share the same tastes are more likely to marry, the retirement preferences of the husband and wife may be correlated. The husband and wife choose paths of consumption, work, and ultimate retirement that maximize their preferences over a time subject to the restriction that lifetime family consumption cannot exceed lifetime family income. As individuals age, the value of retirement eventually outweighs the value of wages, and the individuals retire.

Gustman and Steinmeier find strong evidence for the hypothesis that husbands and wives tend to retire together despite the younger ages of wives. Their estimation suggests that one reason for coordinated retirement is a coincidence of tastes for leisure. They also find that spouses generally, but husbands in particular, value retirement more if their partner has already retired. Gustman and Steinmeier's modeling of the opportunity set accounts for peaks in the retirement hazard of each spouse; however, they find that the co-ordination of opportunities is not responsible for the co-ordination of retirement dates.

Gustman and Steinmeier (2001) use data from the HRS to gauge respondents' knowledge about future Social Security and pension benefits by comparing respondent reports of their expected benefits with benefits calculated from Social Security earnings records and employer provided descriptions of pension plans. Their results suggest general misinformation, imprecision and lack of information about retirement benefits is the norm.

Gustman and Steinmeier (2003) construct a structural dynamic stochastic model of the way individuals make retirement and saving choices in an uncertain world and use it to analyze the effects of the stock market bubble on retirement behavior. The model includes individual variation both in retirement preferences and in time preferences. Estimates are based on information covering the period 1992 through 2000 from the HRS. The high stock market returns in the second half of the 1990's increased retirement rates for the HRS sample of workers by over 3 percentage points and would have decreased the average retirement age by about a quarter of a year if it had not been interrupted. The subsequent decline in the market neutralized the effect on retirement of the preceding stock market gains. Gustman and Steinmeier speculate in their paper that any continuing effects of the bubble after its end would probably be minimal.

More recent research by Gustman and Steinmeier (2008) addresses the topic of whether jointly modeling the retirement behavior of two-earner couples brings with it any advantages over modeling the retirement behavior of the two earners separately. Although the type of models used by Gustman and Steinmeier is different from the one that we use in this study and their focus is different from ours, their results are relevant to the present study since we model only the retirement decision of the male spouse. Gustman and Steinmeier (2008) estimate structural models of saving and retirement behavior in the face of two policies, the effects of which are known *a priori.* The findings of the study suggest that joint modeling and separate modeling give roughly the same results.

The work by David Blau primarily uses the Retirement History Survey. Blau (1994) examines movements of older men through labor force states using quarterly observations from the Retirement History Survey. He compares these transitions with those from the more typical biannual records and uncovers substantial under-counts in the biannual data. He concludes that the prevalence of labor force movements at older ages has been previously under-estimated. Blau has also studied the retirement behavior of married couples. Under the “dependent’s benefits” provision of Social Security a female spouse is eligible for a spousal benefit equal to 50 percent of her husband's benefits if she chooses not to receive a retired worker benefit based on her own earnings record. Blau (1997) uses data from the Retirement History Survey to show that the spousal benefit provision has a small negative impact on labor force participation of older female spouses and a small positive impact on the labor force participation of older married men.

Blau (1998) analyzes the dynamics of the joint labor force dynamics of older couples in the United States. Using data from the Retirement History Survey, he finds strong associations between the labor force transition probabilities of one spouse and the labor force status of the other. Blau and Riphahn (1999) use monthly observations from the German Socio-Economic Panel (GSOEP) to model the labor force behavior of older married couples in Germany. They estimate a discrete-time competing-risks hazard model of transitions among labor force states that are defined by the employment status of both spouses. Their empirical results suggest, broadly speaking, that spouses are more likely to move towards states in which both are employed or in which both are not employed.

The focus of the present study is the effect of financial wealth and housing equity wealth on the retirement decision. One important study in this regard is by Case, Quigley, and Schiller (2005). Case, Quigley, and Schiller examine the links between increases in housing wealth, financial wealth, and consumer spending. They draw on annual data from 14 countries and quarterly state-level data from the United States to estimate regression models in levels, first differences and in error-correction form relating consumption to income and wealth measures. Case, Quigley, and Schiller find a large, statistically significant effect of housing wealth on household consumption.

Using cross-MSA variation in house-price movements in data provided by the Office of Housing Enterprise Oversight, Farnham and Sevak (2007) find evidence that changes in housing wealth affect retirement timing for a sample of older workers from the HRS. They also find evidence that housing-wealth shocks affect retirement expectations as well as present retirement rates. They estimate that a 10 percent increase in housing wealth is associated with a reduction in expected retirement age of between three and a half and five months.

Finally, three important recent studies examine the employment status and retirement expectations of older U. S. workers in the wake of the recent recession, topics which are clearly closely related to the focus of the present study. Copeland (2010) uses the March Current Population Survey to examine how employment rates of workers aged 55 and older changed over the period from 1987 to 2008. Copeland finds that the percentage of older workers working full-time throughout the year increased steadily from 1993 to 2007 before decreasing during the recession year of 2008. Goda, Shoven, and Slavov (2010) use the HRS to investigate the relationship between stock market performance and retirement plans over the 1998 to 2008 period. The authors find a statistically significant negative relationship between the probability of working full-time at age 62 and the value of the S&P 500 index toward the end of their study period. They do not, however, find strong evidence that changes in equity markets influence changes in retirement plans over the period as a whole. They conclude that the higher probabilities of working in recent years may be related to factors other than stock market performance, such as pessimism about economic security. Unlike in previous recessions, layoffs for older workers became a fact of life with the recession that started in 2007. Gustman, Steinmeier and Tabatabai (2011) report that the percentage of retirement-age workers who were not retired at the start of the 2000-2001 Recession and were both not working and not retired four years later was 6.2 percent, while the comparable percentage of workers not retired in 2006 (one year before the Housing Bust) who were both not working and not retired four years later was 11.7 percent, an increase of 4.5 percent.

## Hazard Estimation

We define age at retirement as the age at the first self-report of retirement for the sample of work-able married males drawn from the 1992 through 2012 waves of the HRS. A continuous work histories constructed starting at age 59 can each be stopped in five ways: first, after a self-reported retirement; second, after the last wave; third, before a non-response for the retirement question; fourth, before a wave in which the marriage ends; and fifth, before a wave in which the male spouse is reported to be disabled. Our goal is to find the determinants of the conditional retirement rate (retirement hazard rate) and to investigate how the determinants change after the Housing Bust. Note that the retirement rate might be thought of as the retirement rate at a point in time within the calendar year or as the retirement rate for a given year. In most cases the meaning should be clear from the context.

Suppose that a given sample is composed of $N$ work histories. The $N$ work histories provide information on $N$ independent individual retirement ages. Let $T_i$, a continuous variable, be the retirement age for individuals $i = 1, \ldots, N$. The hazard rate for individual $i$ takes the proportional hazard form developed by Cox (1972):

$$\lambda_i(t) = \lambda_0(t)\exp(z_i(t)'\beta)\,, \qquad (1)$$

where $\lambda_0(t)$ is the unknown baseline hazard at time $t$, $z_i(t)$ is the vector of time-varying covariates, and $\beta$ is the coefficient vector.

To estimate the coefficient vector, we use the technique proposed by Prentice and Gloeckler (1978) as well as the adaptation of Meyer (1990) that allows controls for unobserved heterogeneity. In the Prentice-Gloeckler technique the parameters $\lambda_0(t)$ of the log-integrated baseline hazard are non-parametrically estimated simultaneously with the coefficient vector. The estimation method does not use the continuous quality of the duration variable, but rather discretizes this variable into time intervals (in our study we use annual intervals). The Prentice-Gloeckler technique uses the extreme-value distribution function to estimate the conditional survivor function at age $t+1$:

$$\Pr\left[T_i \geq t+1 \,|\, T_i \geq t\right] = \exp(-\exp(z_i(t)'\beta + \gamma(t)))), \qquad (2)$$

where the covariate vector $z_i(t)$ is assumed to remain constant over the period from $t$ to $t+1$. (This type of estimation is called "grouped" or "interval-censored".) Generally, when the Prentice-Gloeckler technique is used, a $\beta$ parameter is estimated for each interval.

The interpretation of parameters is an important component of the estimation procedure. The $\beta$ coefficients in the Prentice-Gloeckler likelihood have an interpretation similar to that of the regression coefficients in a log-linear or semi-log regression model. In a log-linear model where both the dependent variables and regressors are logged, a regression coefficient can be interpreted as an elasticity. Similarly, if a regressor is logged in the Prentice-Gloeckler likelihood, its coefficient can be interpreted as a hazard elasticity. In a semi-log regression in which the dependent variable is logged but the regressors are not, the elasticity of the dependent variable with respect to a regressor is given by the value the regressor times the coefficient. Similarly, if a regressor is not logged in a Prentice-Gloeckler likelihood, its hazard elasticity is given by the value the regressor times the coefficient.

The theoretical contribution of Meyer (1990) is to use random effects to incorporate unobserved heterogeneity into the Prentice-Gloeckler likelihood. The resulting likelihood is now called the Prentice-Gloeckler-Meyer likelihood. The random effect summarizes the effects of all (unobserved) excluded regressors that are constant over the work lifetime and orthogonal to included regressors. It is well known that failure to control for such unobserved heterogeneity will result in inconsistent parameter estimates.

Incorporating the multiplicative random effect $\theta$ into the hazard results in

$$\lambda_i(t) = \theta_i \lambda_0(t) \exp(z_i(t)' \beta) \tag{3}$$

Meyer (1990) assumes that the random effects $\theta_i$ are independent of the $z_i(t)$ and are i.i.d. Gamma variates with mean one and variance $\sigma^2$.

Note that when $\theta_i$ equals one, the value of the hazard is the same as that in the Prentice-Gloeckler likelihood. This means that conditional on the random affect assuming its mean value, the regressor coefficients have the same interpretation in both likelihoods. The Prentice-Gloeckler-Meyer technique estimates the survivor function at age $t+1$ using the following probability:

$$\Pr\left[T_i \geq t+1\right] = \left[1+\sigma^2 \sum_{k=0}^{t} \exp(z_i(k)'\beta + \gamma(k))\right]^{-\sigma^2} \qquad (4)$$

The variance $\sigma^2$ must now be estimated together with the coefficient vector $\beta$ and the $\gamma(t)$'s. Testing the significance of the estimate of $\sigma^2$ is complicated by the fact that zero is on the edge of the parameter space. Under these conditions the appropriate critical value for a test of size $\alpha$ is the critical value for a test of size $2\alpha$ under standard conditions. Finally, note that when $\theta_i$ equals one, the value of the hazard is the same in equations (1) and (3). This means that, conditional on the random effect assuming its mean value, the regressor coefficients and hazard ratios have the same interpretation in the Prentice-Gloeckler-Meyer likelihood as in the Prentice-Gloeckler likelihood.

In the work below, we use the formula from Follain, Ondrich, and Sinha (1997) to examine the Prentice-Gloeckler-Meyer annual hazards at the $10^{th}$, $50^{th}$ and $90^{th}$ percentiles of the local foreclosure rate for three specific cohorts. Individuals in the first cohort reach age 65 (normal retirement age) in the year 2007; individuals in the second cohort reach age 62 (early retirement age) in 2007 and 65 in 2010; and individuals in the final cohort reach age 62 in 2010. The functional form of the annual hazard is:

$$h_t(t) = 1 - \left\{ \frac{1+\sigma^2 g_i(t)}{1+\sigma^2 g_i(t-1)} \right\}^{-\sigma^2} \qquad (5)$$

where $g_i(t) = \sum_{s=0}^{t} \exp(\gamma(t) + z_i(t)' \beta)$ and $g_i(-1) = 0$. For this analysis indicator variables and control variables are assigned age-specific means.

## The Data

The empirical analysis used in this study comes from the HRS, originally a longitudinal survey of a nationally representative sample of the U.S. population 51 to 61 years old in 1992. In 1998 the sample membership of the HRS increases in size when it merges with the Asset and Health Dynamics among the Oldest Old (AHEAD) survey and two new special cohorts are added, the Children of the Depression Era (CODA), born in the period 1924-30 and War Babies (WB), born in 1942-47. Since 1998 new sample members are added every six years: Early Baby Boomers (EBB) are added in 2004, and Mid Baby Boomers (MBB) are added in 2010.

As discussed previously, a continuous work history is constructed for each sample individual starting at age 59. Each history can be stopped in six circumstances: first, after a self-reported retirement; second, after the last wave of the HRS; third, before a non-response for the retirement question; fourth, before a wave in which the marriage has ended; fifth, before a wave in which the male spouse is reported to be disabled; and sixth, before a year in which the male's stated retirement date conflicts with previous wave statements of work. Work histories are not included in the sample if either the husband or his wife is disabled before 1991, the first year of the HRS. These restrictions on the disability-ability status of the spouse(s) help guarantee that a retirement decision is made freely and is not forced on the household by functional limitations. After additionally dropping a handful of work histories because of missing data that cannot be filled in any reasonable way, the number of work histories becomes 3,293. These 3,293 work histories provide a total of 14,454 person-years to the present study.

The estimation uses six types of variables. The first type is demographic variables. The HRS 2010 Tracker file provides the time-invariant demographic variables, while the HRS Core provides the time-varying demographic variables. There are two race indicators, one for if the male spouse is African-American and the second for if the male spouse is non-White and non-African-American. There is an indicator for whether the male spouse has a college degree and another for whether he reports that he is in good health. Included in the list of demographic variables are four variables that describe the female spouse. Three of them are indicator variables, one for whether the female spouse is disabled, one for whether the female spouse is retired, and one for whether the female spouse has been a nonworking homemaker. The final variable of the demographic type is meant to capture the effect of the Social Security spousal benefit on retirement behavior. The spousal benefit will be larger if the principal breadwinner, typically the male spouse, waits until the Social Security full retirement age before he retires. The effect of the Social Security spousal benefit is more likely to come into play when the female spouse is a homemaker. Therefore, the final variable of the demographic type gives the number of years to the male spouse's Social Security full retirement age when the female spouse is a homemaker. The variable is zero otherwise.

There are seven workplace variables. These variables, as well as all financial and housing wealth values, come from the Rand HRS Data Set, Version P and the Rand HRS Income and Wealth Imputations. The first variable is the real annual log income of the female spouse, and the second is the real annual log income of the male spouse. (All deflated nominal values used in this study have been deflated by the implicit GDP deflator for personal consumption expenditures (year 2005=100) constructed by the Bureau of Economic Analysis.) Although we did not feel that we could get accurate information on employment-related pension plans, we did create three indicators for the type of pension plan. The first indicator is for whether the male spouse has ever had a defined benefit plan; the second is an indicator for whether the male spouse has not had a defined benefit plan but has had a defined contribution plan; and the third is an indicator for whether the male spouse has both a defined benefit plan and a defined contribution plan. Finally, we use restricted HRS data on three-digit occupation codes for the respondents to create three occupation categories: manager/professional, office worker (including technical and sales staff), and blue-collar. The first two indicators are included in the regressions and blue-collar is the reference category.

We experimented with three housing variables in preliminary estimations. The first is the log of the real home value, set to zero when the household does not own its own home. The second variable is the log of the real value of the sum of mortgage and home loans. Both of these variables had significant coefficients with the correct sign in virtually all of the estimations in which they were used, although none of these results are presented here. The final variable is the real value of home equity, real home value minus real mortgage value, in millions of dollars.

The HRS is a biannual survey, although in a few cases it may interview households three years apart. The present work constructs annual work histories until 2012 from the HRS. We use the 12th (2014) wave to correct self-report errors.

One of the unique features of our preferred results is that we do not impute home equity after 2006 based on a trend for the individual household, nor do we rely on the household's own assessment of home equity over the Great Recession years.

Even in cases where a household reports a value for home equity during the Great Recession, it is likely that the household is less certain about this value compared to values in previous years because of the nature of the substantial decline in housing demand. It is clear from the high foreclosure rates that the ownership of many homes reverted to the lending institutions. In order to stay liquid, these institutions sold these properties at greatly reduced prices. The extent to which the outcomes of such sales were made public is debatable, since municipalities had an incentive to "hide" such sales to protect their tax base. As a result, unless a household attempted to sell its home, which fewer households did, it is unlikely that it would feel confident about its assessment of its home equity.

Nor does it seem to be appropriate to use a value from a general house price index to construct home equity, which can be accomplished with the HRS by combining the county information from the restricted HRS geography data with the Federal Housing Finance Agency MSA-level Repeat Sales House Price Index to impute home prices across the Great Recession years. It seems likely that the decline of mean home values is smaller than the FHFA Housing Price Index (HPI) during the Great Recession. Silva, Eren, Heiland and Martin (2010) find the self reported home value in the HRS is approximately 10 percent higher than the final selling price over the period 1994-2008. We suspect that this number is likely to have increased over the period 2007-2012 because of the fall in the demand for homes.

On the other hand, households are likely to know their peak home value preceding the Housing Bust. Because municipalities have an incentive to keep assessments high, households are likely to know these peak home values. Moreover, many households may have believed that these peak values were the true long-run values. Accordingly, over the Great Recession years, we use the 2006 value reported by households as the basis for the calculation of home equity. In our estimation we allow the effects of the other financial variables to change during the Great Recession as well. We use two forms of local (zip-code level) foreclosure rate in our estimation: first, the foreclosure rate for years after 2006; and second, the same foreclosure rate with the effect for year 2009 zeroed out (the local foreclosure rate value for the year 2009 is replaced by zero). For both forms of the foreclosure rate variable, effects for the year 2007 are zeroed out outside Florida, California, Arizona, the Northeast and Midwest Census regions.

We experiment with several financial wealth variables, based for the most part on real non-housing wealth. Several variants use a two-part linear spline. The estimation presented in this study has an unexpected sign for real non-housing wealth in the period preceding the Great Recession. However, a spline with a knot at the median value of real non-housing wealth has an expected sign for the lower part of the spline (lower values of real non-housing wealth) and an unexpected sign only for the upper part of the spline (the same is true of the home equity spline). We conjecture that the wealthiest individuals have jobs from which they do not want to retire is not entirely unreasonable.

Since 2000 there is no longer an earnings test for Social Security for workers who retire at or above the Social Security full retirement age (normal retirement age). By allowing these individuals to work without actuarial penalty after previously collecting Social Security, the average probability of an initial retirement at or after normal retirement age should have increased. Accordingly, we include a variable interacting a post-1999 year with the male being of normal retirement age.

The final type of variable is the age-indicator variable. Together the age-indicator variables allow a flexible baseline for the proportional hazard estimation.

**[Insert Figure 1 here]**

# Results

Figure 1 presents married male annual retirement rates for both early and normal retirement ages over the period 1994-2012. Normal retirement rates show a steady decline before the 2008. It falls from 14.6 percent to 9.3 percent at the 2008. Although it bumps up and down during the Great Recession, normal retirement rates are below the 2006 level. Early retirement rates substantially fall over the period 2001-2004 from 19.5 percent to its lowest 10.2 percent. It remains the 2 percentage points of 15 percent after the 2006. Both series show a clear reverse at the 2009 in which the housing market is far away from the recovery. Older men who might have delayed retirement past 2009 because of the effect of a recessionary economy on personal wealth become more optimistic. The American Recovery and Reinvestment Act of 2009, which includes a broad spectrum of spending and tax cuts, provides a strong fiscal stimulus. The unemployment rate begins to fall, and the growth rate of GDP stops decreasing, even though housing price continues to decline.

The continued decline in the retirement rate after 2000 may be due to the elimination of earnings test and a generous adjustment of delaying Social Security benefits. Song and Joyce Manchester (2007) argue that increases in work participation aged 65-69 after the suspension of the Social Security earnings test are attributable to older workers continuing to work rather than inducing older workers back into the workforce. David M. Blau and Ryan M. Goodstein (2010) find that increases in the Normal Retirement Age and the Delayed Retirement Credit explain one quarter to one half of the recent increases in the labor force participation rate (their data span

1962 to 2005, source: CPS, SIPP, SSA). Moreover, Alan Gustman and Thomas Steinmeier (2009) alter the budget constraint in the structural model and find that approximately one-sixth of the increase in labor force participation in Health and Retirement Study between 1998 and 2004 for married men aged 65 to 67 is due to evolving Social Security policies.

**[Insert Tables 1 through 5 here]**

Definitions for the variables used in the empirical analysis are presented in Table 1 and their means and standard deviations are presented in Table 2. The results of seven models are given in Tables 3 through 5, while calculation of the Bayesian Information Criterion (BIC) and Akaike Information Criterion (AIC) for these models are presented in Table 6. The degree of financial uncertainty that starts with the Great Recession is modeled through a structural break in 2007 for variables related to housing and non-housing financial wealth.

Whether or not married households use the pre-Recession value of their home (equity) as a reference point (see Kahneman and Tversky 1979) is a debatable question. The level of uncertainty about house prices undoubtedly increased during the Great Recession. Many homes remained in a state of limbo between a homeowner who abandoned it and a bank that did not want to be held liable for the property taxes. Municipal governments treated the sales of foreclosed homes differently than other sales to protect a tax base inflated by housing boom prices. If municipal governments officially acknowledge housing price declines, tax revenues decline. On the other hand, if these governments maintain that housing prices did not decline locally since the peak of the housing boom, tax revenues remain unaffected. To the extent that assessments in many cases continue at peak or close to peak values during the Great Recession, the argument that the peak values may become reference points seems to be somewhat

**Figure 1:**


Married male retirement rates, 1994–2012
Retirement Rate
0.0
0.1
0.2
0.3
0.4
0.5
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
Year
group
Normal Retirement
Early Retirement

**Table 1**
**Variable Definitions**

| Variable | Definition |
|---|---|
| **Demographic Variables** | |
| Black | African-American indicator for male spouse (1=yes). |
| Other Race | Non-White, Non- African-American indicator for male spouse (1=yes). |
| College | College degree indicator for male spouse (1=yes). |
| Health Good | Indicator for report of good health for male spouse (1=yes). |
| Spouse Disabled | Indicator for disabled female spouse (1=yes). |
| Spouse Retired | Indicator for retired female spouse (1=yes). |
| Spouse Homemaker | Indicator for female spouse always non-working homemaker (1=yes). |
| Spouse Homemaker x Years Off | Number of years until normal retirement age of male spouse if female spouse always non-working homemaker and zero otherwise. |
| **Workplace Variables** | |
| Log Spouse Income | Log of female spouse's real annual earnings ($) in year. |
| Log Own Income | Log of male spouse's real annual earnings ($) in year. |
| Defined Benefit Plan | Indicator for whether male spouse has defined benefit plan (1=yes). |
| Defined Contribution Plan | Indicator for whether male spouse has no defined benefit plan but has defined contribution plan (1=yes). |
| Both Types of Plan | Indicator for whether male spouse has both defined benefit plan and defined contribution plan (1=yes). |
| Manager or Professional | Indicator for whether male has managerial or professional occupation(1=yes) |
| Office Worker | Indicator for whether male is office worker(1=yes) |
| **Housing Variables** | |
| Home Equity Spline Part 1 | Part 1 of spline for real value of home equity ($ million).Variable equals zero if not homeowner. |
| Home Equity Spline Part 2 | Part 2 of spline for real value of home equity ($ million).Variable equals zero if not homeowner. |
| Log Mortgage | Real value of total home loans. |
| Ownership | Indicator for whether male is home owner(1=yes) |
| **Financial Variables** | |
| Financial Assets Spline Part 1 | Part 1 of spline for real value of non-housing wealth ($ million). |
| Financial Assets Spline Part 2. | Part 2 of spline for real value of non-housing wealth ($ million).. |
| Post – 1999 Indicator | Indicator for whether the year is after 1999 (1=yes). |

**Table 1**
**Variable Definitions**
**(cont'd)**

| Variable | Definition |
|---|---|
| **Great Recession Variables** | |
| Home Equity 2006 | Real value of home equity ($ million) interacted with Great Recession. |
| Foreclosures Started July 20xx x Ownership | Percent of homes in zip code with foreclosures started in July 2007, 2008, 2010, 2011 or 2012 interacted with ownership; = 0 in other years. |
| Foreclosure Started July 2009 x Ownership | Percent of homes in zip code with foreclosures started in July 2009 interacted with ownership; =0 in other years. |
| Defined Benefit Plan x Great Recession | Indicator for whether male spouse has defined benefit plan (1=yes) ) interacted with Great Recession. |
| Defined Contribution Plan x Great Recession | Indicator for whether male spouse has no defined benefit plan but has defined contribution plan (1=yes) interacted with Great Recession. |
| Both Types of Plan x Great Recession | Indicator for whether male spouse has both defined benefit plan and defined contribution plan (1=yes). ) interacted with Great Recession. |
| Financial Assets x Great Recession | Real value of financial assets ($ million) interacted with Great Recession. |
| Manager or Professional x Great Recession | Managerial or professional occupation (1=yes) interacted with Great Recession. |
| Office Worker x Great Recession | Office Worker (1=yes) interacted with Great Recession. |
| Ownership x Great Recession | Indicator of home owners (1=yes) interacted with Great Recession. |
| **Age Indicators** | |
| Age xx | Indicator for whether male spouse is age xx in year (1=yes). The values for xx run from 59 through to 70. |
| Age 71-78 | Indicator for whether male spouse is between the ages of 71 and 78 in year (1=yes). |

**Table 2. Variable Means**

| | All Years | |
|---|---|---|
| **Variable** | **Mean** | **Std Dev** |
| **Demographic Variables** | | |
| Black | 0.095 | 0.294 |
| Other Race | 0.057 | 0.233 |
| College | 0.315 | 0.464 |
| Health Good | 0.854 | 0.353 |
| Spouse Disabled | 0.071 | 0.256 |
| Spouse Retired | 0.115 | 0.319 |
| Spouse Homemaker | 0.242 | 0.428 |
| Spouse Homemaker x Years Off | 0.128 | 0.805 |
| **Workplace Variables** | | |
| Log Spouse Income | 5.940 | 4.782 |
| Log Own Income | 8.634 | 4.110 |
| Defined Benefit Plan | 0.135 | 0.341 |
| Defined Contribution Plan | 0.436 | 0.496 |
| Both Types of Plan | 0.084 | 0.277 |
| Manager/Professional | 0.345 | 0.475 |
| Office Worker | 0.184 | 0.388 |
| **Housing Variables** | | |
| Home Equity | 0.150 | 0.387 |
| Ownership | 0.920 | 0.271 |
| **Financial Variables** | | |
| Financial Assets | 0.388 | 1.353 |
| Post – 1999 Indicator | 0.643 | 0.480 |
| **Age Indicators** | | |
| Age 59 | 0.207 | 0.405 |
| Age 60 | 0.175 | 0.380 |
| Age 61 | 0.146 | 0.353 |
| Age 62 | 0.123 | 0.328 |
| Age 63 | 0.086 | 0.280 |
| Age 64 | 0.065 | 0.246 |
| Age 65 | 0.051 | 0.220 |
| Age 66 | 0.036 | 0.187 |
| Age 67 | 0.026 | 0.159 |
| Age 68 | 0.020 | 0.141 |
| Age 69 | 0.017 | 0.128 |
| Age 70 | 0.013 | 0.114 |
| Age 71-78 | 0.035 | 0.183 |

**TABLE 3**
**PRENTICE-GLOECKLER-MEYER ESTIMATION**

| Variable Name | Model 1 Coefficient | Model 1 Std Error | Model 2 Coefficient | Model 2 Std Error |
|---|---|---|---|---|
| **Demographic Variables** | | | | |
| Black | -0.183 | 0.149 | -0.185 | 0.148 |
| Other Race | 0.044 | 0.190 | 0.039 | 0.190 |
| College | -0.264 | 0.112 | -0.259 | 0.112 |
| Very Good Health | -0.169 | 0.094 | -0.168 | 0.095 |
| Spouse Disabled | 0.259 | 0.146 | 0.255 | 0.146 |
| Spouse Retired | 0.321 | 0.127 | 0.319 | 0.126 |
| Spouse Homemaker | -0.219 | 0.122 | -0.217 | 0.122 |
| Spouse Homemaker x Years Off | -0.005 | 0.055 | -0.006 | 0.054 |
| **Workplace Variables** | | | | |
| Log Spouse Income | -0.021 | 0.010 | -0.021 | 0.010 |
| Log Own Income | -0.131 | 0.013 | -0.131 | 0.012 |
| Defined Benefit Plan | 1.610 | 0.141 | 1.610 | 0.141 |
| Defined Contribution Plan | 0.624 | 0.123 | 0.626 | 0.123 |
| Both Types of Plan | 0.875 | 0.174 | 0.879 | 0.174 |
| Manager/Professional | -0.486 | 0.120 | -0.487 | 0.120 |
| Office Worker | -0.301 | 0.127 | -0.300 | 0.127 |
| **Housing Variables** | | | | |
| Home Equity Spline Part 1 | -0.204 | 1.555 | -0.205 | 1.552 |
| Home Equity Spline Part 2 | -0.651 | 0.342 | -0.650 | 0.342 |
| Log Mortgage | -0.036 | 0.008 | -0.036 | 0.008 |
| Ownership | 0.773 | 0.212 | 0.770 | 0.212 |
| **Other Wealth Variables** | | | | |
| Non-Housing Wealth Spline Part 1 | 5.693 | 1.232 | 5.649 | 1.230 |
| Non-Housing Wealth Spline Part 2 | -0.125 | 0.066 | -0.136 | 0.067 |
| **Great Recession Variables** | | | | |
| Equity 2006 | -0.669 | 0.328 | -0.549 | 0.344 |
| Non-Housing Wealth x Great Recession | | | -0.098 | 0.096 |
| Defined Benefit Plan x Great Recession | 1.493 | 0.257 | 1.476 | 0.257 |
| Defined Compensation x Great Recession | 0.559 | 0.170 | 0.552 | 0.170 |
| Both Types of Plan x Great Recession | 1.240 | 0.260 | 1.235 | 0.260 |
| Manager/Professional x Great Recession | -0.068 | 0.180 | -0.052 | 0.180 |
| Office Worker x Great Recession | -0.446 | 0.213 | -0.427 | 0.213 |
| Ownership x Great Recession | 0.052 | 0.202 | 0.061 | 0.202 |
| Post 1999 | -0.086 | 0.085 | -0.088 | 0.085 |

**TABLE 3 (cont'd)**
**PRENTICE-GLOECKLER-MEYER ESTIMATION**

| | Model 1 | | Model 2 | |
|---|---|---|---|---|
| **Variable Name** | **Coefficient** | **Std Error** | **Coefficient** | **Std Error** |
| **Age Indicators** | | | | |
| Age 59 | -3.067 | 0.241 | -3.064 | 0.240 |
| Age 60 | -2.661 | 0.241 | -2.659 | 0.240 |
| Age 61 | -2.505 | 0.248 | -2.503 | 0.247 |
| Age 62 | -0.946 | 0.256 | -0.947 | 0.255 |
| Age 63 | -1.007 | 0.290 | -1.010 | 0.289 |
| Age 64 | -1.110 | 0.321 | -1.113 | 0.319 |
| Age 65 | -0.387 | 0.349 | -0.390 | 0.347 |
| Age 66 | -0.118 | 0.393 | -0.122 | 0.391 |
| Age 67 | -0.412 | 0.446 | -0.418 | 0.444 |
| Age 68 | -0.414 | 0.484 | -0.422 | 0.481 |
| Age 69 | -0.479 | 0.522 | -0.487 | 0.519 |
| Age 70 | -0.233 | 0.547 | -0.239 | 0.543 |
| Age 71-78 | -0.290 | 0.574 | -0.296 | 0.570 |
| Gamma Variance | 1.207 | 0.291 | 1.193 | 0.289 |
| Log L | -3930.463 | | -3929.898 | |
| LR test between Model 1 and Model 2 = | | 1.130 | | |

**TABLE 4**
**PRENTICE-GLOECKLER-MEYER ESTIMATION**

| Variable Name | Model 3 Coefficient | Model 3 Std Error | Model 4 Coefficient | Model 4 Std Error |
|---|---|---|---|---|
| **Demographic Variables** | | | | |
| Black | -0.192 | 0.151 | -0.195 | 0.149 |
| Other Race | 0.027 | 0.194 | 0.024 | 0.191 |
| College | -0.271 | 0.114 | -0.261 | 0.113 |
| Very Good Health | -0.170 | 0.096 | -0.166 | 0.095 |
| Spouse Disabled | 0.269 | 0.149 | 0.259 | 0.147 |
| Spouse Retired | 0.324 | 0.129 | 0.320 | 0.127 |
| Spouse Homemaker | -0.236 | 0.125 | -0.229 | 0.123 |
| Spouse Homemaker x Years Off | -0.006 | 0.055 | -0.007 | 0.055 |
| **Workplace Variables** | | | | |
| Log Spouse Income | -0.022 | 0.011 | -0.022 | 0.011 |
| Log Own Income | -0.132 | 0.013 | -0.130 | 0.013 |
| Defined Benefit Plan | 1.610 | 0.143 | 1.608 | 0.142 |
| Defined Contribution Plan | 0.615 | 0.125 | 0.620 | 0.124 |
| Both Types of Plan | 0.854 | 0.178 | 0.868 | 0.175 |
| Manager/Professional | -0.496 | 0.123 | -0.492 | 0.121 |
| Office Worker | -0.309 | 0.129 | -0.304 | 0.128 |
| **Housing Variables** | | | | |
| Home Equity Spline Part 1 | -0.232 | 1.571 | -0.234 | 1.558 |
| Home Equity Spline Part 2 | -0.540 | 0.336 | -0.571 | 0.336 |
| Log Mortgage | -0.037 | 0.008 | -0.037 | 0.008 |
| Ownership | 0.780 | 0.215 | 0.773 | 0.213 |
| **Other Wealth Variables** | | | | |
| Non-Housing Wealth Spline Part 1 | 5.776 | 1.249 | 5.664 | 1.239 |
| Non-Housing Wealth Spline Part 2 | -0.121 | 0.066 | -0.135 | 0.067 |
| **Great Recession Variables** | | | | |
| Foreclosure Rate | -25.223 | 10.536 | -24.226 | 10.501 |
| Foreclosure Rate x Year 2009 | -4.747 | 10.187 | -4.201 | 10.153 |
| Non-Housing Wealth x Great Recession | | | -0.140 | 0.094 |
| Defined Benefit Plan x Great Recession | 1.518 | 0.262 | 1.482 | 0.261 |
| Defined Compensation x Great Recession | 0.560 | 0.173 | 0.552 | 0.171 |
| Both Types of Plan x Great Recession | 1.251 | 0.264 | 1.245 | 0.263 |
| Manager/Professional x Great Recession | -0.103 | 0.182 | -0.063 | 0.181 |
| Office Worker x Great Recession | -0.475 | 0.216 | -0.437 | 0.214 |
| Ownership x Great Recession | 0.150 | 0.215 | 0.176 | 0.214 |
| Post 1999 | -0.084 | 0.086 | -0.087 | 0.085 |

**TABLE 4 (cont'd)**
**PRENTICE-GLOECKLER-MEYER ESTIMATION**

| | Model 3 | | Model 4 | |
|---|---|---|---|---|
| **Variable Name** | **Coefficient** | **Std Error** | **Coefficient** | **Std Error** |
| **Age Indicators** | | | | |
| Age 59 | -3.055 | 0.244 | -3.058 | 0.241 |
| Age 60 | -2.645 | 0.244 | -2.651 | 0.242 |
| Age 61 | -2.483 | 0.252 | -2.493 | 0.249 |
| Age 62 | -0.915 | 0.262 | -0.933 | 0.258 |
| Age 63 | -0.963 | 0.299 | -0.991 | 0.293 |
| Age 64 | -1.058 | 0.332 | -1.090 | 0.325 |
| Age 65 | -0.323 | 0.362 | -0.360 | 0.355 |
| Age 66 | -0.045 | 0.410 | -0.090 | 0.401 |
| Age 67 | -0.336 | 0.464 | -0.389 | 0.454 |
| Age 68 | -0.334 | 0.505 | -0.393 | 0.494 |
| Age 69 | -0.389 | 0.545 | -0.451 | 0.533 |
| Age 70 | -0.139 | 0.572 | -0.202 | 0.559 |
| Age 71-78 | -0.210 | 0.602 | -0.273 | 0.585 |
| Gamma Variance | 1.281 | 0.310 | 1.223 | 0.301 |
| Log L | -3929.337 | | -3928.069 | |
| LR test between Model 3 and Model 4 = | | 2.536 | | |

**Table 5**
**PRENTICE-GLOECKLER-MEYER ESTIMATION**

| Variable Name | Model 5 Coefficient | Model 5 Std Error | Model 6 Coefficient | Model 6 Std Error | Model 7 Coefficient | Model 7 Std Error |
|---|---|---|---|---|---|---|
| **Demographic Variables** | | | | | | |
| Black | -0.195 | 0.149 | -0.196 | 0.148 | -0.179 | 0.151 |
| Other Race | 0.037 | 0.191 | 0.032 | 0.190 | 0.033 | 0.194 |
| College | -0.257 | 0.112 | -0.252 | 0.112 | -0.281 | 0.114 |
| Very Good Health | -0.166 | 0.095 | -0.164 | 0.095 | -0.174 | 0.096 |
| Spouse Disabled | 0.253 | 0.147 | 0.249 | 0.146 | 0.279 | 0.149 |
| Spouse Retired | 0.322 | 0.127 | 0.320 | 0.126 | 0.324 | 0.129 |
| Spouse Homemaker | -0.222 | 0.123 | -0.221 | 0.122 | -0.233 | 0.125 |
| Spouse Homemaker x Years Off | -0.006 | 0.055 | -0.007 | 0.054 | -0.006 | 0.055 |
| **Workplace Variables** | | | | | | |
| Log Spouse Income | -0.021 | 0.010 | -0.021 | 0.010 | -0.022 | 0.011 |
| Log Own Income | -0.130 | 0.012 | -0.130 | 0.012 | -0.133 | 0.013 |
| Defined Benefit Plan | 1.606 | 0.141 | 1.606 | 0.141 | 1.616 | 0.143 |
| Defined Contribution Plan | 0.621 | 0.123 | 0.623 | 0.123 | 0.617 | 0.126 |
| Both Types of Plan | 0.869 | 0.175 | 0.874 | 0.174 | 0.857 | 0.178 |
| Manager or Professional | -0.488 | 0.120 | -0.489 | 0.120 | -0.495 | 0.123 |
| Office Worker | -0.301 | 0.127 | -0.299 | 0.127 | -0.311 | 0.130 |
| **Housing Variables** | | | | | | |
| Home Equity Spline Part 1 | -0.256 | 1.554 | -0.256 | 1.550 | -0.171 | 1.576 |
| Home Equity Spline Part 2 | -0.652 | 0.342 | -0.651 | 0.342 | -0.524 | 0.336 |
| Log Mortgage | -0.037 | 0.008 | -0.037 | 0.008 | -0.036 | 0.008 |
| Ownership | 0.778 | 0.212 | 0.776 | 0.212 | 0.774 | 0.215 |
| **Other Wealth Variables** | | | | | | |
| Non-Housing Wealth Spline Part 1 | 5.663 | 1.233 | 5.619 | 1.230 | 5.827 | 1.251 |
| Non-Housing Wealth Spline Part 2 | -0.125 | 0.066 | -0.133 | 0.067 | -0.119 | 0.066 |
| **Great Recession Variables** | | | | | | |
| Equity 2006 | -0.604 | 0.327 | -0.491 | 0.343 | | |
| Foreclosure Rate | -23.184 | 10.436 | -22.886 | 10.441 | | |
| Foreclosure Rate * Year 2009 | -3.534 | 9.970 | -3.397 | 9.994 | | |
| Non-Housing Wealth x Great Recession | | | -0.093 | 0.096 | | |
| Defined Benefit Plan x Great Recession | 1.484 | 0.258 | 1.468 | 0.258 | 1.533 | 0.263 |
| Defined Contribution x Great Recession | 0.570 | 0.171 | 0.563 | 0.170 | 0.546 | 0.173 |

**TABLE 5 (cont'd)**
**PRENTICE-GLOECKLER-MEYER ESTIMATION**

| | Model 5 | | Model 6 | | Model 7 | |
|---|---|---|---|---|---|---|
| **Variable Name** | **Coefficient** | **Std Error** | **Coefficient** | **Std Error** | **Coefficient** | **Std Error** |
| Both Types of Plan x Great Recession | 1.251 | 0.261 | 1.245 | 0.261 | 1.237 | 0.263 |
| Manager or Professional x Great Recession | -0.051 | 0.181 | -0.036 | 0.180 | -0.127 | 0.182 |
| Office Worker x Great Recession | -0.435 | 0.213 | -0.417 | 0.213 | -0.494 | 0.216 |
| Ownership x Great Recession | 0.209 | 0.215 | 0.216 | 0.214 | -0.031 | 0.201 |
| Post 1999 | -0.085 | 0.085 | -0.087 | 0.085 | -0.086 | 0.086 |
| | | | | | | |
| **Age Indicators** | | | | | | |
| Age 59 | -3.073 | 0.241 | -3.070 | 0.240 | -3.045 | 0.244 |
| Age 60 | -2.667 | 0.241 | -2.665 | 0.240 | -2.635 | 0.245 |
| Age 61 | -2.510 | 0.248 | -2.509 | 0.247 | -2.472 | 0.253 |
| Age 62 | -0.953 | 0.256 | -0.955 | 0.255 | -0.899 | 0.264 |
| Age 63 | -1.015 | 0.290 | -1.019 | 0.287 | -0.944 | 0.300 |
| Age 64 | -1.115 | 0.322 | -1.120 | 0.320 | -1.041 | 0.333 |
| Age 65 | -0.391 | 0.350 | -0.397 | 0.348 | -0.304 | 0.363 |
| Age 66 | -0.127 | 0.394 | -0.132 | 0.392 | -0.021 | 0.411 |
| Age 67 | -0.428 | 0.447 | -0.436 | 0.444 | -0.301 | 0.467 |
| Age 68 | -0.432 | 0.485 | -0.442 | 0.482 | -0.295 | 0.507 |
| Age 69 | -0.492 | 0.524 | -0.503 | 0.520 | -0.354 | 0.547 |
| Age 70 | -0.244 | 0.548 | -0.254 | 0.545 | -0.104 | 0.574 |
| Age 71-78 | -0.313 | 0.574 | -0.323 | 0.570 | -0.162 | 0.605 |
| | | | | | | |
| Gamma Variance | 1.202 | 0.292 | 1.186 | 0.289 | 1.302 | 0.312 |
| Log Likelihood | -3927.482 | | -3926.986 | | -3932.726 | |
| LR test between model 5 and model 6 = | | | 0.992 | | | |
| LR test between model 5 and model 7 = | | | 12.768 | | | |

strengthened. Unless they sell their home, the peak value is the only true value that homeowners know.

Models that we estimate are consistent with the idea that households use peak housing values as a reference point after the Great Recession starts. Households are uncertain about the true current value of their home. Households are certain only about the peak value of their home and the fact that the true current value is substantially lower than the peak. The greater is the peak value, the greater is the amount of wealth possibly lost. So, if households respond to lost wealth by delaying retirement, a possible conclusion to be drawn is that Great-Recession retirement rates are lower, the higher is the peak value of housing.

The Prentice-Gloeckler-Meyer estimation results for the first self-reported retirement of male spouses using the pre-Recession peak housing value to calculate 2006 home equity are presented in Table 3. The effect of financial wealth after 2006 is excluded in Model 1 and included in Model 2.[3] Corresponding estimation results using the local foreclosure rate[4] and not 2006 home equity are presented in Table 4. Models 5 and 6 in Table 5 include both 2006 home equity and the local foreclosure rate. Model 7 is the baseline model for model selection; it excludes 2006 home equity, the local foreclosure rate and financial wealth variables in the post-2006 period.

Table 6 gives BIC and AIC for the seven models. Because of the large number of parameters in our study, model selection penalties for additional parameters using BIC are

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[3] Similarly, in Tables 3 through 5 even-numbered models include post-2006 financial wealth while odd-numbered models do not.

[4] The local foreclosure rate represents the percentage of homes in the zip code for which foreclosure proceeding start in the first week of July of the given calendar year. The variable is zeroed out for renters. In 2007, the start of the Great Recession, the variable is zeroed out for residents of states other than California, Arizona, Florida and those in the Northeast and Midwest. For 2009 only, the variable has a new value for residents of all states.

substantially larger than those using AIC. In our case this means that BIC will always choose the model with fewer additional parameters, while AIC may choose the larger model. Therefore, we will use AIC as our model selection criterion. AIC indicates that Model 5, the model including 2006 home equity and the local foreclosure rate but excluding financial wealth in the post-2006 period, is best. Figure 2 presents the predicted retirement rates from Model 5. It captures the empirical retirement rates in Figure 1 very well.

**[Insert Table 6 and Figure 2 here]**

The first important result in Model 5 is that the coefficients of the 2006 home equity and the local foreclosure rate for the post-2006 period are jointly significant negative. The second important result is that unobserved heterogeneity matters. The Gamma-distributed random effect is significantly greater than zero at the 1 percent level.

Looking next at the demographic variables, race does not matter for retirement behavior, but having a college degree and being in good health both significantly delay retirement. Male spouses are more likely to retire if their wives have already retired. This is consistent with the life cycle theories and other studies claiming couples will jointly retire and enjoy more leisure together. Male spouses are less likely to retire if their wives are homemakers.

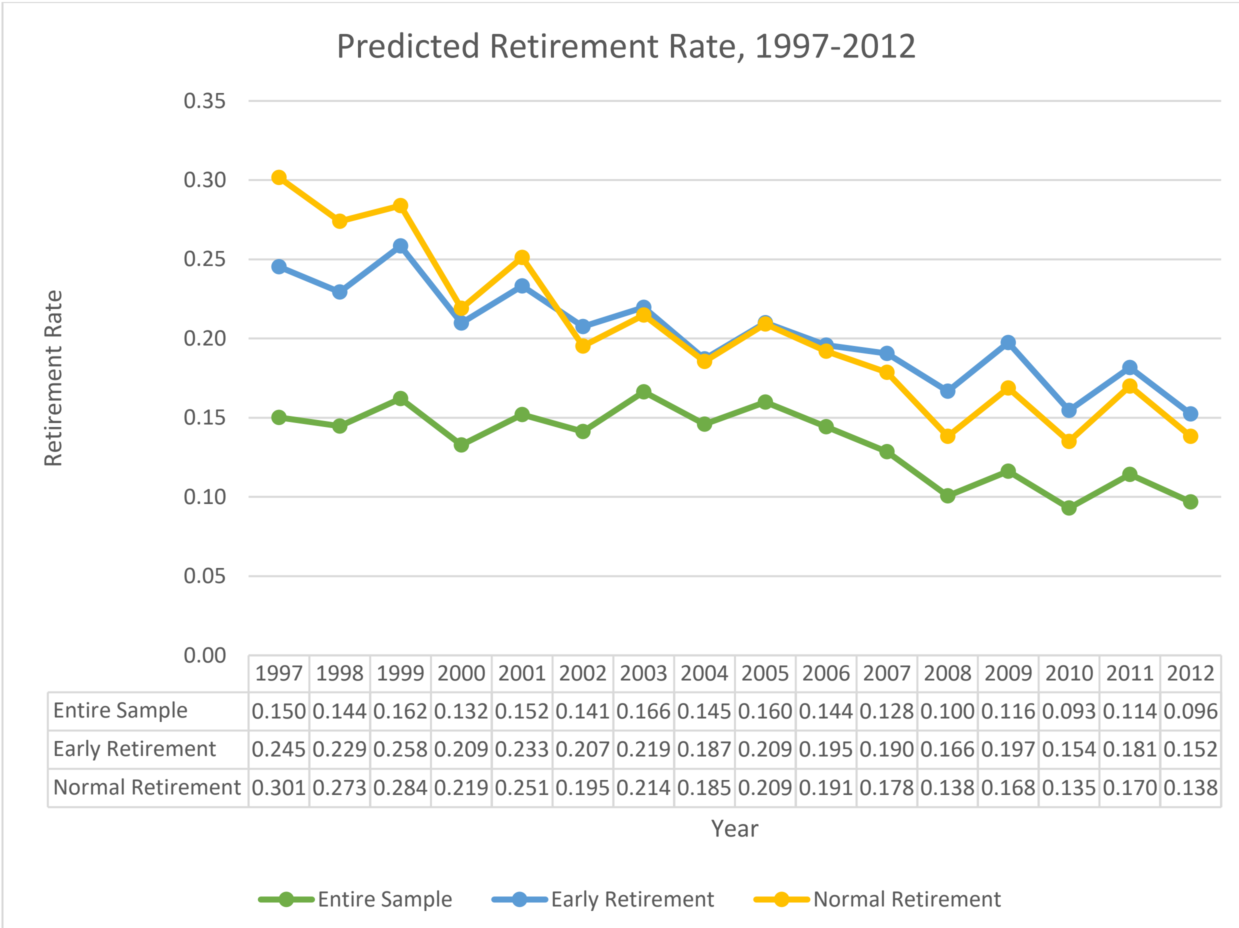
The workplace variables are better predictors of retirement behavior than the demographic variables. A married male will delay his retirement the higher is his own income, and the higher is his wife's income.

The effect of having a defined benefit plan apparently swamps the effect of having a defined contribution plan, although having either type of plan significantly increases the retirement hazard rate. These results do not change qualitatively in the period after 2006.

**Table 6: Model Selection Criteria**

| | **BIC** | **AIC** |
|---|---|---|
| Model 1 | 8170.768 | 7946.926 |
| Model 2 | 8176.844 | 7947.796 |
| Model 3 | 8175.722 | 7946.674 |
| Model 4 | 8180.392 | 7946.138 |
| Model 5 | 8179.226 | 7944.972 |
| Model 6 | 8185.431 | 7945.972 |
| Model 7 | 8168.089 | 7949.452 |

**Figure 2:**




| | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Entire Sample | 0.150 | 0.144 | 0.162 | 0.132 | 0.152 | 0.141 | 0.166 | 0.145 | 0.160 | 0.144 | 0.128 | 0.100 | 0.116 | 0.093 | 0.114 | 0.096 |
| Early Retirement | 0.245 | 0.229 | 0.258 | 0.209 | 0.233 | 0.207 | 0.219 | 0.187 | 0.209 | 0.195 | 0.190 | 0.166 | 0.197 | 0.154 | 0.181 | 0.152 |
| Normal Retirement | 0.301 | 0.273 | 0.284 | 0.219 | 0.251 | 0.195 | 0.214 | 0.185 | 0.209 | 0.191 | 0.178 | 0.138 | 0.168 | 0.135 | 0.170 | 0.138 |

For the pre-Great Recession years, married males who own a home tend to retire earlier, but this effect is mitigated the greater is any mortgage. Home equity enters the specifications as a two-part spline with the knot at the median pre-2007 level of home equity ($94K in 2005 dollars). Both parts of the spline have coefficients that are insignificantly negative at the 5 percent level based on a two-tailed test. A possible reason for these signs is that married males with greater home equity do not retire as early because they have jobs that they find pleasant. But note that the point estimate of the coefficient for the home-ownership indicator dominates the effect of home equity so that the combined effect is positive.

The situation changes with the Housing Bust. We have argued that, after the Housing Bust, homeowners become more uncertain about current and future values of homes and that retirement is delayed when the uncertainty and possible equity loss, which is correlated with pre-Housing Bust home values, increases. The coefficient on home equity is negative with a one-tailed p-value of 0.0301. The coefficient has the same magnitude as the second part of the home-equity spline before the Housing Bust. So, we cannot conclusively say that married males who own their homes delay retirement because of concerns over possible equity loss, because we cannot rule out job satisfaction as the reason for the delay. However, the coefficient of the home-ownership indicator has become insignificant, suggesting that housing wealth matters less after the Housing Bust.

**[Insert Figures 3, 4 and 5 here]**

The coefficient on the local foreclosure rate has a p-value less than 0.01, suggesting that a higher foreclosure rate decreases the retirement rate of homeowners. (The LR Chi-square of joint significance for home equity and the local foreclosure rate also has a p-value less than 0.01.) Figures 3-5 present the average predicted retirement rates based on model 5 for three cohorts at the 10th percentile, median, and 90th percentile values for the local foreclosure rate over the period from 2007 to 2012. The largest difference between the 10th percentile and the 90th percentile is always at early retirement age and at normal retirement age. The retirement rate of 10th percentile would decrease by about 25 percent if a male were living in an area with the 90th percentile foreclosure rate.

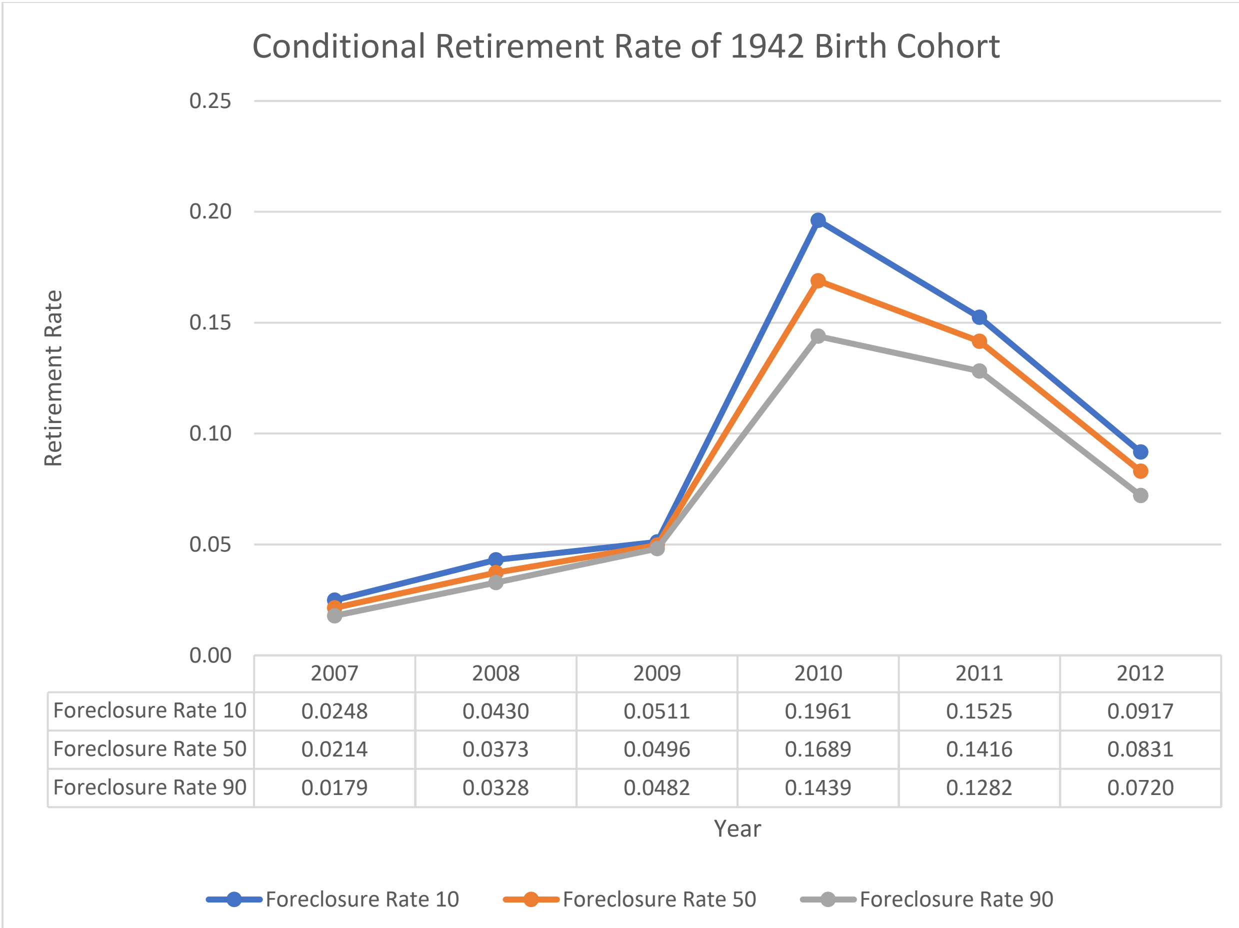
The level of financial assets in years before 2007 enters the specifications as a two-part spline with the knot at the median pre-2007 level of financial assets ($107K in 2005 dollars). The first part of the spline (to the left of the knot)) is significantly positive with a p-value less than 0.01. This is consistent with the hypothesis that households with more wealth retire earlier. The second part of the spline, with higher values of financial wealth, is negative but insignificant.

The retirement hazard rate increases sharply at early retirement age and again at normal retirement age. It declines gradually thereafter.

## Summary

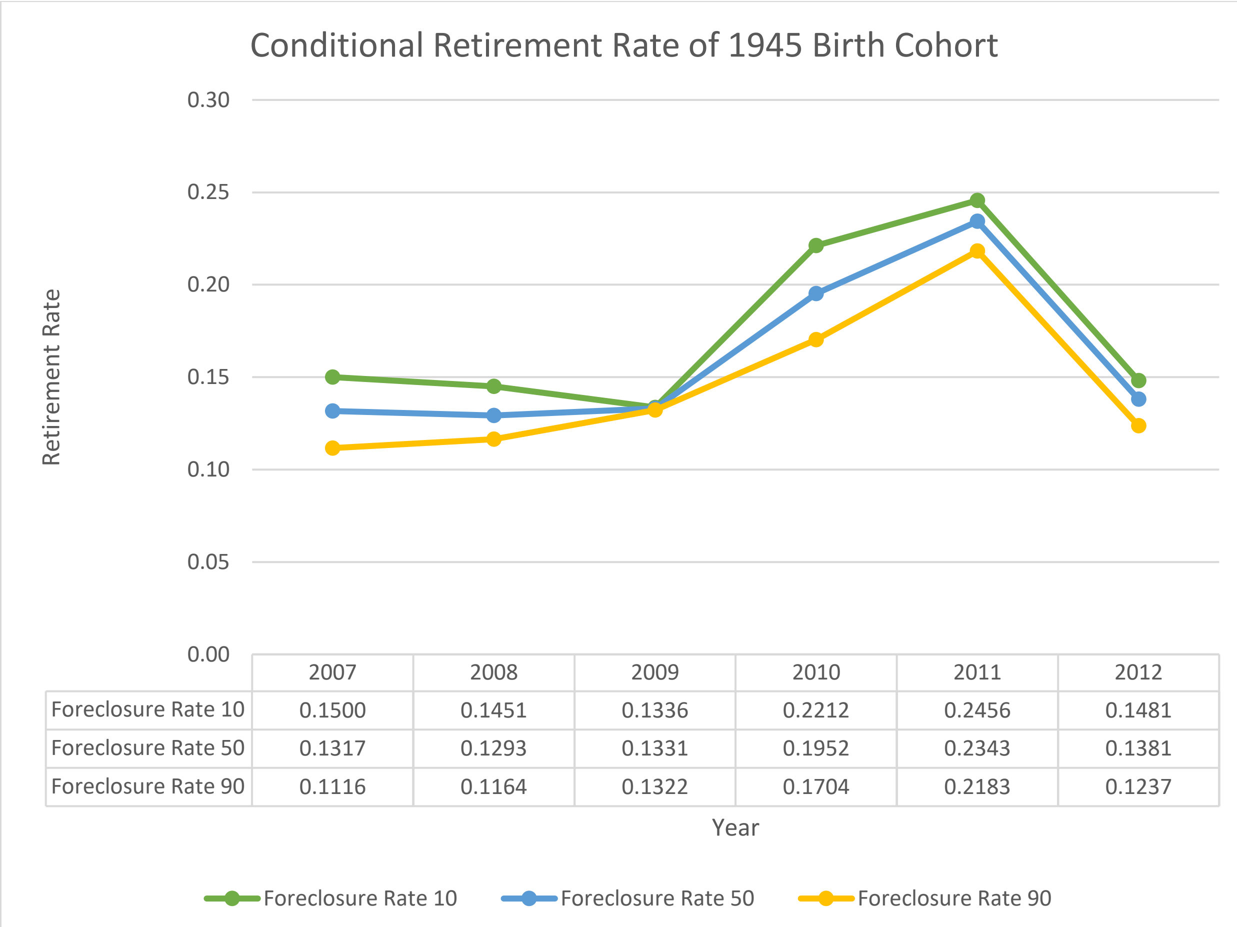
This study uses Health and Retirement Study data from waves 1992 through 2012 together with restricted SSA data on geographic location to estimate a model of the age at first self-reported retirement for the subsample of married males. The model covariates include demographic variables, workplace variables, non-housing financial wealth, and housing equity. We estimate proportional hazard models with controls for unobserved heterogeneity and find that controlling for unobserved heterogeneity improves the fit. The proportional hazard estimates are, for the most part, significant and of the correct sign. The model estimates are consistent with the hypothesis that uncertainty about the extent of current and future declines in housing wealth after the Housing Bust significantly delayed the retirement of married males. In particular, the effect of local foreclosures on the retirement rate significantly decreased retirement rates in four parts of the country (Northeast, Midwest, Florida, and Arizona/California) in 2007. The effect was national by 2008.

**Figure 3:**



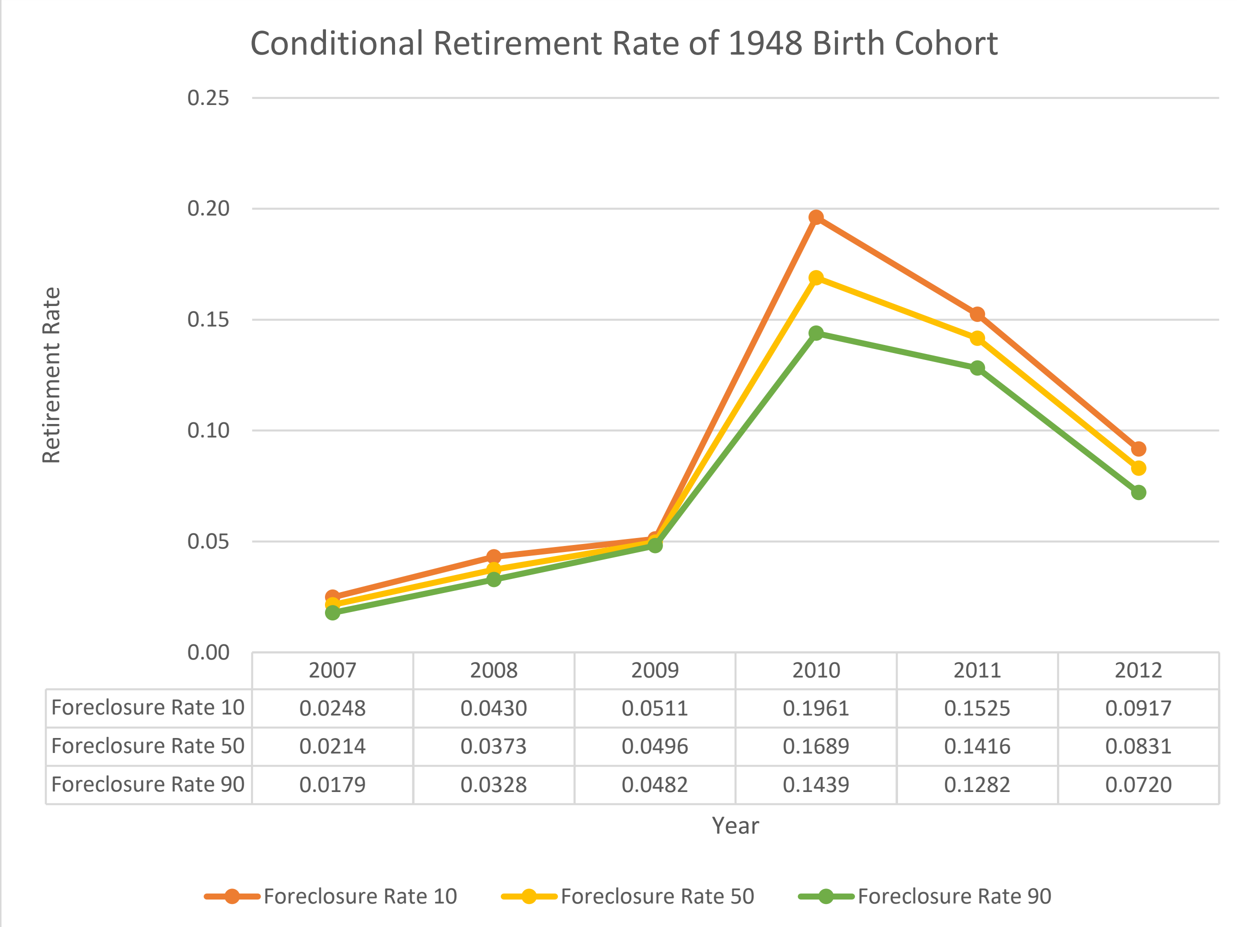

| | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 |
|---|---|---|---|---|---|---|
| Foreclosure Rate 10 | 0.0248 | 0.0430 | 0.0511 | 0.1961 | 0.1525 | 0.0917 |
| Foreclosure Rate 50 | 0.0214 | 0.0373 | 0.0496 | 0.1689 | 0.1416 | 0.0831 |
| Foreclosure Rate 90 | 0.0179 | 0.0328 | 0.0482 | 0.1439 | 0.1282 | 0.0720 |

**Figure 4:**




| | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 |
|---|---|---|---|---|---|---|
| Foreclosure Rate 10 | 0.1500 | 0.1451 | 0.1336 | 0.2212 | 0.2456 | 0.1481 |
| Foreclosure Rate 50 | 0.1317 | 0.1293 | 0.1331 | 0.1952 | 0.2343 | 0.1381 |
| Foreclosure Rate 90 | 0.1116 | 0.1164 | 0.1322 | 0.1704 | 0.2183 | 0.1237 |

**Figure 5:**




| | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 |
|---|---|---|---|---|---|---|
| Foreclosure Rate 10 | 0.0248 | 0.0430 | 0.0511 | 0.1961 | 0.1525 | 0.0917 |
| Foreclosure Rate 50 | 0.0214 | 0.0373 | 0.0496 | 0.1689 | 0.1416 | 0.0831 |
| Foreclosure Rate 90 | 0.0179 | 0.0328 | 0.0482 | 0.1439 | 0.1282 | 0.0720 |

# Chapter 2

## Outline

The aging population has become substantially larger as baby boomers have started entering the end of their working lifetime, when the security provided by wealth becomes more important. Approximately 80 percent of households near retirement age are homeowners and housing wealth is the principal form of savings for the majority of households. This figure declines only slightly until age 80, after which there is greater mortality and nursing home utilization.

It is still a puzzle why the elderly rarely tap into housing wealth. Hurd and Smith (2001) find that death and medical expenses do not substantially reduce the size of estates in the Asset and Health Dynamics Among the Oldest Old (AHEAD). Venti and Wise (2004) find that elderly movers are not typically taking substantial home equity out of their housing wealth to support other consumption. Furthermore, couples are even likely to move into more expensive homes after entering retirement or widowhood. Few elderly American households have sufficient financial wealth for increasing medical costs. In fact, the total wealth (including housing wealth) of many older workers may be inadequate unless they are willing to move into smaller homes (Skinner 2007). Recently, a growing empirical literature argues that consumption responds to house price movements, thus suggesting housing wealth should not be ignored in the dynamic consumption model (Campbell and Cocco 2007; Mian, Rao, and Sufi et al. 2013.). On the other hand, an increasing number of studies construct life cycle models with durable consumption and examine the effects of housing wealth on non-durable consumption, asset accumulation, financial investment and labor incentives.

Ondrich and Falevich (2015) estimate hazard models to show that significant declines in housing wealth delay retirement. If consumers only expect a slow recovery from large housing price declines, borrowing constraints related to housing wealth may hurt their ability for smooth consumption after retirement and force them to work more. Furthermore, housing wealth plays an important role in the precautionary saving and bequest motive. It may be used to pay unexpected medical costs and large funeral fees. In addition, a desired bequest level may force elderly households to work more and leave more non-housing wealth to offset the loss of housing wealth. Although housing investment decisions are not considered, the purpose of this paper is to study the role of housing wealth on retirement plans in a structural framework.

There are four possible explanations why the elderlies are reluctant to tap housing wealth. The first one is psychological. The elderly may find it difficult to leave a place where they have lived for a long time and have a well-established social network. The second explanation is that home ownership may provide utility. The third explanation is precautionary savings. An uncertain lifespan and medical costs are two large contingencies for the elderly. Venti and Wise (2004) argue that housing wealth is ideal for future contingencies because home equity can easily be used to finance unexpected shocks. However, they note that utilization of reverse mortgages and selling homes are available options not commonly used by retirees. The fourth explanation is the bequest motive. When the elderlies treat their children as their own extended lives, planning a bequest of housing wealth is reasonable. Incorporating bequests into an economic model is problematic. Dynan, Skinner and Zeldes (2002) explain that it is virtually impossible to distinguish a bequest from precautionary saving.

To study retirement behavior, it is important to take account of non-housing resources available to households as well. Social Security is one of the important source of income affecting the living standards of the elderly. Unfortunately, Social Security expenditures already represent a large portion of government spending. In 2002 Social Security expenditures accounted for 22.6 percent of Federal spending[5]. Moreover, these expenditures are expected to increase substantially as baby boomers begin to the retire and the program's future solvency is a major policy concern.

The goal of Social Security is to provide insurance against a long lifespan. However, Social Security distorts incentives to work and may cause people to retire early (see.French 2005, and Blundell, French, and Tetlow 2017). According to previous studies, for example, Blau (1994), French (2005), French and Jones (2011), and Gustman and Steinmeier (2015), there is a spike in the retirement rate at early retirement age. Some unusual application strategies can maximize Social Security wealth, but we find little evidence that the elderly know about those strategies. Hence, we do not attempt to model non-standard application strategies. Finally, because sample members in the sample used in this study were born between 1940 and 1945, Social Security rules enacted in 2000 that eliminate the earnings test after the normal retirement age apply.

Pensions and spousal income outside of Social Security are also included as liquid assets in our model, even though we do not distinguish between single, widowed and coupled males. Although males with any marital status may be sample members, wealth measurements in the Health and Retirement Study (HRS) are at the household level. Pensions are included in our model as annuities, and spousal income is included as a determinate function of male health and age.

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[5] URL: https://www.ssa.gov/history/percent.html

Medical costs, health insurance and Medicare are the focus of several studies in the last decade (see, for example, Rust and Phelan 1997, French 2005, De Nardi, French, and Jones 2010, and French and Jones 2011). It is important to include these factors in a discussion of retirement behavior. Poor health not only limits the functional ability but also induces higher medical expenses for the elderly. Time persistence of medical costs accelerates the decline of liquid wealth. Moreover, if the elderlies suffer from severe health problems and must move to a nursing home, the extraordinarily high medical costs may force them to tap housing wealth. Medicare may be the main reason for a second-high retirement rate peak at age 65, because deduction of medical costs from Medicare decreases out-of-pocket medical costs. Our model considers the dynamics of medical costs through three insurance types: no insurance, retiree covered insurance and job-tied insurance. This insurance categorization follows the model of French and Jones (2011).

In summary, this paper studies retirement and saving behavior and the bequest motive through housing wealth in a world of risks, with five main sources of uncertainty: health status, wage, medical cost, and mortality risk as determined partially by health status, as well as housing prices. We construct a life-cycle model with wealth and bequest components and distinguish between liquid assets and housing wealth. We experiment with the two asset accumulations and constraints and examine the savings behavior in the presence of housing wealth. The most relevant financial variables are carefully addressed. Additionally, we take into account the strong bequest motive among wealthy households and the manner in which social welfare programs affect poor households. The Method of Simulated Moments (MSM) is used to estimate parameters in the life cycle model. Robustness checks are based on the models without housing wealth and heterogeneity.

The literature review is presented in the following section. It includes important studies in Social Security, retirement, housing, saving behavior, and methodologies. The third section develops the construction of a life cycle dynamic model. Two alternative asset accumulation equations to cope with housing wealth are compared and discussed. The first takes into account the "imaginary" part of housing wealth in the liquid asset accumulation. The other one follows two traditional types of consumption model with a collateral constraint. The purpose is to account for households with high housing wealth but low non-housing wealth. The fourth section describes the data preparation and profile estimation. This is followed by a discussion of the moment conditions and methodology used in the paper. The methodology contains the numerical solution to the dynamic programming problem and Minimum Distance Estimation to identify the parameters. The sixth section presents the estimation results, model fitness and robustness check, followed by a comparison of three counterfactual experiments. The final section presents conclusion and discussion.

## Literature Review

In the last two decades, many papers show that Social Security is one of the main reasons for the high retirement rate at age 62 and availability of Medicare causes another peak at normal retirement age[6]. Rust and Phelan (1997) implement Rust's dynamic discrete choice framework to analyze how Social Security and Medicare affect the labor supply of poorer households. Saving behavior is not modeled, but the model fits actual labor supply behavior and accounts for the spikes in retirement at 62 and 65. However, liquidity constraints and saving behavior may be needed to study the effects of the Social Security rules on lifetime labor supply more generally

[6] Social Security Disability Insurance is an important part of the Social Security program. This paper mainly focuses on the retirement benefits.

(French 2005). Blau (2008) shows that median assets in the HRS grow until people are in their later 60s. Furthermore, French and Jones (2011) take account of health insurance and medical costs in their structural model and find that people without health insurance are more likely to retire at the normal retirement age, while people with health insurance are more likely to continue to work. None of these studies separate housing wealth from total wealth.

Some reduced-form studies conclude that Social Security is one of the main reasons older workers retire at age 62. Blau (1994) analyzes labor force movements of older men using quarterly data from the Retirement History Survey, and his estimates indicate that Social Security benefits have strong effects on labor force transitions of older men. Medicare availability may cause the retirement spike at age 65. Using an option-value model, Coile and Gruber (2007) implement forward-looking models and invent a new measure which they call peak value to show that higher future Social Security benefits delay retirement. However, reduced-form studies often model retirement and Social Security claim as simultaneous decisions. An exception is Hurd, Smith and Zissimopoulos (2004), who use a bivariate probit model to study Social Security claim and retirement behavior at age 62. They find that people with a high subjective survival probability retire earlier and claim Social Security earlier. The advantage of the dynamic programming model which we use is that it allows households to be forward-looking and make various decisions interactively.

It is not clear how well structural models can predict actual Social Security claiming behavior in the face of rules and economic environment changes. Many policy changes increase the gains from delays in claiming, particularly for cohorts that are eligible to collect Social Security after 2000. It has been shown theoretically that postponing the claiming of Social Security is advantageous for most individuals, especially couples, given increases in life expectancy and recent declines in interest rates (Shoven and Slavov, 2012, 2013). However, empirical evidence does not agree. Gustman and Steinmeier (2015) use the MSM technique to estimate an enhanced version of a structural model that jointly explains benefit claiming, wealth and retirement with uncertain interest rates and wages. They find that the observed timing of claims in the HRS is earlier than the optimal timing. They estimate that observed timing and optimal timing would coincide if benefits were cut 20 percent, suggesting that individuals expect benefit cuts in the future.

In the traditional life-cycle model, a significant decline in housing prices should have a strong impact on life-cycle wealth and hence on retirement consumption and other related behavior. Skinner (1996) takes advantage of housing windfalls during the 1970s to study consumption responses and argues that housing wealth is not a sideshow. But if households do not tap housing wealth, how is housing wealth embodied into the budget constraint? Rising house prices may stimulate consumption by increasing household's perceived present and expected future wealth or by relaxing borrowing constraints. Campbell and Cocco (2007) find that regional house prices affect growth in regional consumption, but do not provide a structural justification. There are some studies on housing wealth and life-cycle portfolio choices (Cocco 2004, Yogo 2016). Kaplan and Violante (2014) develop an optimal life cycle model with two assets and replicate the phenomenon that many households hold little or no liquid wealth despite owning sizable quantities of illiquid assets. They solve the long-term Euler equation for housing investment and compare it to the short-term one. They find strong wealth effects on consumption.

Precaution against future contingencies is the primary reason for saving. The Survey of Consumer Finance Finds the primary reason to be retirement (for 45 percent of households), emergency or illness (40 percent), and estate (15 percent) (Dynan, Skinner, and Zeldes, 2002). Bequests are likely to be luxury goods. Although households may care about leaving money to their descendants, adding a bequest motive on top of an existing motive for precautionary saving would have relatively little impact on capital accumulation for nearly all households, except maybe those at the highest wealth level. De Nardi (2004) develops a quantitative overlapping-generations model in which parents and children are linked by voluntary bequests and replicates empirical wealth inequality in old age: bequests are luxury goods.

Recently, more attention has been paid to durable consumption in the life-cycle model. Cocco (2004) studies the effect of housing wealth on the portfolio choice of stock and bond investment in the Panel Study of Income Dynamics (PSID). Campbell and Cocco (2014) extend Coco's model to incorporate fixed and adjustable rate mortgages and construct a structural mortgage-default model. In the labor field, Aaronson, Agarwal and French (2013) include housing wealth in asset accumulation and study the spending and debt response to changes in the minimum wage. Including housing wealth allows the agents to have debt on an asset and guarantees no bankruptcy through a collateral constraint. Nakajima and Telyukova (2017) give a thorough study of the utilization of reverse mortgage loans in the HRS. Many of the models are partial equilibrium in the sense that housing price is exogenous. The study by Burnside, Eichenbaum, and Rebelo (2016) is an exception. Their study successfully generates the boom-bust episodes when skeptical agents happen to be correct.

Because of computational improvements, more complex structural models can now be estimated. Discrete choice dynamic programming is widely used in labor economics, industrial organization, and other fields. General surveys are found in Rust (1994), Aguirregabiria and Mira (2010), and Todd, Wolpin, and Keane (2010). Rust (1987) proposes a framework for estimating parameters in structural models and uses it empirically solve the optimal bus-engine replacement problem. Rust (1994) describes the process of dynamic structural model estimation and both partial and full information estimators in detail. By imposing an extreme value distribution, the likelihood function becomes closed form and easily estimated by maximum likelihood estimation (MLE). However, when decisions are continuous and unobservable, like consumption, the MLE method becomes difficult. As an alternative, McFadden (1989) develops the MSM to deal with high-dimensional decisions. The criterion is minimization of weighted mean-square error. Epple and Sieg (1999) extend this technique to estimate quantile moments. Rust (1997) proves that the Monte Carlo randomization method in dynamic models is useful to break the curse of dimensionality and asymptotically approaches a normal distribution. Empirical applications are Gourinchas and Parker (2002) for consumer behavior, French (2005) for retirement, and Del Boca, Flinn, and Wiswall (2014) for education investment.

## Forward-Looking Structural Model

The starting point is the structural model developed by French and Jones (2011). A representative agent faces five time-varying uncertainties: mortality, wages, housing price, health status, and latent health-dependent re-entry type. Utility at time *t* takes the Cobb-Douglas form:

$$u_t(C_t, L_t) = \frac{1}{1-\nu} * (C_t^{\alpha} * L_t^{1-\alpha})^{1-\nu} \tag{6}$$

where $C_t$ is consumption at age $t$, and $L_t$ is leisure at age $t$. The within-period leisure constraint is given by:

$$\begin{aligned} L = L_t + Hours_t + \theta_0 * I(Health_t = bad) + \\ \theta_w * I(Par_t = 1) + \theta_r * I(Par_t = 1 \mid Par_{t-1} = 0, R_t = 1) \end{aligned} \tag{7}$$

where $L$ is the total time endowment, $Hours_t$ is the chosen number of working hours, $\theta_0$ is the time cost of poor health, $\theta_w$ is the time cost of labor force participation and $Par_t$ is one if the individual chooses to be in the labor force at age $t$, $\theta_r$ is the time cost of labor force re-entry. $R_t$ is the dependent re-entry latent class type (re-entry is possible only for individuals with $R_t$ equal to one); $R_t$ is a logit probability, the index function for which falls with poor health and as individuals age.

The time cost of labor force participation is given by:

$$\theta_w = \theta_1 + \theta_2 (t - 60) \qquad (8)$$

where $\theta_1$ is the fixed time cost of working, and $\theta_2$ is the age-dependent variable time cost of working. These two time costs take into account the empirical clustering of working hours at 0 and 2000 hours per year, and allow leisure to be more valuable when people get older. $\theta_r$ is zero when there is lagged labor-force participation or the current re-entry is not possible. If retirees want to work again, they experience loss of leisure to find a new job. More details on $R_r$ are presented in the profile estimation section. The model is a partial equilibrium of labor supply market in which wage is exogenous. To determine wages within the model, we calibrate the wage elasticity from French and Jones (2011).

Asset accumulation within the model is determined by five resources: wages, Social Security benefits, private pensions, spousal income and an unknown proportion of housing wealth. Given that we do not allow bankruptcy, assets should be non-negative. But putting housing wealth into the assets accumulation equation directly will allow those who are housing rich but financially poor to sometimes be in violation of the nonnegative asset constraint. To prevent this from happening, we impose a collateral constraint. Housing wealth is taken to be exogenous. Kaplan and Violante (2015) provide an excellent life-cycle model with housing choice. For downsizing homes, readers can refer to Yogo (2016). The asset accumulation equation is given by:

$$A_{t+1} + \phi * H_{t+1} = A_t + \phi * H_t + Y_t - C_t - M_t \tag{9}$$

$$A_t \geq 0, \forall t \tag{10}$$

where $A_t$ is non-housing assets, $H_t$ is housing wealth, $Y_t$ is after-tax household income including Social Security and pension benefits and return on assets, $C_t$ is a consumption, and $M_t$ is medical costs. $\phi$ is an unknown parameter that captures the percentage of housing wealth that households view as liquid. Thus, consumer and saving behaviors are affected by housing wealth. When solving the optimization, we move the term of $\phi * H_t$ to the left side and use $A_{t+1} + \phi * (H_{t+1} - H_t)$ as total assets.

We use the 2004 head of households tax formula from taxfoundation.org to obtain available after-tax income. After-tax income is given by:

$$Y_t = Y(W_t * Hours_t + B_t * SS_t + ps_t + sp_t + r * A_t, \tau) \tag{11}$$

where $W_t$ is the hourly wage rate, $SS_t$ is Social Security benefits, $B_t$ is the Social Security application decision, $ps_t$ is pension benefits, $sp_t$ is spousal income, and $r * A_t$ is the return on assets. The interest rate is set equal to 2.5 percent.

A modified model comprises the original model with a modified asset accumulation process. The modified version is given by:

$$A_{t+1} = A_t + Y_t - C_t - M_t \tag{12}$$

$$A_t \geq -\pi_{eqline} * H_t, \forall t \tag{13}$$

where $A_t$ is allowed to be negative, but debt cannot be larger than the equity line on housing wealth. The equity line percentage is set to 0.75 across the entire life cycle. Moreover, there is no fixed cost from borrowing housing wealth. The results of the modified model improve the asset accumulation performance over the original model results.

Government provided aid guarantees a minimum consumption level for households. Because of these social welfare programs, households with low assets may be reluctant to save. The government transfers equation is based on Hubbard, Skinner and Zeldes (1994):

$$tr_t = \max\left\{0, C_{floor} - (A_t + Y_t - M_t)\right\} \tag{14}$$

where $tr_t$ is government transfers at time $t$, and $C_{floor}$ is the guaranteed consumption floor. There are many social welfare programs for poor households, such as SSI, food stamps, and Medicaid. Transfers take place after agents run out of current cash-on-hand and are triggered at the next period. Therefore, poor families tend to maintain low assets to obtain government transfers. If growing housing wealth increases consumption and decreases savings, it may impose more financial burden on the social welfare program.

If the agent dies in the next period, total wealth is the input of the bequest function. With no bequest motive, total wealth is optimally exhausted at the final period. However, empirical evidence shows a great amount of wealth left upon the elderly's death. Lee Lockwood (2012) summarizes properties of different bequest functions in theoretical and empirical studies. The empirical bequest equation is given by:

$$b_t(A_{t+1}+H_{t+1})=\theta_b*\frac{(A_{t+1}+H_{t+1}+\theta_k)^{(1-\nu)*\alpha}}{1-\nu} \qquad (15)$$

where $\theta_b$ is marginal propensity of consumption from bequest, and $\theta_k$ is the curvature of the bequest function. Importantly, the original and modified models include housing wealth in the bequest motive. One robustness check eliminates housing wealth from the bequest component. Intuitively, if $\theta_b$ is high, the consumption path will also be higher and wealth path lower. $\theta_k$ is the curvature of the bequest equation. Families with total wealth above $\theta_k$ will leave a bequest.

Given the above setup, the Bellman equation is:

$$\begin{aligned} &V_t(S_t;\Theta)=Max_{(C_t,Hour_t,B_t)}U_t+\beta*s_{t+1}* \\ &E\left[V_{t+1}(S_{t+1};\Theta)\,|\,S_t,d_t\right]+\beta*(1-s_{t+1})*b_t(A_{t+1}+H_{t+1}),t\in\{55,...,85\} \end{aligned} \qquad (16)$$

where $S_t$ is the set of state variables at time $t$, $s_t$ is the conditional survival probability at time $t$, and $d_t$ represents the set of decision variables. $\Theta$ is the set of unknown parameters, $\{\alpha,\beta,\nu,L,\theta_0,\theta_1,\theta_2,\theta_r,\theta_b,\theta_k,C_{floor},\phi\}$ .

The econometric methodology is based on John Rust's framework combined with MSM. Belief equations constituting an individual's profile are estimated before estimating preference parameters. Belief equations are independent during estimation[7]. Preference estimation is performed in two loops. In the inner loop, we use backward induction to solve maximization of the Bellman equation. Discretization is used to address continuous state variables. We use Tauchen's (1986) method to generate the Markov transition matrix for wage innovations and

[7] This is the conditional independent assumption in John Rust (1994). Full information estimation needs to adjust data generating process during preference parameters estimation. To save time, we use partial information estimation.

medical cost innovations. Because the housing price innovation is i.i.d, five-point Gaussian quadrature is used to solve the expectation of the home price. After solving the dynamic programming problem, three-dimension linear interpolation is used to obtain solutions for consumption, working hours, participation, and Social Security application. In the outer loop, we use the simplex method and MSM to estimate parameters by minimizing the distance between simulated and observed moments.

## Data and Life-Cycle Profile

### HRS Data

We use the HRS to estimate. The main dataset is Rand HRS version p, which includes data from 1992 to 2014. HRS surveys respondents are interviewed every two years and new cohorts are added into the survey every six years. The respondents in our sample are born between 1941 and 1945. The reasons for choosing these particular cohorts are twofold. First, the youngest respondents are age 69 in the year 2014, which are the last moment age and last calendar year, respectively, in the survey. Second, the normal retirement age can be fixed at age 66. The average birth year is close to 1943. For the 1940 cohort, the normal retirement age is 65 and six months. Normal retirement age gradually increases to age 66 for birth years after 1937 and before 1954. On the other hand, we drop respondents who do not pay Social Security tax for five years and work for the government. The effect of private pension plans is higher than Social Security for these respondents. Moreover, some are not eligible for Social Security benefits. To make the sample larger, we do not drop the respondents who collect Social Security Disability benefits.

Labor force status is our object of study. We utilize the information in the current employment and working history, for example, whether the individual works for pay, and information on primary and second jobs. Working hours are the sum of hours on primary jobs and second jobs. We use date information to generate non-survey year working status and use working hours to correct self-report errors. We do not distinguish between full-time jobs and part-time jobs. However, if information on working hours and working weeks is missing, we use 1000 annual working hours for the part-time job and 2000 for the full-time job. Unemployment is treated as non-work[8]. For a non-survey year, if respondents are working or not working in two successive waves, respondents will be in the same labor status in the non-survey year and working hours are equal to the previous wave's working hours. If respondents stop working, the date information from the job history is used to fill the labor status in the non-survey year. Similarly, the date of a job start is used when the status transitions from non-worker to worker.

For other variables in the non-survey year, some imputation rules are followed. Assets contain most of the components in the Rand HRS except home equity. For the non-survey year, assets are assumed to be equal to the previous year. Overall, changes in asset levels are smooth. Housing wealth changes are obtained from the FHFA Repeat Sales Index. The respondents who do not take the interview at wave 4 are dropped. All dollars measurements are deflated to the year 2000 level by the Consumer Price Index.

We use pension wealth from Gustman and Steinmeier's contributions: Updated Pension Wealth Data Files in the HRS Panel: 1992 to 2010, Part III. Self-reported pension wealth is the sum of defined benefits from current job, last job, previous job, and defined contribution. The wave 4 provides the initial pension wealth. We use the method of pension profile estimation from French and Jones (2011) to control the private pension effects.

[8] A different profile is generated with the self-report retirement.

Some information on initial conditions at wave 4 is missing. Not all respondents report their earnings history and pension wealth. We use Little's (1988) method to approximate Average Indexed Monthly Earnings (AIME, used to calculate Social Security benefits) and pension wealth at wave 4. Table 7 presents a data description of initial conditions. Average self-reported private pension wealth is between average housing and non-housing wealth. The mean difference across insurance types is extremely large. Health status is much worse for respondents who do not have insurance. Hourly wages, housing wealth, non-housing wealth and AIME is highest among the job-tied insurance group. Nearly half of job-tied insurance respondents prefer to work after age 62 and 65, while this number is about 38 percent for other insurance respondents.

**[Insert Table 7 here]**

## Wages

Wage depends on age, health status and innovations. Its transition function is given by:

$$W_{t+1} = \exp(w(Age, Health_t) + \varepsilon_{t+1}) \qquad (17)$$

where $W_{t+1}$ is the hourly wage rate at next period, $w$ is the log of hourly wage at current period, $\varepsilon_{t+1}$ is a transitory shock following a first-order auto-regressive normal distribution.

Endogenous wage selection exists between full-time and part-time jobs. Fringe benefits may make the hourly wage for full-time workers lower than for part-time workers because part-time workers usually do not have benefits such as health insurance. However, full-time jobs may require more skills than part-time jobs. Firms may be reluctant to improve the skills of part-time workers and hire part-time workers to do simpler jobs. We use the French and Jones (2011) wage-generating function:

**Table 7:**
**Initial Conditions**

| Variable | All Mean | None Mean | Retiree Mean | Tied Mean |
|---|---|---|---|---|
| Age | 54.96 | 55.04 | 54.96 | 54.91 |
| Birth Year | 1943 | 1942 | 1943 | 1943 |
| Health | 0.2270 | 0.4537 | 0.1830 | 0.1441 |
| Participation | 0.8213 | 0.8287 | 0.8093 | 0.8190 |
| Non-housing wealth | 163600 | 95250 | 170600 | 198300 |
| Housing wealth | 105100 | 63610 | 111500 | 122600 |
| Medcost | 1491 | 1650 | 1416 | 1501 |
| Pension wealth | 134200 | 33780 | 175800 | 136400 |
| Hourly wage | 18.61 | 13.07 | 18.75 | 22.08 |
| AIME | 28180 | 17060 | 30620 | 31790 |
| Initial Preference | 0.4202 | 0.3789 | 0.3849 | 0.5029 |
| # of observations | 1097 | 227 | 530 | 340 |

**Table 8:**
**Parameter Values of Wage and Medical Cost Innovations**

| **Variables** | $\rho_w$ | $\sigma_w$ | $\rho_{mc}$ | $\sigma_{mc}$ |
|---|---|---|---|---|
| **Value** | 0.977 | 0.12 | 0.925 | 2.278 |

$$\ln W_t = \alpha * \ln Hours_t + f(Age, Health_t) + \eta_i + \varepsilon_t \quad (18)$$

where $\alpha$ is the inverse labor supply elasticity, $\eta_t$ is an individual fix effect and $\varepsilon_t$ is an AR(1) error term. We use the inverse labor supply elasticity value from Aaronson and French (2004): $\alpha = 0.412$, which implies "work more and earn more." By using $(\ln W_t - \alpha * \ln Hours_t)$, wage profiles are not different between full-time and part-time jobs. The first two columns of Table 8 are the calibrations of wage innovations from French (2005)[9]. Time correlation is a nearly unit root process, which is not surprising because the uncertainty of wage for elderly is quite low when approaching the end of their working career.

**[Insert Table 8 here]**

Retirement is not a one-time decision. The dynamic pattern of job transitions can still cause real wage changes. In the forward-looking model, if working agents know that they will face a decrease in wages or have difficulty finding a job after retiring, they may postpone their retirement. On the other hand, social pensions and private pensions may trigger an incentive to stop working. Computational resources do not allow inclusion of those situations in our model. A study by van der Klaauw and Wolpin (2008) using low-income households that includes the effects of job tenure on the wage does these situations into account.

## Medical Costs and Insurance Types

Medical costs are the sum of the various medical expenditures in the Rand HRS and the insurance premia in the core file. In our model they depend on four control variables: age, health, labor force status and insurance type. Except for updating the estimation of dynamic medical

[9] Altonji, Smith, and Vadingos (2013) systematically studies the trends of earnings, employment, job changes, wage rates, and work hours over a career. However, I do not include education, occupation and aggregation shocks on wage. Stratifying the samples could mitigate the bias but limit the sample size.

costs with our data, we again follow the method of French and Jones (2011). Following French and Jones (2011), there are three insurance types in our model: no insurance, job-tied insurance, and retiree-coverage insurance.[10] Insurance type is not chosen directly. When an agent leaves the labor force, his insurance type becomes no insurance. Moreover, only job-tied agents can experience an insurance transition in our model; in other words, the no-insurance type is an absorbing state, as is the retiree-coverage insurance type.

**[Insert Figure 6 here]**

Figure 6 shows the exit rate by insurance type for ages 59 to age 68. The first peak occurs at age 62 for all insurance types. Unlike in previous studies, retiree-coverage insurance has the second transition peak at normal retirement age. Agents of the no-insurance type are more likely to retire at Medicare age 65. The likelihood is lower than the corresponding likelihood at early retirement age. There is no peak at either age for job-tied insurance. However, as expected, the exit rate from job-tied insurance increases monotonically with age. Insurance-type exit rates contribute to the moment conditions.

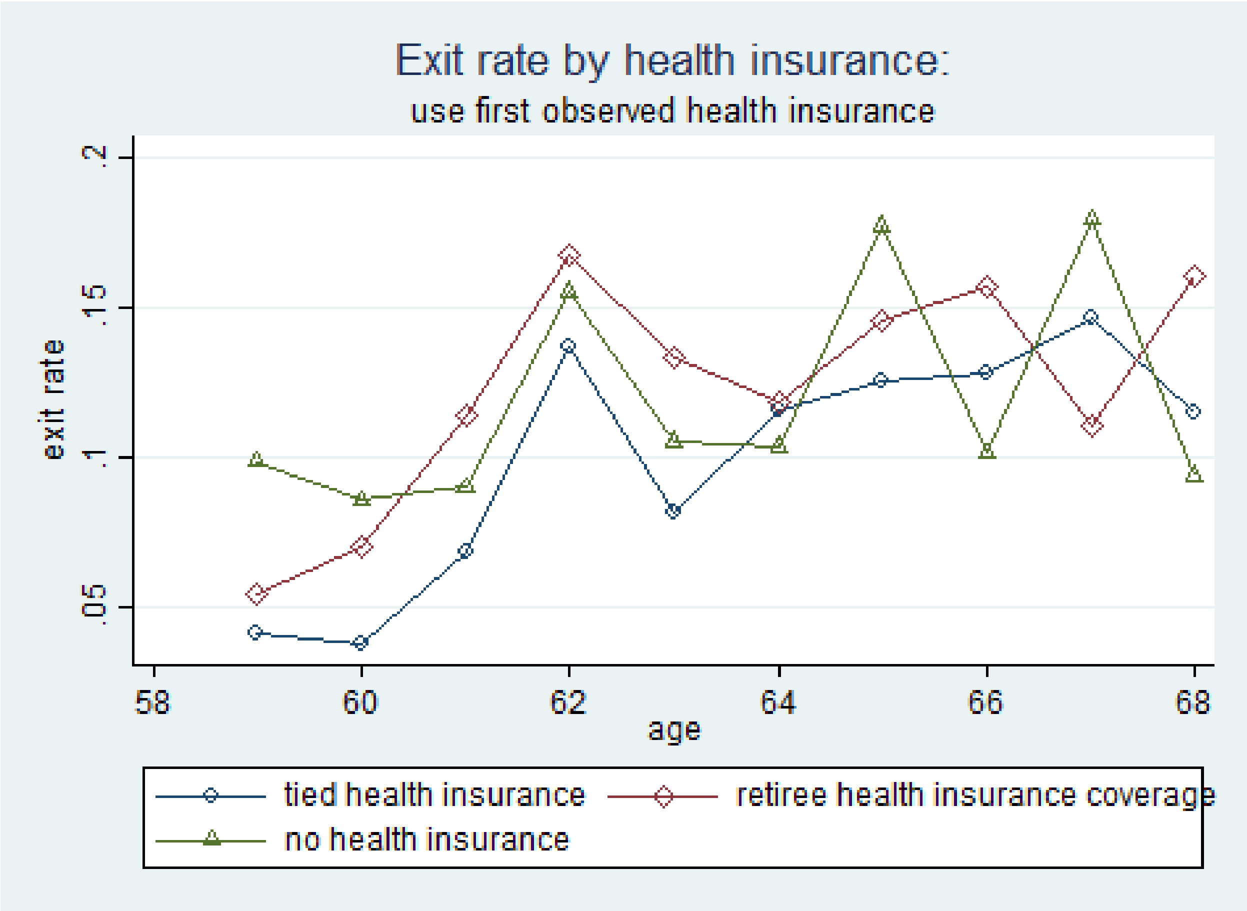
Medical costs follow a first-order moving-average (MA(1)) process, the variance and mean for which are calibrated using French and Jones (2011)[11]. Estimation across the twelve combinations (four control variables times three insurance types) are performed using data from waves 4 through 12 of the HRS using MSM. 30 moments and 30 quantiles are matched.

---

[10] Current insurance type is determined by respondent answers to the following questions: 1) whether respondent has employer-provided insurance; 2) if yes, whether this insurance covers retirement. Additional information can be used to determine whether there is retiree-coverage insurance. Veteran benefits and a combination of employer-provided plus spousal insurance are assumed to imply retiree-coverage insurance. The retiree-coverage state is assumed to be absorbing because employers may be reluctant to hire retirees who ask for insurance benefits.

[11] The last two columns of Table 8 gives the value of the time correlation and variance of medical cost generating process.

**Figure 6:**


Exit rate by health insurance:
use first observed health insurance
exit rate
.05
.1
.15
.2
58
60
62
64
66
68
age
tied health insurance
retiree health insurance coverage
no health insurance

## Housing

Housing wealth plays the most important role in our study. For a study that forecasts local housing price changes based on a vector-autoregressive model, which takes into account local drivers such as population growth, unemployment rate and average income, see Follain and Giertz (2016). To minimize the number of state variables in the dynamic programming model, we assume a national housing market. The housing-wealth generating process is given by:

$$H_{t+1} = (1+g_t)*(1-\varphi)*\exp(h_t+\varepsilon_t) \tag{19}$$

where $h_t$ is the log of housing wealth, $g_t$ is the housing price growth rate, $\varphi$ is the depreciation rate, and $\varepsilon_t$ is the i.i.d. innovation to housing wealth. The growth rate, $g_t$, is taken from the FHFA national housing price index for the years 2003 through 2014. For years beyond 2014, $g_t$ is set to 0.03. Respondents experience the housing boom and bust at different ages. To save computational resources in the calculation, we assume all agents were born in the year 1943, which is the average birth year in our sample.

## Social Security Benefits and AIME

Social Security benefits calculation depends on the primary insurance amount (PIA), which is in turn determined by the average indexed monthly earnings (AIME). The AIME is the average of the 35 years of highest earnings deflated by the national wage index. It is updated each year that the earned wage is higher than the lowest previous one. It is not feasible to consider the employment history of each respondent. Instead, the AIME is imputed using a regression to obtain the ratio, $\alpha_t$ , of the lowest wage to the AIME between the ages of 55 and 70. The national wage growth rate is used to calibrate AIME growth before the age of 60, which is the last age indexed the national wage index. The structural model uses annual wages instead of earnings. Hence, the ratio of lowest wage to AIME is predicted using the method of French and Jones (2011). Thus, the following calculation is used in the model:

$$AIME_{t+1} = (1+\rho * I(t<60) * AIME_t + \frac{1}{35} * \max\{0, W_t - \alpha_t * (1+\rho * I(t<60)) * AIME_t\} \tag{20}$$

where $\rho$ is the average wage growth rate, 0.016, from 2000 Green Book.

## Pension Benefits

We assume that all pension plans in the model are defined benefits plans, even though defined contribution plans have become more common recently. A defined contribution plan is riskier than a defined benefits plan. The elderlies also are likely to have experienced a large loss in their defined contribution balance during the Great Recession, which would provide another incentive for the elderly to delay retirement. The determinants of pension benefits in our model are age and the PIA. Hence, working one more year increases not only Social Security benefits, but also pension benefits in our model.

The pension updating model is given by:

$$PW_{t+1} = \frac{1}{1+s_{t+1}} * \left[(1+r) * PW_t + Pacc_t - ps_t\right] \tag{21}$$

where $PW_t$ is pension wealth, $s_t$ is the probability of living one more year, $r$ is the rate of return, $Pacc_t$ is the pension accrual amount from working one more year, and $ps_t$ is the level of collected pension benefits. The initial value of $PW$ is taken from the data provided by Gustman and Steinmeier (2014), while the pension accrual rate profile that provides values of $Pacc_t$ and the coefficients necessary to compute the values of $ps_t$ are taken from French and Jones (2011).

Even though we have the values of $ps_t$, adding these values as a new state variable is computationally prohibitive, so we use the PIA, which is already a state variable to impute the values of $ps_t$ when we estimate the structural model.

## Spousal Income

Spousal income is a linear function of the first four powers of the male's age, health status, and interaction of the powers of his age with his health status. Spousal income is the sum of earnings, Social Security benefits, and pension benefits. We assume that the spouse will not die before the husband.

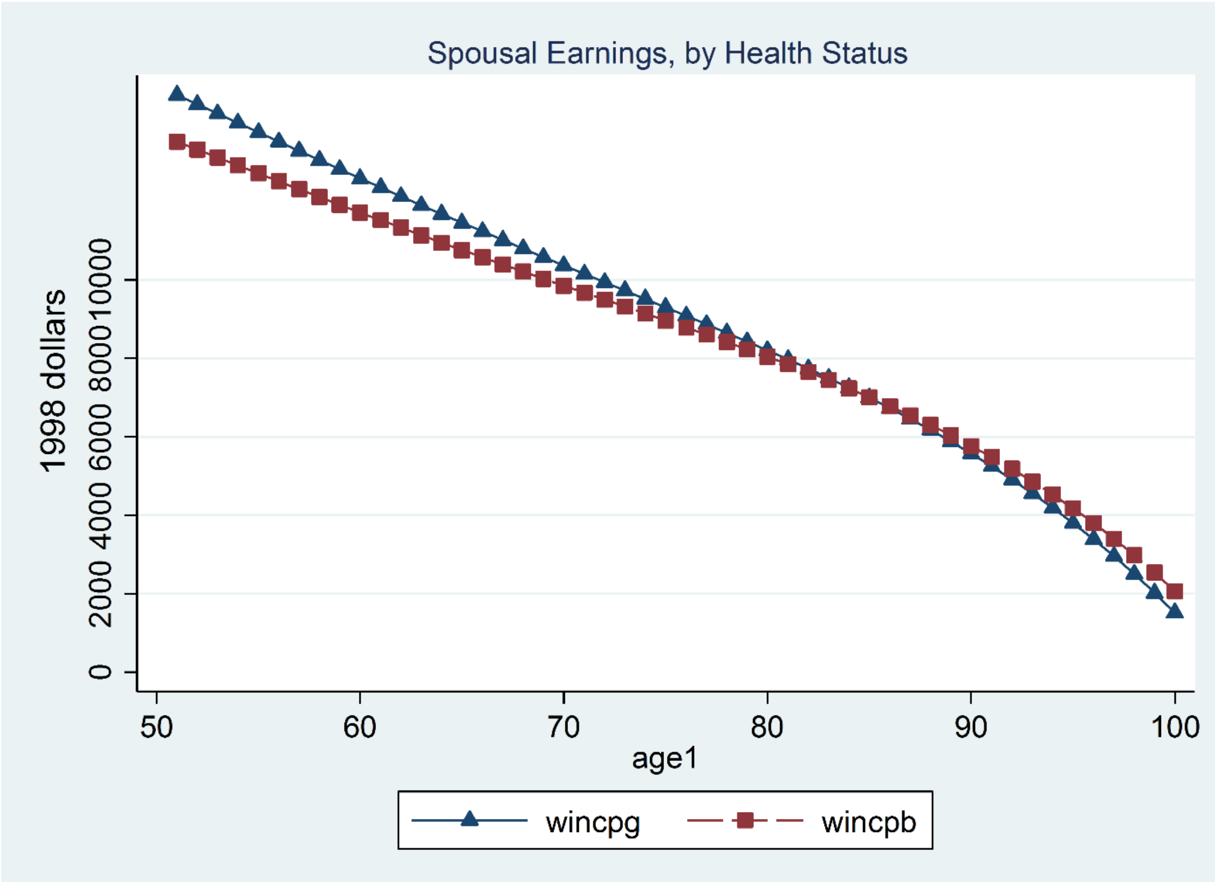
**[Insert Figure 7 here]**

Spousal income profile estimations use the entire sample in the HRS. For single males, spousal income is zero. The curvature of spousal income presented in Figure 7 seems reasonable. The spousal income curve for a healthy husband is higher than the curve for an unhealthy one. After the peak at the male age of 58, both curves decline.

## Health Transition and Mortality

The estimation of health status transition uses a logit model, with the first three powers of the male's age, and interaction of the powers of his age with his lagged health status. Because HRS is a biannual survey, the lagged health status is from two years before. We assume the same health transition Markov matrix in the non-survey year as in the survey year. In Figure 8, the probabilities of bad health increase monotonically with age. Bad-to-bad health probabilities are time-persistent. The mortality estimation uses the same functional form and explanatory variables as the health transition estimation. The results presented in Figure 9 indicate the mortality of unhealthy males is higher than that of healthy ones.

**Figure 7:**


Spousal Earnings, by Health Status
1998 dollars
0
2000
4000
6000
8000
10000
50
60
70
80
90
100
age1
wincpg
wincpb

**[Insert Figures 8 and 9 here]**

## Types of Heterogeneity

The heterogeneity definition of French and Jones (2011) is only available for the first wave in the HRS. Our initial wave is the fourth wave. We experiment with three definitions of heterogeneity: prefer to save, strong bequest motive, and more likely to work after age 62 and age 65. The first definition has a low response rate and the second turns out to be uninformative. The third definition uses survey questions of "Probability of working after age 62" and "Probability of working after age 65". The two types are defined by the sum of the two probabilities, greater than one (Type 1 heterogeneity) and less than or equal to one (Type 2 heterogeneity). We use the first value that appears in the HRS as our definition of heterogeneity types. Hence, the structural model has two sets of consumption weights and discount rates.

## Re-Entry Status

The purpose of the re-entry status is to account for the fact that retirees are less likely to re-enter the labor force when they get older and unhealthier. If we do not use re-entry status, retirees are more likely to seek jobs when the earnings test is eliminated after normal retirement age. In this case, the model shows an incorrect trend for labor participation at age 66. The estimation generating re-entry status is similar to the mortality estimation. Figure 10 presents the estimated unconditional (not restricted to currently being retired) re-entry rate by health status for the entire sample. It declines across age and unhealthy retirees are less likely to re-enter.

**[Insert Figure 10 here]**

# Moment Conditions and Numerical Methods

The estimation method is minimum distance estimation. The objective is to find the preference vector minimizing the following function:

**Figure 8:**

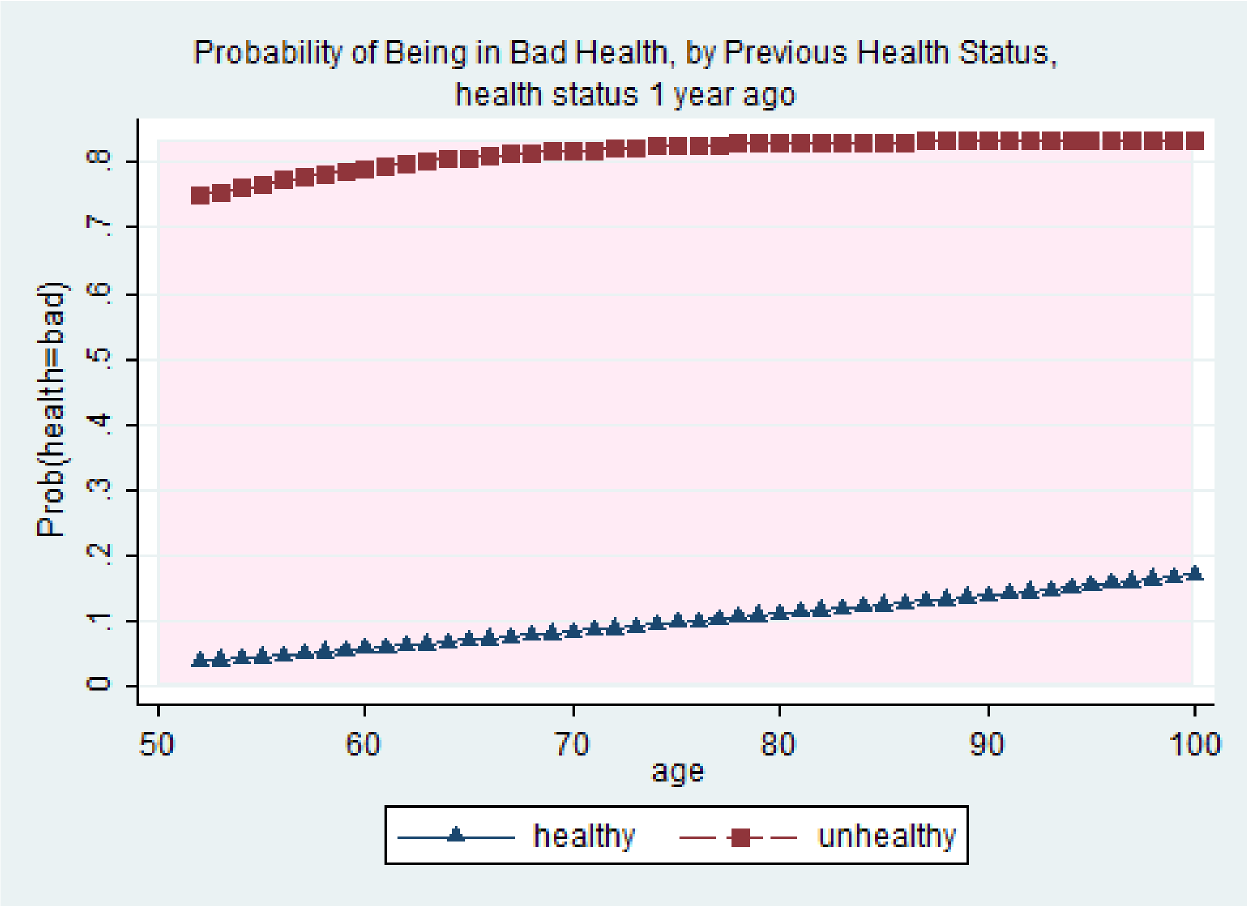

Probability of Being in Bad Health, by Previous Health Status,
health status 1 year ago
Prob(health=bad)
0
.1
.2
.3
.4
.5
.6
.7
.8
50
60
70
80
90
100
age
healthy
unhealthy

**Figure 9:**

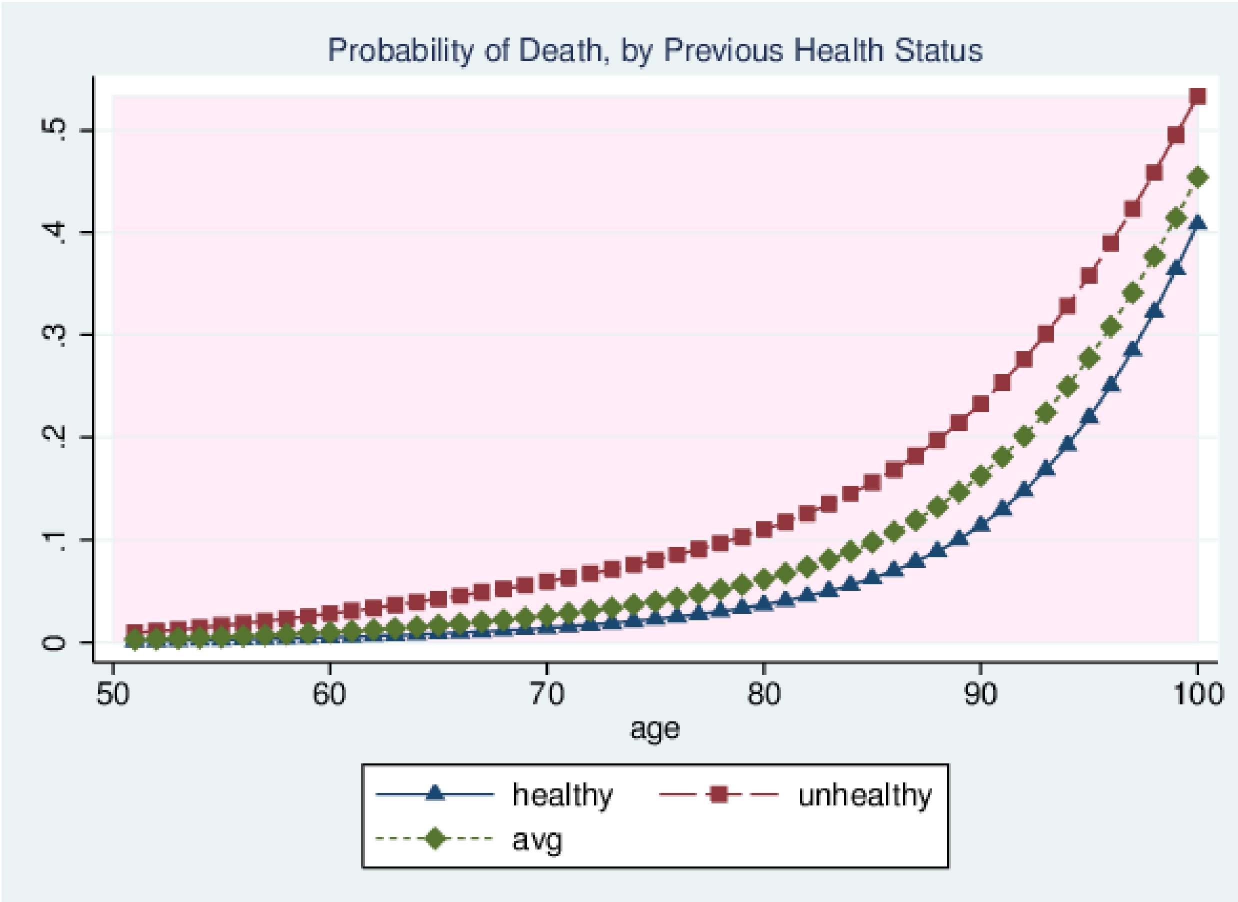
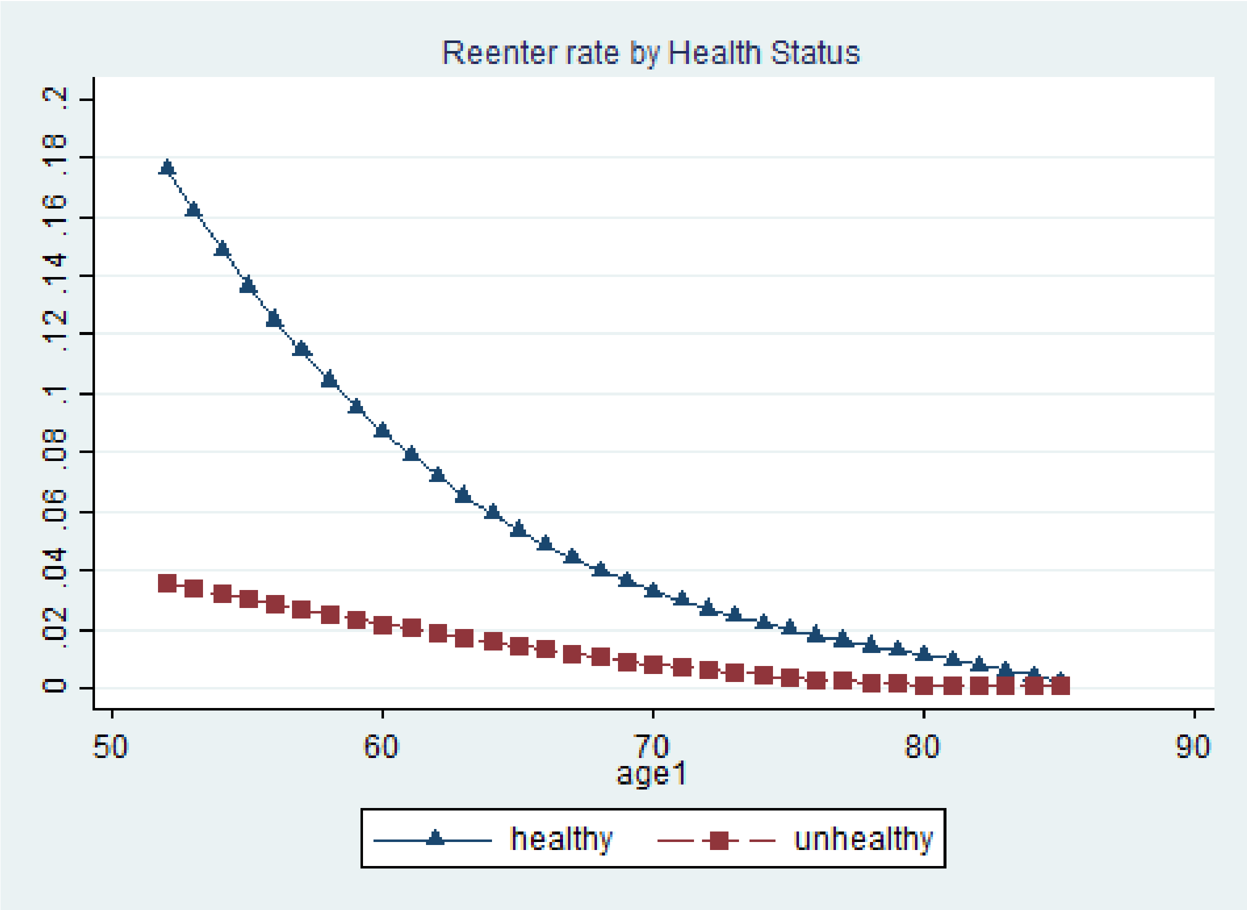

Probability of Death, by Previous Health Status
0
.1
.2
.3
.4
.5
50
60
70
80
90
100
age
healthy
unhealthy
avg

**Figure 10:**


Reenter rate by Health Status
0
.02
.04
.06
.08
.1
.12
.14
.16
.18
.2
50
60
70
80
90
age1
healthy
unhealthy

$$\arg\min_{\Theta} \frac{I}{1+\tau} \varphi_i(\Theta, \chi_0)' W \varphi_i(\Theta, \chi_0) \tag{22}$$

where $I$ is the number of individuals in the sample, $\tau$ is the ratio of simulated to observed samples, $\varphi$ is the distance between simulated and observed moments, and $W$ is weighting matrix. $\chi_0$ is the set of beliefs, discussed in the section immediately above. We use the variance-covariance matrix of the observed data as the weighting matrix. The weighting matrix does not change within the estimation Moments are from ages 58 to 69. The moment conditions are:

- First and second asset terciles by age to capture the saving behavior and the effect of housing wealth on the consumption.
- Labor-force participation hazard moments by age and insurance type to capture the effect of Social Security and Medicare on the labor-force participation decision.
- Labor-force participation rates conditional on asset terciles and insurance type.
- Labor-force participation rates conditional on heterogeneity type.
- Log of working hours and labor-force participation rates conditional on health status.

In total, there are 240-moment conditions that need to be matched. Because of the existence of working decisions and government transfers, the Euler equation for consumption has multiple interior solutions. Solving and coding the Euler equations is extremely complicated. Instead of computing solutions to these equations, we use grid search (policy function iteration) to approximate the optimal solutions for consumption, working hours, and Social Security application. Coarse discretization may induce computational errors and enlarge estimation bias.

In the model, we assume that all individuals must apply for Social Security by age 70 and to retire after age 72[12].

We discretize continuous state variables: wage innovation, housing innovation, AIME, housing wealth, and non-housing wealth. We use five-point Gauss-Hermite quadrature for wage and housing innovations, ten-point AIME, and five-point housing, and ten-point non-housing wealth. We do not discretize uniformly. We use more points for the lower levels of the housing and non-housing wealth distributions to control for wealth concentration. Because of the fixed cost of work and the re-entry cost, the valuation function is not globally concave. Besides the larger grids for consumption, we also use nearest-neighbor search to look for the optimal consumption decision. We recognize that grid selection and fineness of discretization may affect the final results significantly. We use Tauchen's (1986) method to generate the Markov transition matrix for wage and medical cost innovation.

Backward induction is used to solve the optimal decision at each age. Then, I use interpolation and extrapolation to impute the decisions of simulated households from the initial age to the final age. With the solutions of non-housing wealth and labor-force status, we can construct the simulated moments and evaluate the criterion function of MSM.

As Victor Aguirregabiria (2011) says, substantial computing burden is due to repeat solving dynamic programming whenever parameters change. Even though we use OpenMP parallelization, each iteration takes about two and a half hours. An approximation method for dynamic programming is not possible because there is no consumption information in the HRS.

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[12] Postponing the mandatory retirement age helps smooth the labor-force participation trend between ages 59 and 69, but significantly increases computation time.

Another curse of dimensionality comes from the parameters set. We have 14 parameters to estimate, which increases the convergence time. Therefore, we use the simplex method.

## Estimation Results and Model Fitness

Table 9 presents the estimation results for the original model. Consumption weights are similar across heterogeneity types. Agents unlikely to work past ages 62 and 65 have a significantly lower discount rate than their counterparts. This is consistent with the hypothesis that agents who initially say they will not work in the future may in fact prefer to do so. The estimate of the bequest curvature indicates bequest is a luxury good. The fixed costs of bad health and working are positive, which is consistent with our expectations. The consumption floor is nearly 4600 dollars. Because of the large number of moments, the over-identification test is rejected in all estimations. However, the simulated decision profiles are close to the observed counterparts. We discuss some of the differences between simulated and observed decisions.

**[Insert Table 9 here]**

Figure 11 shows the differences for non-housing wealth quantiles. French and Jones (2011) combine housing and non-housing wealth in total assets and find saving occurs in wealthier households. After separating housing and non-housing wealth, agents in the higher quantiles for non-housing wealth reduce saving from the age of 60 to 65. During the calendar period of our sample, housing wealth is booming, and consumption tends to increase. It is not surprising to find the decline for non-housing wealth in the model. When the housing market enters the bust period, agents switch to a saving mode. However, the match quality of the non-housing wealth quantile moments is weak. There are two potential reasons for this. First, many households in the higher quantiles of non-housing wealth also have a significant amount of housing wealth. The wealth effect of housing price increases contributes to a dramatically

**Table 9:**
**Original Model Results**

| Variables | Estimates | Std.Err |
|---|---|---|
| Discount rate (type 0) | 0.6715 | 0.0096 |
| Discount rate (type 1) | 0.9986 | 0.0066 |
| Consumption weight (type 0) | 0.5272 | 0.0065 |
| Consumption weight (type 1) | 0.5788 | 0.0064 |
| Risk aversion | 2.655 | 0.0534 |
| Leisure endowment (*1000) | 4.636 | 0.4707 |
| Bequest Curvature (*100000) | 4.634 | 0.0478 |
| Propensity of bequest (%) | 10.64 | 0.7929 |
| Fix cost of bad health (*100) | 4.462 | 0.1877 |
| Fix cost of working (*100) | 1.747 | 0.0635 |
| Age effects of working (*10) | 0.808 | 0.0533 |
| Fix cost of reentry (*100) | 1.563 | 0.2077 |
| Consumption floor (*1000) | 3.284 | 0.0710 |
| Housing proportion rate | 0.252 | 0.0106 |
| Over-identification test= | 3732 | |
| Degrees of Freedom | 206 | |
| P value | <0.001 | |

increased level of consumption, resulting in further declines of non-housing wealth. The second reason is the collateral constraint and debt. If households are extremely risk-averse, they avoid borrowing against housing wealth. The modified model does better in fitting saving behavior.

**[Insert Figure 11 here]**

Figures 12 and 13 show both the unconditional labor-force participation rate and the rate conditional on health status. The rates decrease with age in both graphs. The largest improvement because of the addition of re-entry status in our model is the absence of an upward movement of the labor-force participation rate at the normal retirement age. However, the hazard rate is underestimated at the early retirement age, which leads to the higher exit rates after normal retirement age in Figure 8. This is possibly because of the approximation of the AIME and coarse discretization of non-housing wealth. (There are only 10 discretizations.) We cannot identify whether it reflects the liquidity constraint is binding for most of the households. The liquidity constraint is key to increasing the exit rate at early retirement age. The approximate mean level of the AIME used in our model is 20 percent lower for those respondents for which the actual level is known in the restricted data. On the other hand, the modeling of the re-entry status may be too simple. If agents expect they will not re-enter the labor market after retirement, they are reluctant to retire earlier. Figure 14 is the labor-force participation profile from the modified model. Although the bias is smaller, our estimates still slightly overestimate between the ages of 62 and 65 and slightly underestimate after age 65.

**[Insert Figures 12, 13 and 14 here]**

Figures 15 shows the labor-force exit rates. The simulated exit rate at the early retirement age is about seven percent, which is only half of the sample mean. Figures 16, 17, and 18 show

**Figure 11: Non-housing Wealth Quantiles, Data versus Simulations**

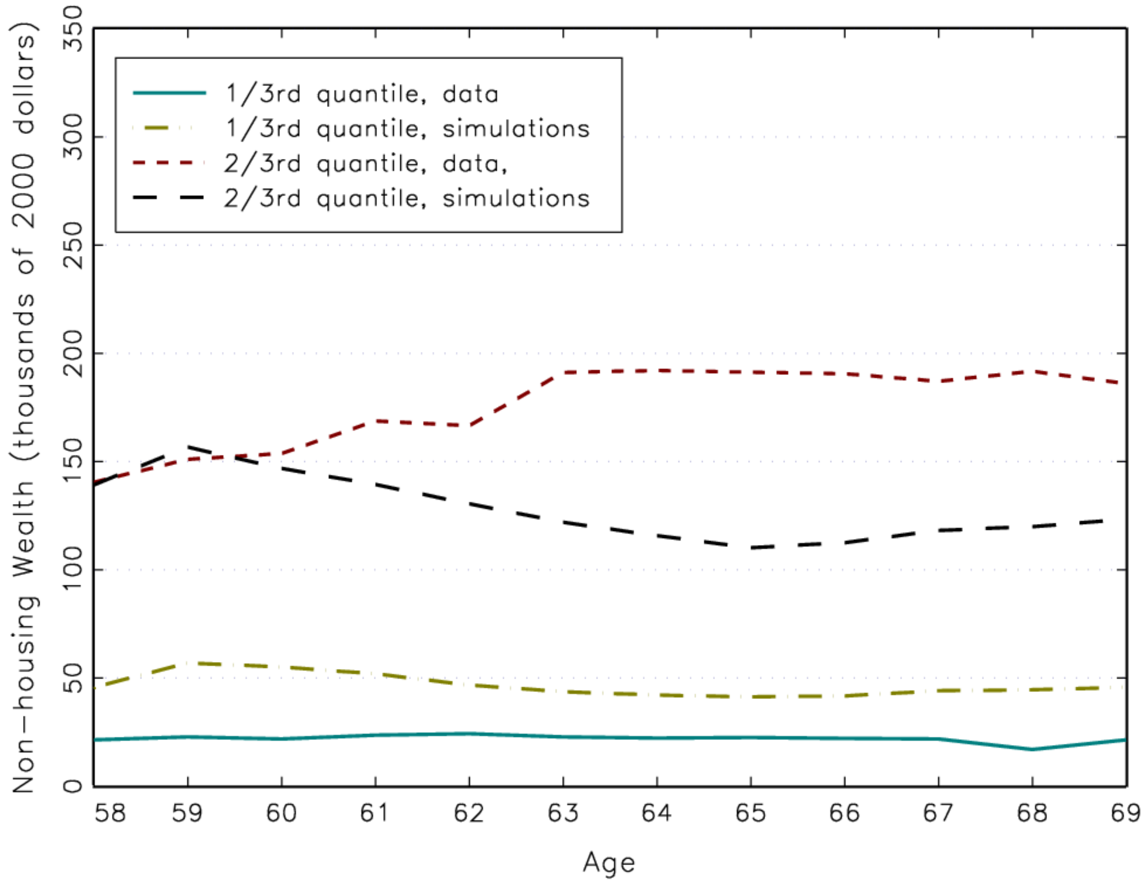


**Figure 12: Labor Conditional on Health, Data versus Simulations**

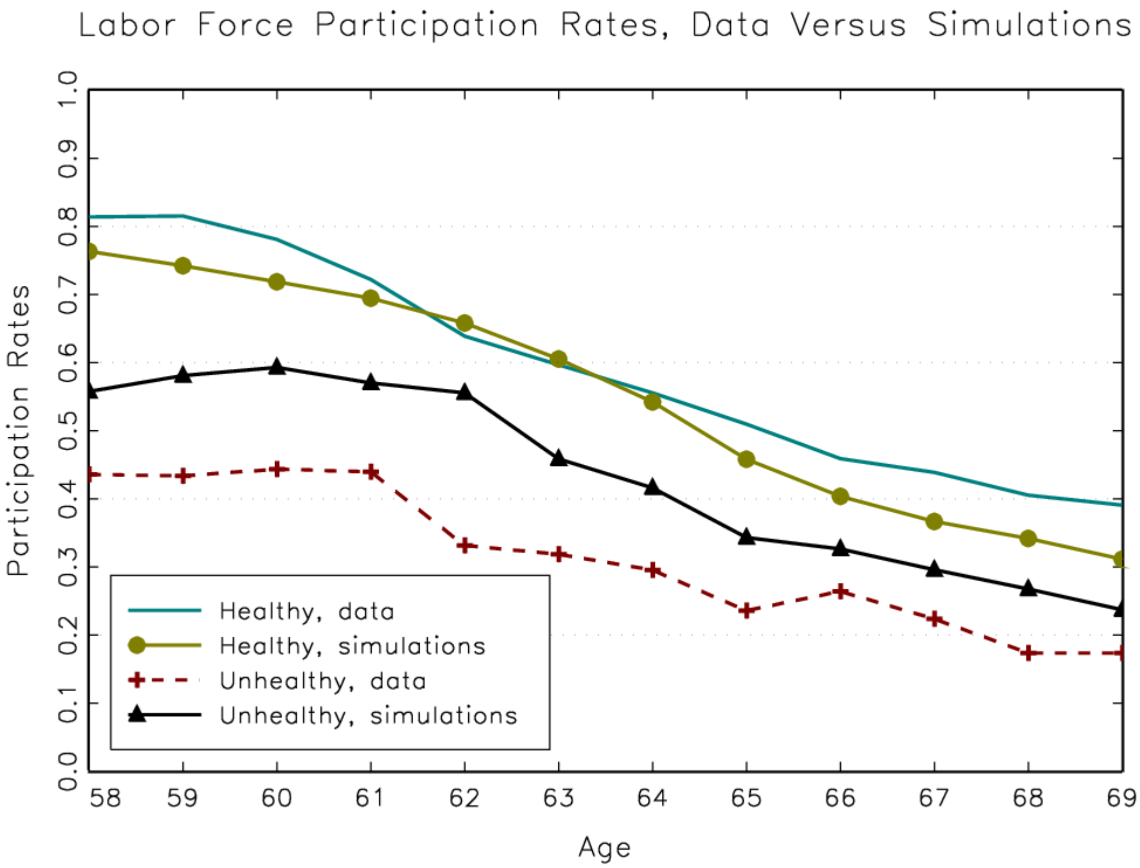


**Figure 13: Labor, Data versus Simulations**

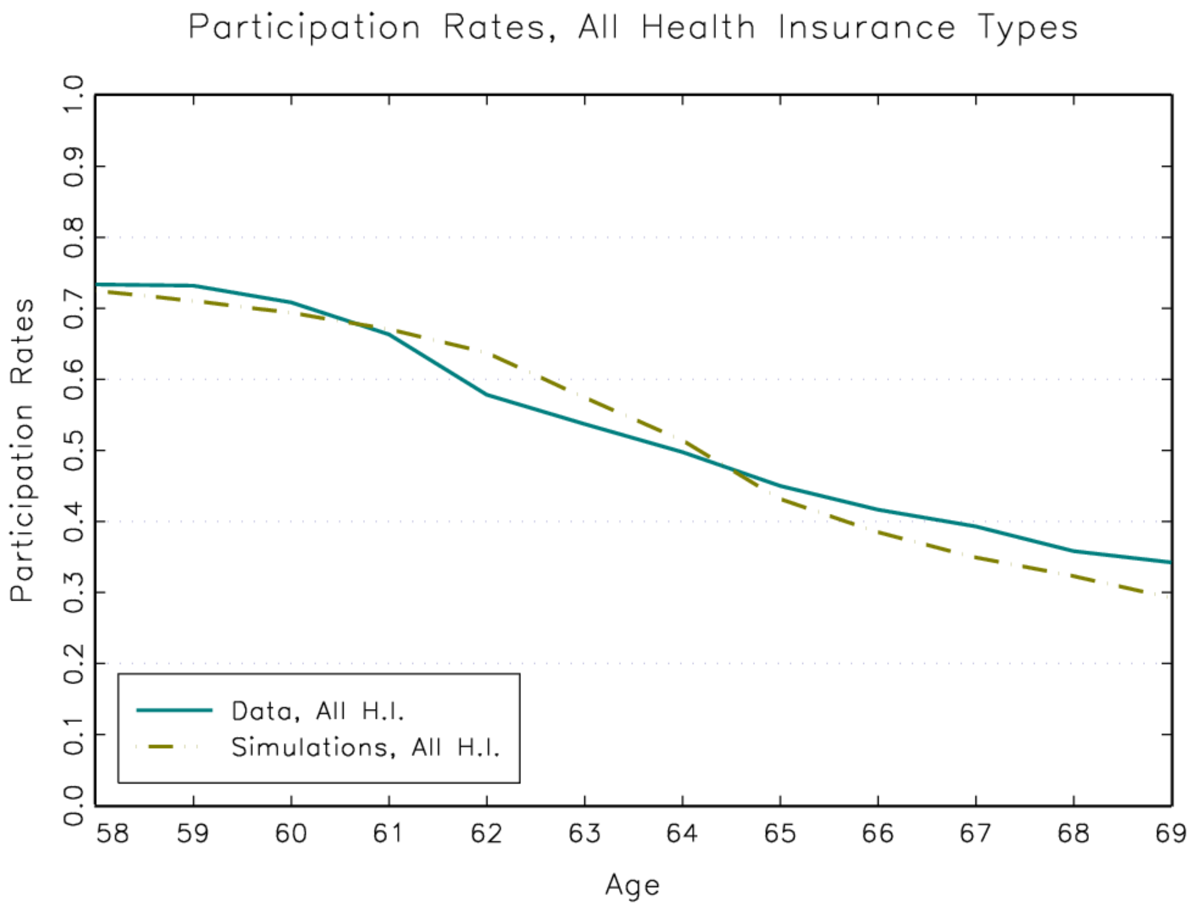
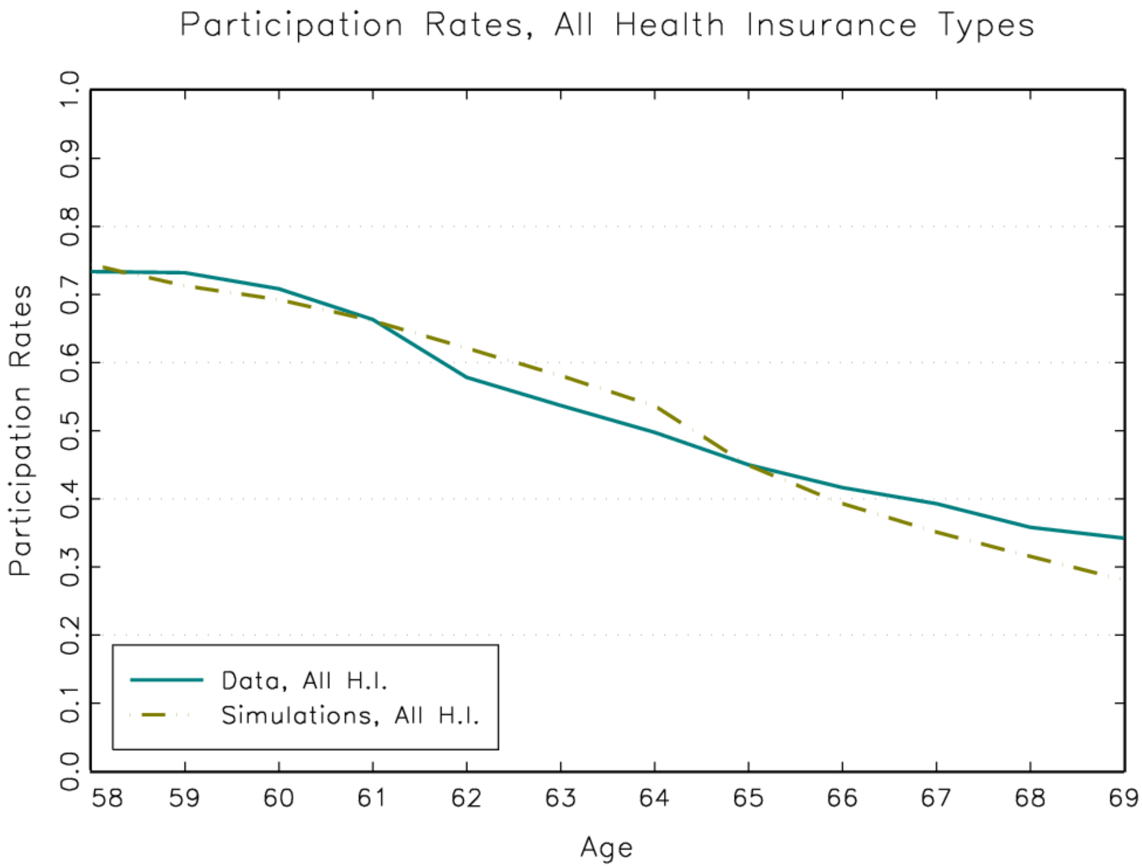


**Figure 14: Labor, Data versus Simulations, extension**



the labor-force participation rates across different insurance types. The model underestimates the labor-force participation rate at younger ages for the no-insurance group. There is overestimation for the retiree-coverage insurance group. The simulated curve rotates to the right around age 64. To examine the reasons, I would have to use se the AIME from the restricted data on the high-performance computer, which is not possible. The level of saving during the bust is smaller than the use of non-housing wealth during the boom in the original but not in the modified model. After obtaining government transfers payments, agents are locked into social welfare programs. When the proportion of "free ride" agents increases, savings behavior becomes weaker.

**[Insert Figures 15, 16, 17, 18 and 19 here]**

Table 10 presents the estimation results from the modified model with the collateral constraint. There are three important differences between the original and modified models. First, the risk- aversion coefficient nearly doubles from 2.6 in the original model to 5.3 in the modified model, so that the results for saving behavior improve (see Figure 19) The reason the simulated second tercile for non-housing wealth becomes flat is perhaps a result of the high exit rate at age 65 with subsequent loss of wages. Second, the bequest motive propensity change. In the modified model, households are more inclined to leave a bequest. Third, the consumption floor nearly doubles in the modified model.

**[Insert Table 10 here]**

# Robustness Check

Table 11 presents the estimates without housing wealth. The coefficients do not change when we use non-housing wealth moments in our model fitness criteria, compared to when we use total wealth. There are four differences compared to the original model. First, the discount

**Figure 15: Job Exit, Data versus Simulations**

**Figure 16: Labor of None, Data versus Simulations**

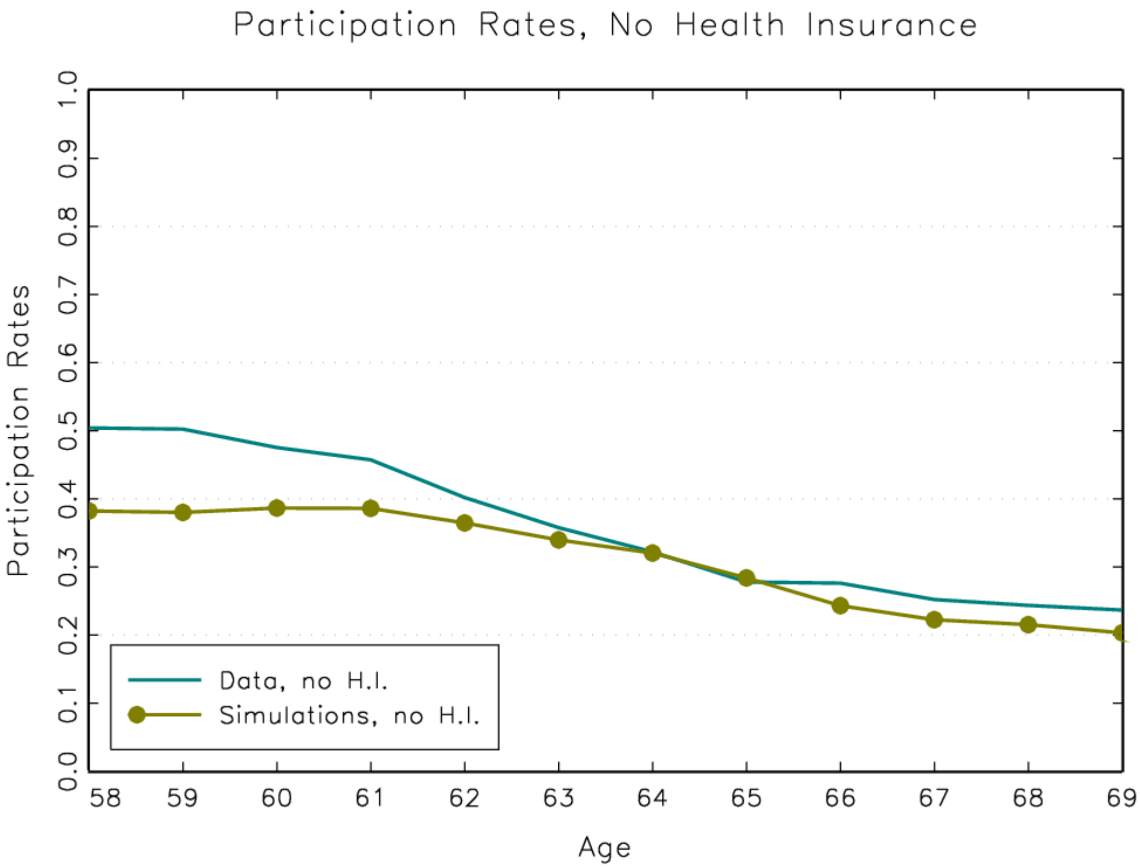


**Figure 17: Labor of Retiree, Data versus Simulations**

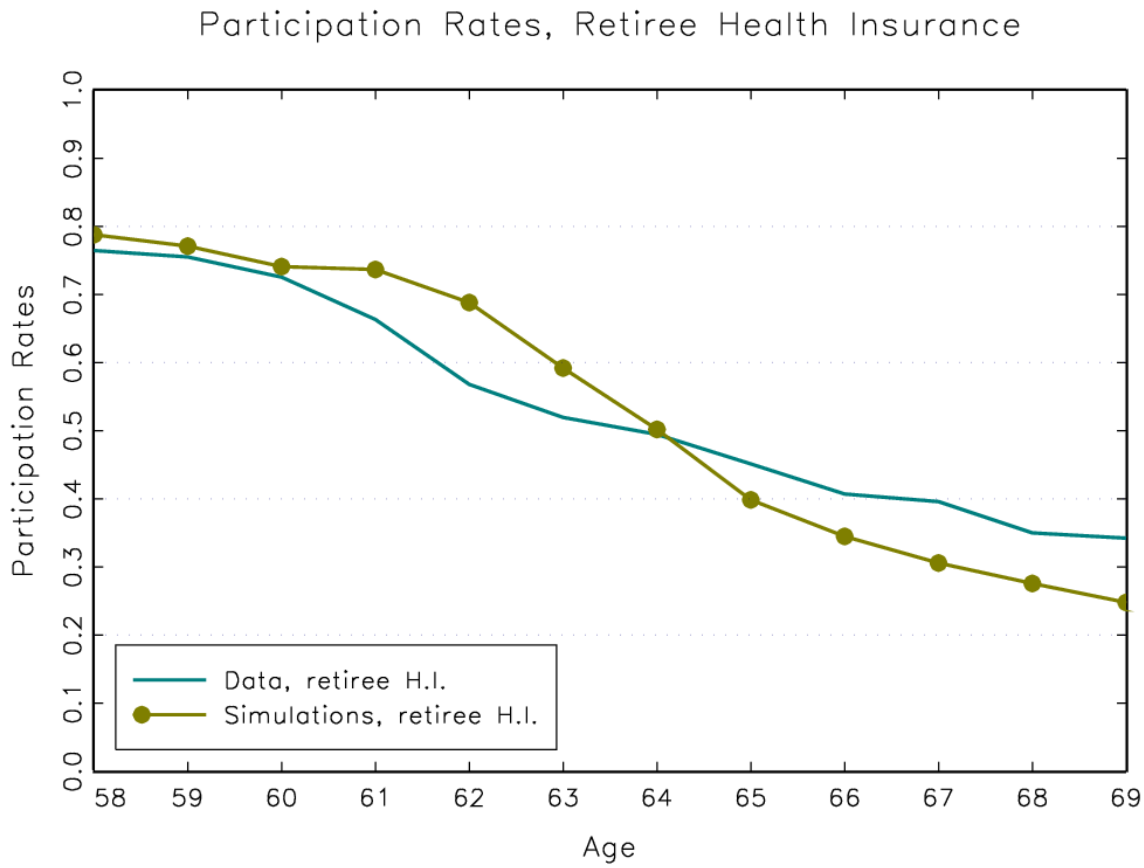


**Figure 18: Labor of Tied, Data versus Simulations**

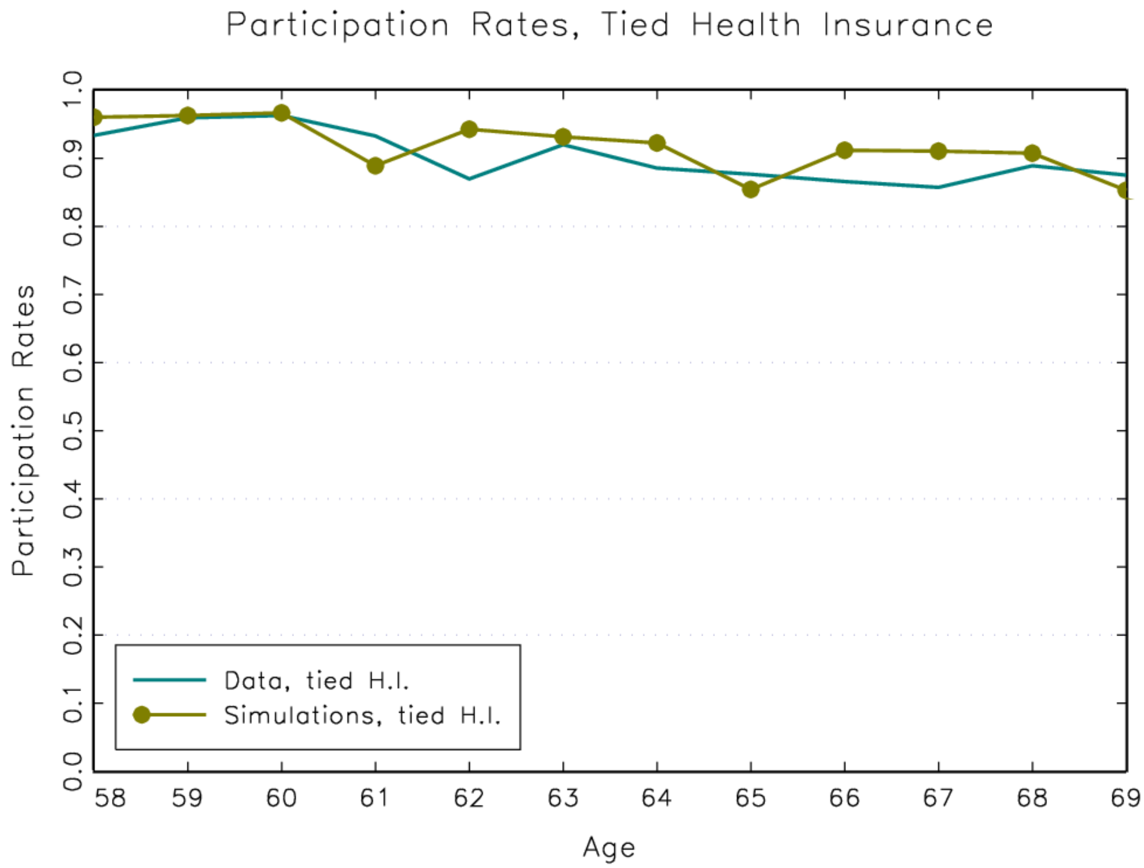


**Figure 19: Non-housing Wealth Quantiles, Data versus Simulations, Modified**

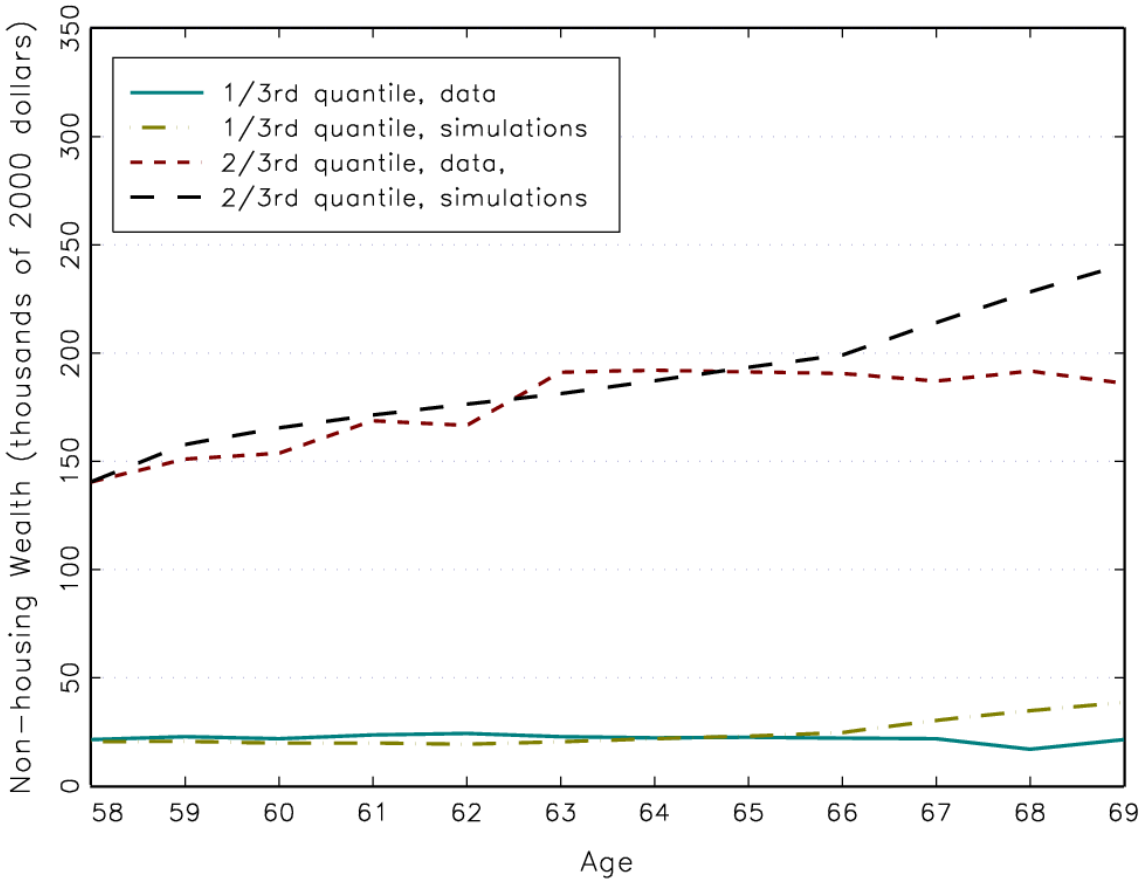


**Table 10:**
**Modified Model Results**

| Variables | Estimates | Std.Err |
|---|---|---|
| Discount rate (type 0) | 1.0699 | 0.0119 |
| Discount rate (type 1) | 0.9100 | 0.0129 |
| Consumption weight (type 0) | 0.5439 | 0.0121 |
| Consumption weight (type 1) | 0.6892 | 0.0131 |
| Risk aversion | 5.3710 | 0.1627 |
| Leisure endowment (*1000) | 3.8391 | 0.0816 |
| Bequest Curvature (*100000) | 4.2322 | 0.3180 |
| Propensity of bequest (%) | 5.0479 | 0.2064 |
| Fix cost of bad health (*100) | 4.8031 | 0.4043 |
| Fix cost of working (*100) | 1.6459 | 0.1318 |
| Age effects of working (*10) | 0.8604 | 0.1055 |
| Fix cost of reentry (*100) | 1.6524 | 0.5641 |
| Consumption floor (*1000) | 6.2219 | 0.2134 |
| Housing proportion rate | 0 | **** |
| Over-identification test= | 1625.6 | |
| Degrees of Freedom | 207 | |
| P value | <0.001 | |

rates for Type 1 heterogeneity and Type 2 heterogeneity switch. Type 2 agents become more patient than Type 1 agents. The original model results indicate that Type 1 agents are patient and work in order to save. On the contrary, now in the robustness check, Type 1 agents are impatient and work in order to consume. Second, the risk-aversion coefficient increases to nearly 5. Housing is an insurance mechanism. If there were no precautionary saving through housing wealth accumulation, the elderly would be more risk averse. Third, the bequest motive curvature increases by nearly $110,000. By coincidence, the gap is the mean of housing wealth. Excluding housing wealth makes the bequest motive more of a luxury good. Fourth, the estimate of the consumption floor in the robustness check is approximately $5,000, which is similar to that of French and Jones (2011). The saving behavior for the higher tercile appears in Figure 20.

**[Insert Table 11 and Figure 20 here]**

Table 12 presents the estimates from a specification without housing wealth and heterogeneity types. The estimation excludes housing wealth from the asset accumulation function and uses the total wealth moments, in order to compare the results to those of French and Jones (2011). The bequest motive is strong as well. Risk aversion increases and the bequest propensity decreases. In our second robustness check, the bequest motive is even stronger than in the results of the original model and the robustness check with heterogeneity. The leisure endowment and all time costs decrease, and the consumption weight is higher than in the other two results.

**[Insert Table 12 here]**

**Table 11:**
**Robustness Check, Without Housing Wealth**

| Variables | Estimates | Std.Err |
|---|---|---|
| Discount rate (type 0) | 1.012 | 0.0097 |
| Discount rate (type 1) | 0.5376 | 0.0153 |
| Consumption weight (type 0) | 0.4623 | 0.0076 |
| Consumption weight (type 1) | 0.5581 | 0.0073 |
| Risk aversion | 4.964 | 0.1351 |
| Leisure endowment (*1000) | 4.581 | 0.0642 |
| Bequest Curvature (*100000) | 5.766 | 0.5706 |
| Propensity of bequest (%) | 13.20 | 1.1570 |
| Fix cost of bad health (*100) | 7.086 | 0.2846 |
| Fix cost of working (*100) | 1.220 | 0.0311 |
| Age effects of working (*10) | 0.4583 | 0.0390 |
| Fix cost of reentry (*100) | 2.368 | 0.1675 |
| Consumption floor (*1000) | 4.911 | 0.0648 |
| Housing proportion rate | 0 | **** |
| Over-identification test= | 2580 | |
| Degrees of Freedom | 207 | |
| P value | <0.001 | |

**Figure 20: Non-housing Wealth Quantiles, Data versus Simulations, Robust**

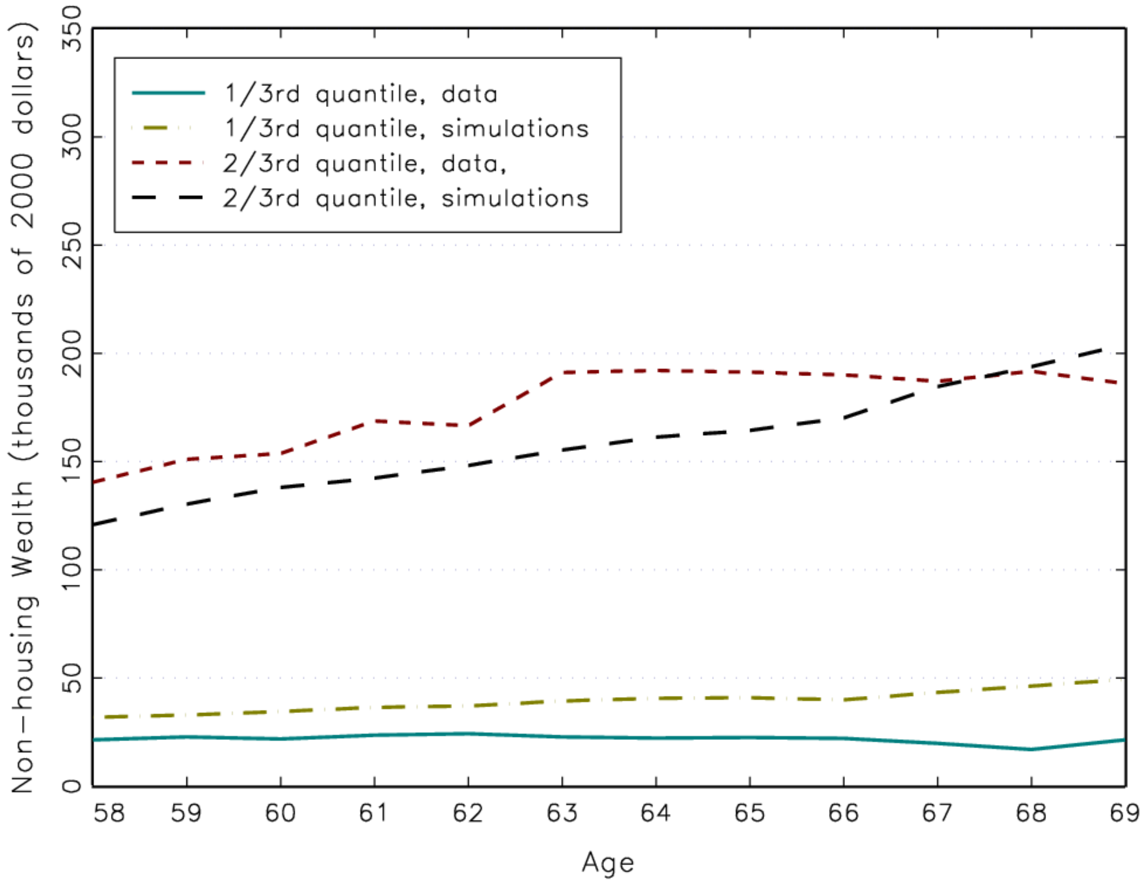


**Table 12:**
**Robustness Check, Without Housing Wealth and Heterogeneity**

| Variables | Estimates | Std.Err |
|---|---|---|
| Discount rate | 0.843 | 0.0123 |
| Consumption weight | 0.592 | 0.0069 |
| Risk aversion | 7.943 | 0.2118 |
| Leisure endowment (*1000) | 3.497 | 0.0555 |
| Bequest Curvature (*100000) | 5.536 | 0.2299 |
| Propensity of bequest (%) | 2.074 | 0.0524 |
| Fix cost of bad health (*100) | 5.189 | 0.1764 |
| Fix cost of working (*100) | 2.642 | 0.1037 |
| Age effects of working (*10) | 1.133 | 0.0814 |
| Fix cost of reentry (*100) | 0.888 | 0.1137 |
| Consumption floor (*1000) | 4.551 | 0.1061 |
| Housing proportion rate | 0 | **** |
| Over-identification test= | 2003 | |
| Degrees of Freedom | 187 | |
| P value | <0.001 | |

## Counterfactual Experiments

The counterfactual experiments examine different housing price expectations and tighter borrowing constraints. The first counterfactual experiment examines what happens when the return on housing wealth is fixed at its long-run level of 3 percent annually. Note that both original and modified models use the actual HPI. The second experiment examines what happens in the absence of a housing bust. We use the long-run housing growth rate after the year 2008 (average age of 66). The third experiment examines the effect of a tighter borrowing constraint from home equity. The new equity line is 50 percent of home value, which represents a decrease from the 75 percent level in the modified model.

**[Insert Figures 21, 22 and 23 here]**

Because the modified model results best match the actual saving behavior, the counterfactual experiments are based on the estimation results from Table 10. Figures 21 through 23 show the observed working profile, the simulated working profile from the original model and the simulated working profile from the modified model across the non-housing wealth terciles. The original model uses housing wealth change as a potential financial resource and does not allow the households to borrow. Hence, households with limited non-housing wealth who expect a decline in housing wealth may return to the labor market. The reason that the original model shows that the households with higher levels of non-housing wealth re-enter the labor market at age 62 maybe because of the underestimation of the labor-force participation rate before this age. In the modified model, we fit declining rates of labor-force participation well, except for households with low levels of non-housing wealth. In the observed data, there is no large decrease in labor-force participation rates either at Medicare age and normal retirement age. Perhaps, this is because of the substantial loss of housing wealth for wealthy households

**Figure 21: Labor Participation Rate, Data, Non-housing Wealth Quantile**

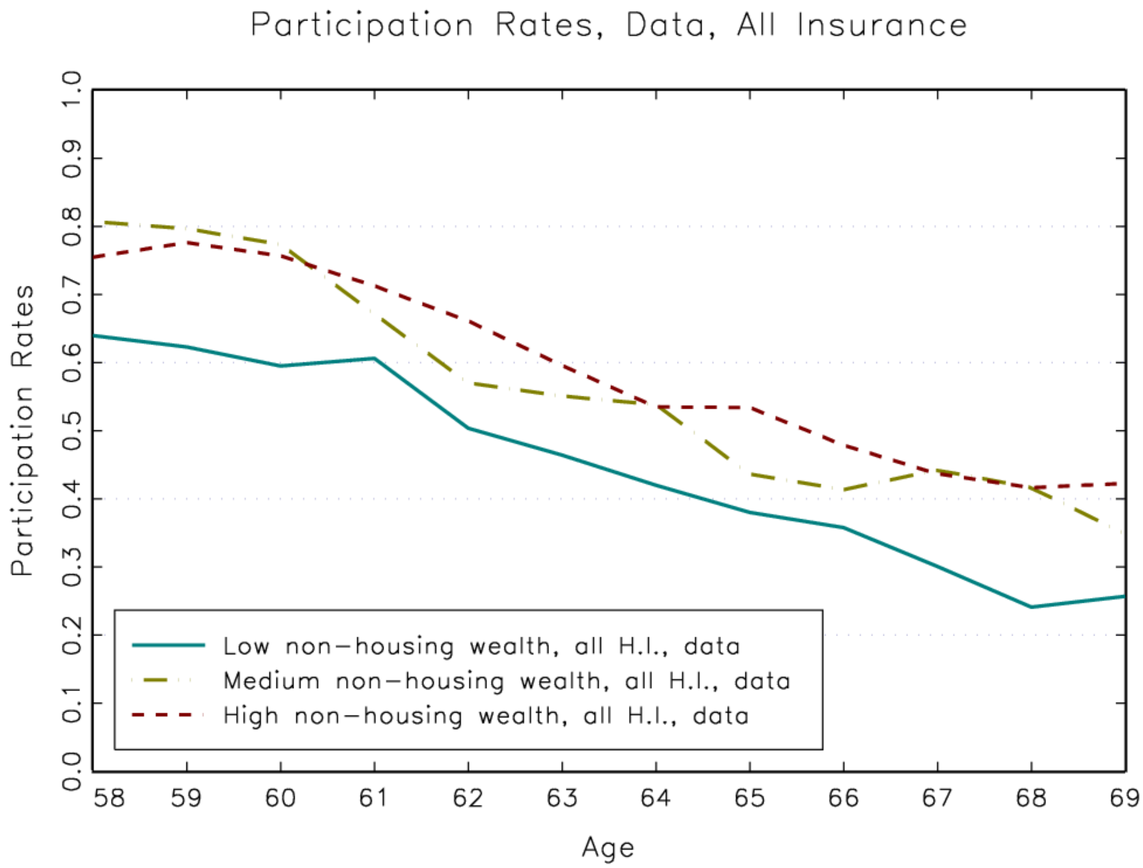


**Figure 22: Labor Participation Rate, Original Model, Non-housing Wealth Quantile**

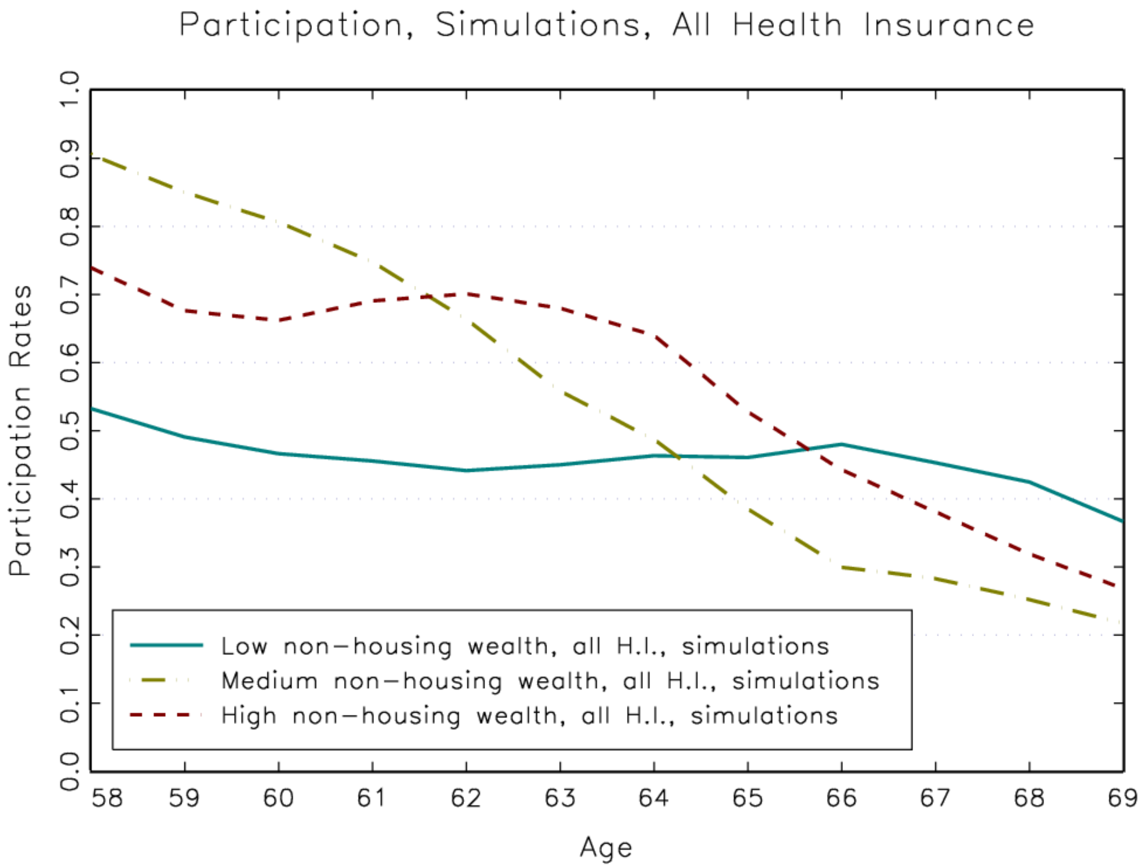
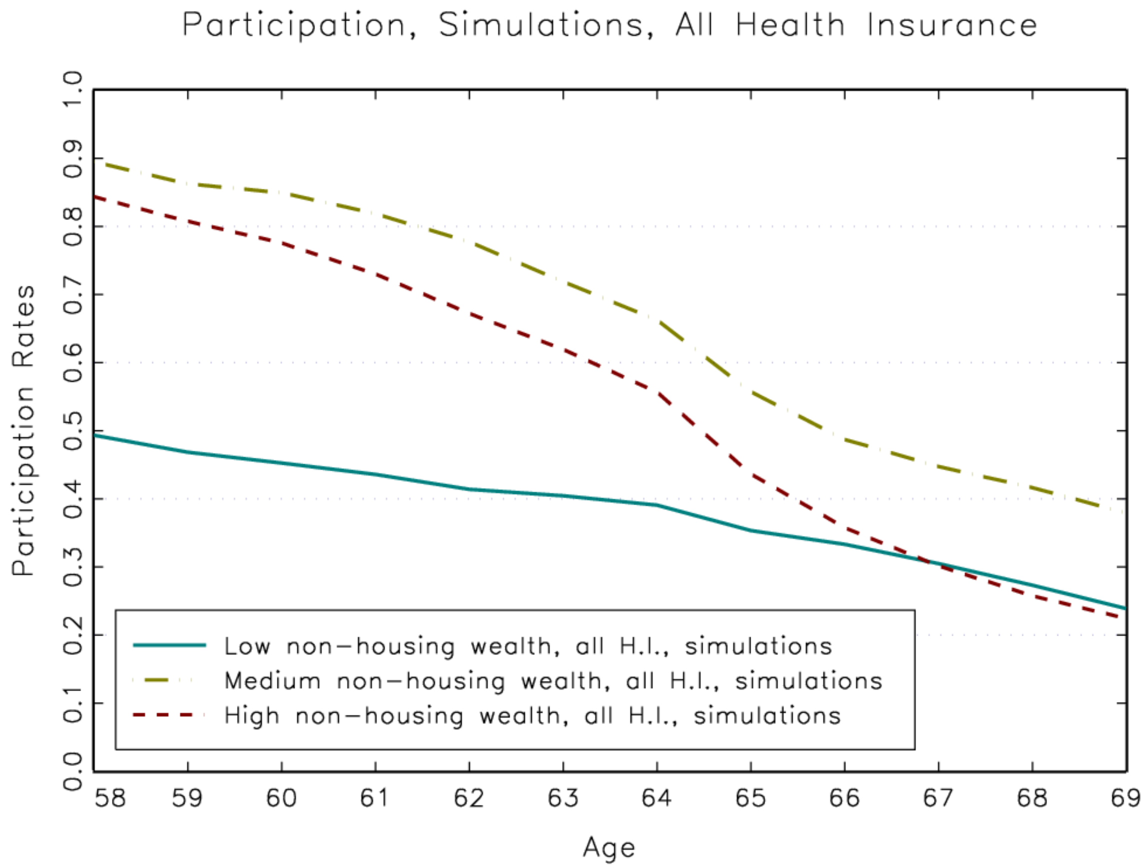


**Figure 23: Labor Participation Rate, Modified Model, Non-housing Wealth Quantile**



after the housing bust and the limited borrowing ability of poorer households. Moreover, the declining labor-force participation rate reverses at age 67 among households in the second tercile for non-housing wealth. Our original and modified models cannot capture this phenomenon.

**[Insert Table 13 and Figure 24 here]**

Table 13 presents the summary from the simulations. There is only a 1 percent change in the average labor-force participation rate in experiment 1. It is reasonable that the average HPI from the year 2000 to 2014 is three percent, which is close to the long-run growth rate. However, Figure 24 shows that the retirement profile is quite different in the low asset quantile. When the housing price return is high, the working rate is nearly ten percent lower in the modified model than in experiment 1 at age 59. When the housing bust begins, the declining trend of labor participation is much flatter in experiment 1 than in the modified model after the age of 64. The two different assumptions on HPI expectation do not lead to large differences for wealthy households.

**[Insert Figure 25 here]**

In experiment 2, if households do not expect a housing bust, the average labor-force participation rate is 5 percent lower than the estimation results. The largest effects are for households with the lower two terciles of non-housing wealth. In Figure 25, their labor-force participation profiles can be seen to shift downward. It reconfirms that housing price declines mainly affect households at the borrowing margin.

**[Insert Figure 26 here]**

There is a 2 percent increase of the labor-force participation rate in experiment 3, where we decrease the level of the home-equity line. The tighter borrowing limit acts similarly to a

**Table 13:**
**Labor-force Participation Profiles: Modified Model and Experiments**

| Age | Modified | Experiment 1 | Experiment 2 | Experiment 3 |
|---|---|---|---|---|
| 59 | 0.7126 | 0.7360 | 0.6598 | 0.7119 |
| 60 | 0.6924 | 0.7066 | 0.6335 | 0.6958 |
| 61 | 0.6614 | 0.6634 | 0.5926 | 0.6661 |
| 62 | 0.6209 | 0.6086 | 0.5494 | 0.6283 |
| 63 | 0.5808 | 0.5509 | 0.5097 | 0.5927 |
| 64 | 0.5366 | 0.4941 | 0.4699 | 0.5522 |
| 65 | 0.4489 | 0.4004 | 0.3841 | 0.4690 |
| 66 | 0.3925 | 0.3554 | 0.3429 | 0.4151 |
| 67 | 0.3511 | 0.3240 | 0.3137 | 0.3741 |
| 68 | 0.3156 | 0.2988 | 0.2910 | 0.3371 |
| 69 | 0.2805 | 0.2764 | 0.2704 | 0.2961 |
| **Avg.** | 0.5084 | 0.4922 | 0.4561 | 0.5217 |

**Figure 24: Labor Participation Rate, Experiment 1, Non-housing Wealth Quantile**

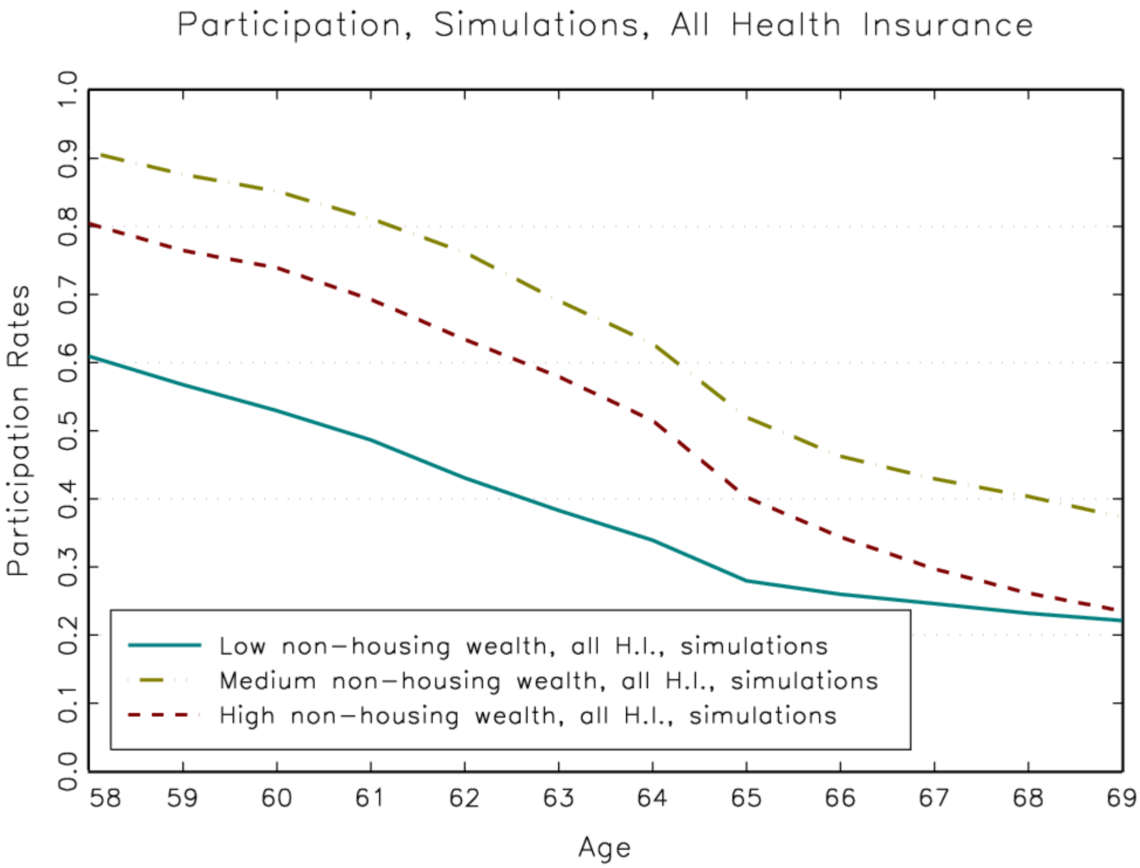


**Figure 25: Labor Participation Rate, Experiment 2, Non-housing Wealth Quantile**

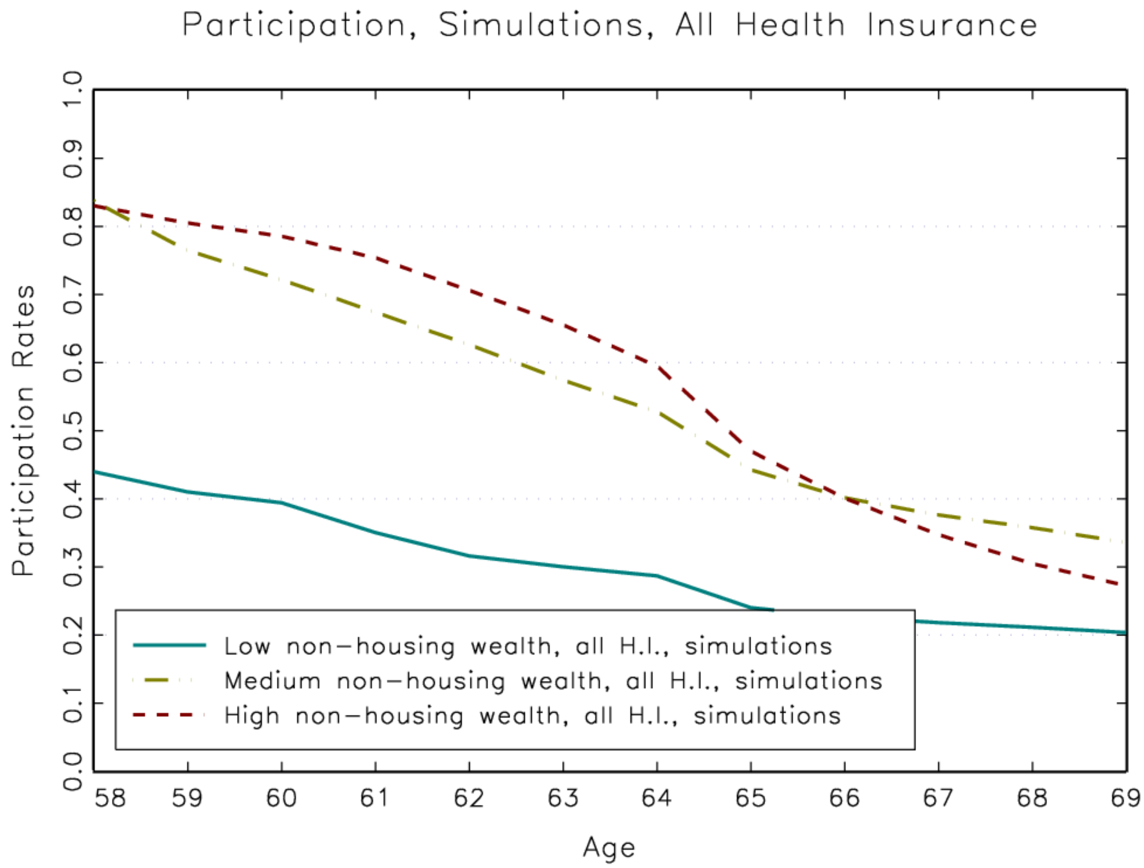
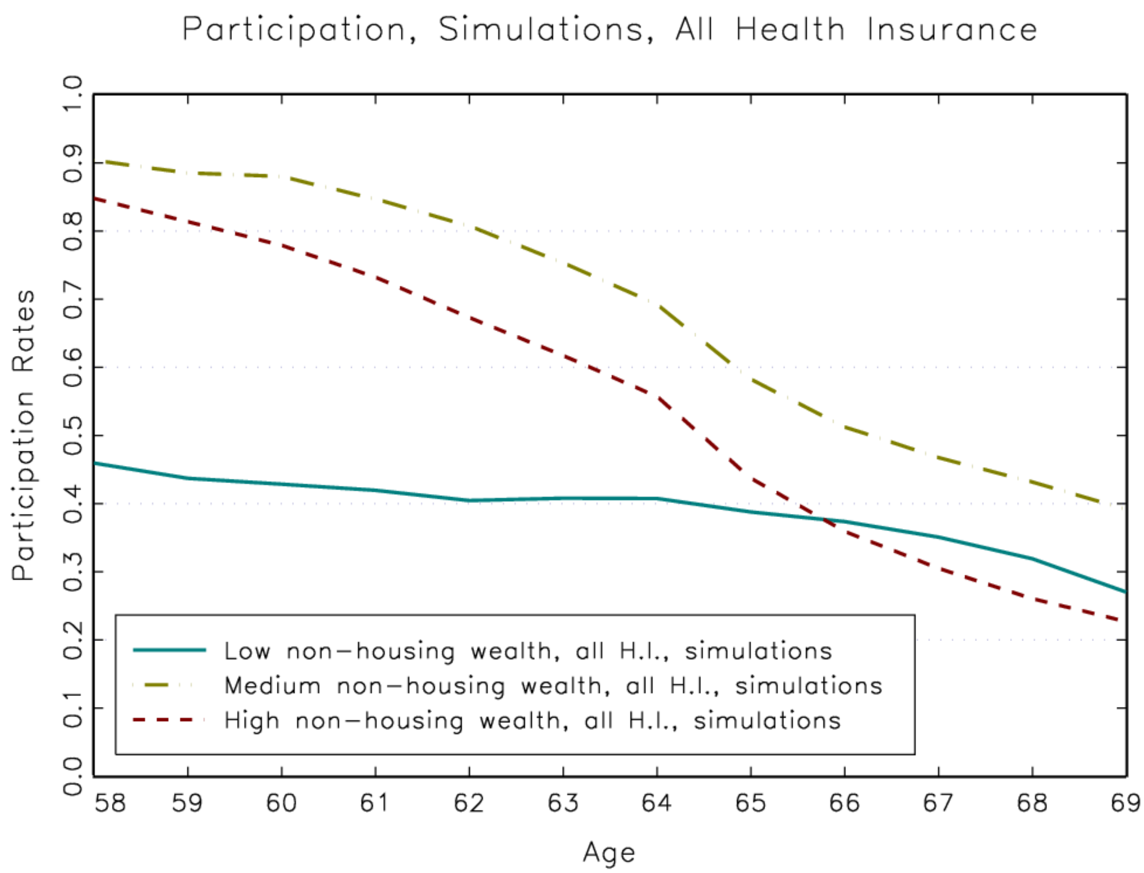


**Figure 26: Labor Participation Rate, Experiment 3, Non-housing Wealth Quantile**



decrease in housing wealth. The increase in the overall labor-force participation rate stems from increased participation rates for males in the lower two terciles of non-housing wealth. In Figure 21, the labor-force participation trends for males in these quartiles become flatter, while rates for males in the top tercile remain nearly unchanged.

## Discussion and Conclusion

Several recent studies have examined durable and non-durable consumption in the context of a life-cycle model. Aaronson, Agarwal and French (2012) conclude that housing wealth changes affect the debt levels of poorer households. This is consistent with the finding in this paper that the non-housing wealth accumulation profile is significantly different when housing is included as an illiquid asset. During housing boom-bust periods, most loans are originated to extract cash, by refinancing an existing mortgage loan into a larger mortgage loan (Demyanyk and Van Hemert 2011). Extracted cash can finance consumption or invest in the financial market (Cocco 2004). Most of the studies do not focus on the elderly (Aaronson, Agarwal, and French 2012, Cocco 2004, and Yang 2009). The role of the effect of home equity on elderly labor-force participation needs further investigation.

Both original and modified models fit labor-force participation well and the modified model fits non-housing wealth accumulation closely. Including housing wealth in the model significantly affects the savings behavior of wealthy households. The change of housing wealth affect labor-force attachment through the different channels, specifically, consumption, the bequest motive, and precautionary savings. if the elderly expect the decline in housing wealth, they may postpone retirement to secure their future living standards in the face of possible adverse outcomes. In the original model, consumption Increases due to increases in housing wealth induces declines in non-housing wealth accumulation for males in their early 60's, and social welfare programs disincentivize saving in poorer households. Therefore, declines in non-housing wealth accumulation lead to smaller bequests in the original model. In the modified model, concerns regarding debt increaser saving and the bequest motive becomes stronger.

We introduce a new state variable, potential re-entry status that blocks a large re-entry rate at the normal retirement age due to the elimination of the Social Security earnings at that age. The probability of re-entry decreases with age and unhealthy males are unlikely to re-enter the labor market. The coefficient of housing wealth in the original model is estimated to be close to the ratio of mortgage to home value in the sample. This suggests that an equity line of credit collateralized by housing wealth is one of the leading factors affecting consumption and saving.

Our experiments examine how results would change when 1) households expect HPI to increase at its long-run value of 3 percent, 2) there is no housing-bust episode and 3) there is a tight borrowing constraint. In the first experiment, the labor-force participation choices of households change significantly across non-housing wealth terciles, even though the change in average labor-force participation is small. In the second experiment, where there is no housing bust, the average of labor-force participation rate decreases by almost 5 percent and households at the borrowing margin are strongly affected compared to the modified model. In the third experiment, the effect of a tighter borrowing constraint will increase the average labor-force participation rate by 2 percent. In summary, the three experiments suggest that decreasing housing wealth and tighter borrowing constraints will delay retirement, particularly for households with little liquid assets.

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## EDUCATION

**Syracuse University**, Ph.D. in Economics — July 2012-June 2018 (expected)

- Fields of Interests: Econometrics, Computational Economics, and Labor Economics.
- Dissertation Topics: Essays on Retirement Behavior during the Housing Boom and Bust.
- Committee Members: Jan Ondrich (advisor), Alfonso Flores-Lagunes, William Horrace, Hugo Jales, John Yinger.
- Relevant coursework: Spatial & Panel Data, Time Series Econometrics, Discrete Choice & Duration Analysis.

**North China Electricity Power University**, B.S. in Economics — 2008-2012

## TECHNICAL SKILLS

Programming: Matlab, SAS (advanced certificate), C++, Gauss, Stata, Python.
Language: English (fluent), Mandarin (native).

## RESEARCH PROJECTS

1. Retirement and Saving Behavior in the Housing Boom and Bust (Job Market Paper).
   - Created a life-cycle portfolio choice model with consumption, Social Security application and retirement in a world with health, mortality, wage, and housing price risks.
   - Used SAS and Stata to construct estimation data from Health and Retirement Study and to estimate life-cycle profiles.
   - Programed massive amounts of code in Matlab to implement the Method of Simulated Moments and execute the C++ program to obtain the structural coefficients and standard errors.
   - Programed the C++ code with OpenMP in Visual Studio to solve the dynamic programming numerically by backward induction.
   - Validated the better fitness of new models and evaluated retirement under different scenarios.
2. How Did the Housing Bust Affect Retirement Decisions? (Amy Crews Cutts, Wancong Fu, and Jan Ondrich).
   - Constructed the estimation samples from Health and Retirement Study and Equifax Credit Trends 4.0 data in SAS to estimate a Prentice-Gloeckler-Meyer proportional hazard model.
   - Built the cross-walk tables from multiple sources to link geographic information between zip code, county FIPS, and MSA FIPS.
   - Used Stata to obtain the estimation coefficients.
   - Identified the significant negative effect of foreclosure rate on retirement.
3. Technological Spillovers Effects of State Renewable Energy Policy: Evidence from Patent Counts (Wancong Fu, Chong Li, Jan Ondrich, and David Popp).
   - Investigated the effect of state renewable policies on innovation and the spillover effect of these policies on innovation in other states by using Honores panel Tobit model.
   - Programmed spatial weighting matrix in Matlab.
   - Used Stata to obtain the baseline results and do sensitivity analysis.

## WORKING EXPERIENCE

**Research Assistant** — Fall 2015 to present

Supervisor: Jan Ondrich.
Project: "How Did the 2007-2008 Housing Bust Affect Retirement Decisions?"

**Teaching Assistant**

Intermediated Macroeconomics, Survey Microeconomic Theory (Ph.D.), Financial Econometrics.