Unstable Leisure Complementarity and Dual Career Couples' Joint Retirement Behavior

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Abstract

In this paper, I use the Health and Retirement Study (HRS) data and build a dynamic life-cycle model to analyze how dual-career couples jointly make their retirement decisions, seriously considering the heterogeneous and unstable preferences for joint leisure. I follow the stream of literature that explains joint retirement behavior through leisure complementarity between couples. Contrary to previous findings that couples always enjoy joint leisure and prefer to retire together, the estimates in this paper show that when people have a low preference for joint leisure, they even experience distaste for shared leisure time. When the wife has a low preference for joint leisure, her leisure is only half as enjoyable when her husband has retired than when her husband is still working. When the husband has a low preference for joint leisure, his leisure is only 0.93 times as enjoyable when his wife has retired than when his wife is still working. The wife's preferences for joint leisure are relatively more stable than the husband's. The findings also show that preference for joint leisure has a significant impact on the probability of working. Disutility from joint leisure can potentially be vital for explaining the older population's labor participation behavior.

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1 Introduction

Based on the reports by the U.S. Bureau of Labor Statistics, both spouses were employed in 47.8 percent of married-couple families in 2010 and this number was 49.7 percent in 2019. Dual career couples account for a large proportion of married-couple. As both the husband and the wife are in the labor market, these families can be more flexible in their labor supply decisions. And based on the findings in empirical analysis section, leisure complementarity can be unstable, heterogeneous between husband and wife; and can potentially significantly impact joint retirement behavior. The research questions of this paper are: How do dual career couples' make their joint retirement decisions? And how can the unstable leisure complementarity affect couples' behavior?

This paper proposes and estimates a dynamic life-cycle model to study dual career couples' joint retirement behavior. Here, "dual career couples" specifically represents those who work and pay Social Security taxes and are eligible for Social Security retirement benefits now or in the future. In this paper, I follow the stream of literature which explains joint retirement behavior through complementarity of leisure between couples and integrate a joint household budget constraint. The prototype of my model is mainly based on Gustman and Steinmeier (2000) and Gustman and Steinmeier (2004), and is a non-cooperative bargaining model, in which each individual maximizes his/her own utility and couples influence each other through household consumption and leisure complementarity. Their paper does not have uncertainties, and labor supply decisions are determined at the beginning of the life-cycle, which means their model does not allow precautionary behavior towards uncertainties and may over or underestimate the policy effects. The key improvements I make here are to add uncertainties, uncertainties for leisure preference in particular, into the model.

Based on the conclusions from Wu (2003) and Bound et al. (2010) that health conditions and health shocks are vital in determining labor participation behavior at people's older age, uncertainty for health status is embedded. Moreover, besides this commonly considered source of uncertainty, the primal uncertainty included in my model is uncertainty of leisure complementarity which is rarely studied. In the empirical analysis section, I use the Health and Retirement Study (HRS) data from 1992 to 2018 and use couples' reported "Closeness"[1] as analog for preference for joint leisure to show data patterns and provide evidence to support the necessity of adding this uncertainty. Statistics for "Closeness" implicitly show that leisure complementarity can potentially fluctuate over time and can be heterogeneous between husband and wife. In addition, I run logit regressions which conclude that a respondent is more likely to jointly retire together with his/her spouse at current period, if

[1] In HRS data, closeness question is asked as "How close is your relationship with your partner or spouse?".

the respondent is in a closer self-reported relationship. This indicates that different preferences for joint leisure have the ability to significantly influence people's joint retirement choices. And adding uncertainties of preference for joint leisure may help us have better understanding of couples' joint retirement behavior.

Conditional on this finding, features of heterogeneous and uncertain leisure complementarity are added in the model. This is one of the primary reasons why I choose to build a non-cooperative bargaining model. If using weighted household utility, heterogeneity can not be identified; this is discussed more in Section 5. To be specific, within a representative household, husband and wife can have heterogeneous leisure complementarity (or taste for joint leisure), and for husband or wife, leisure complementarity itself follows a discrete-time time-homogeneous Markov chain. This feature can be important for counterfactual policy design if the range of fluctuation is large and if the fluctuation is with high frequencies, which are shown to be true by results from the estimation.

Other than uncertainties, since Rust and Phelan (1997) showed that Social Security policy has a large impact on individual's retirement behavior and can explain early retirement and age 65 retirement puzzle, Social Security retirement benefits are another aspect that is built in the model.

The choice set for my model only contains household labor supply decisions, and the model is estimated using MLE method and solved through backward induction. To solve the model, I assume that each household's labor supply decisions are determined in a sequential way. At the beginning of each period, all the shocks are received and based on the information known by the household, husband and wife make choices in a sequential way. Detailed reasons why it is assumed as a sequential game are discussed in Section 6.

There are several findings from the estimation of the model and counterfactual behavior analysis. 1) In contrast to conclusions from previous papers that people always value their retirement more once their spouse has retired, in my model and when people have low preference for joint leisure, they value their leisure less when their spouse has retired. This can happen to both husband and wife, and wife has stronger reaction towards this preference change conditional on husband has retired. 2) When the wife is under low preference for joint leisure, leisure is only half as enjoyable when her husband has retired than when her husband is still working. When the husband is under low preference for joint leisure, leisure is only 0.93 times as enjoyable when his wife has retired than when his wife is still working. 3) Wife's preference for leisure is relatively more stable than husband. Both high and low preferences for joint leisure persist longer for wife than for husband. 4) It is also discovered that probability of working can be largely impacted by preference for joint leisure. However, for the second mover, this is only true when the first mover has retired. Disutility from joint leisure can potentially be a vital reason for explaining the older population's labor participation behavior. When the main purpose of policy intervention is to inspire the older population's labor participation, this fluctuating leisure complementarity may be one of the key features that need to be considered.

The rest of the paper is organized as follows: In Section 2, I review different streams of related retirement literature. In Section 3, I describe the data that is used for empirical analysis and for model estimation. Specific constructions for key variables are also described in detail. In Section 4, I do empirical analysis and conduct logit regressions with age and time fixed effects to show heterogeneity and fluctuation of leisure complementarity and its influence on couples' retirement choices. In Section 5, I introduce my theoretical dynamic life-cycle model which contains leisure complementarity uncertainty and health shock uncertainty and a household joint budget constraint. Section 6 describes the model solution in detail. Assuming household labor supply decision making process as a sequential game, the model is solved with MLE method and through backward induction. Section 7 presents estimates of the model. Section 8 presents the model fit. In Section 9, I conduct counterfactual behavior analysis for both husband and wife. Section 10 gives conclusions for my current work.

2 Streams of retirement literature

With the increase of share of old age population in the total population, and with the improvement of health status of older people, as well as with the extension of average life expectancy, much attention has been paid to financial strain such as fiscal constraints of the Social Security pool or Medicare.

To have better understanding about how government should intervene and what is the influence of government intervention, many papers put efforts on studying people's retirement behaviors. Among them, some of the papers employ the reduced form way. For example, Rogowski and Karoly (2000) studied how health insurance can affect an older worker's retirement decision and showed that workers with retiree health benefit offers are more likely to retire than their counterparts. Wu (2003) showed that a serious health shock has strong effects on household wealth and has significant impact on middle aged and older individuals' continued employment, which provides me good reason to add health uncertainty into my model.

Due to the complication of retirement and due to the purpose of doing counterfactural policy experiments, many other papers construct structural models to understand this question. In the pool of structural papers, a large proportion of the papers study individuals' retirement choices. Bound et al. (2010) found large impacts of health on behavior, however the impacts are substantially smaller than in models that treat self-reports of health as exogenous. Rust and Phelan (1997) found that in an incomplete market, Social Security policy has a vital influence on individuals' retirement behavior and can explain early retirement and age 65 retirement puzzle. French (2005) showed that taxation of the Social Security system and pensions are vital in explaining the high observed job exit rates at ages 62 and 65, and earnings test impedes individuals from working. Based on those findings, my paper incorporates Social Security retirement benefits into the model. For simplification, my model assumes that Social Security benefits are not affected by labor choices after age 50 and everyone claim their benefits at age 65.

Nevertheless, within a household, there can be many possible channels through which couples can share risk or share benefits with each other, and this is especially true for those dual career couples. Misrepresentation may happen if not taking the spouse's side into serious consideration. This is also the main reason why my paper focuses on building a model for dual career couples. Considering the disadvantage of an individual structural model, there are other papers that study people's retirement decision from couple's angle. Among them, one of the main streams focuses on modeling household budget constraint. Lundberg and Ward-Batts (2000) contributed to estimate a more complete unitary model of the determinants of household net worth. They found that characteristics of both husband and wife are important determinants of household net worth. Blau and Gilleskie (2006) constructed a dynamic structural model of older married couples' labor force participation behavior and found that the effect of health insurance on older couples' labor participation behavior is moderate and changes to the Medicare eligibility age have small effects. Van der Klaauw and Wolpin (2008) focused on low-income households and found that changes in Social Security rules such as the removal of the earnings test, the elimination of early retirement and a postponement of the earliest retirement age to 70, have similar and large effects on low-income households' labor participation behavior.

Another stream of the papers focus on modeling leisure complementarity based on the observations that couples usually retire at similar period of time. This is the stream that my paper is bases on. Gustman and Steinmeier (2000) studied retirement in dual career families and found that joint retirement decisions of spouses are significantly affected by preference for joint leisure but are not due to budget sets. Gustman and Steinmeier (2004) further showed that a measure of how much each spouse values being able to spend time in retirement with the other accounts for a good portion of that apparent interdependence.

There are also papers which try to incorporate the above two strands. Casanova (2010) built a structural, dynamic model of older couples' saving and participation decisions which allows for the complementarity in spouse's leisure and where the financial incentives and uncertainty facing spouses are carefully modeled. It showed that leisure complementarity is positive for both husband and wife and the Social Security spousal benefit also accounts for the joint retirement decisions. My paper also tries to incorporate those two strands, but in a much more simplified way.

3 Data

In this paper, I use longitudinal RAND Health and Retirement Study(HRS) data combined with raw HRS 1992-2018 data, which are broadly used in retirement studies. HRS is a major national panel study of the lives of older Americans which makes it an appropriate data set for the topics that I am interested in. HRS has done biennial surveys on more than 22,000 Americans over the age of 50 since 1992. Designed to follow representative individuals and their spouses or partners as their status transits from active worker to retirement, besides traditional demographic information, this data set also includes detailed information about physical and mental health; individual's labor supply such as hourly wage, weekly wage, hours worked per week, weeks worked per year; self-considered retirement status such as completely retired, partly retired, not retired; Social Security claiming history if claimed and expectation if not claimed; insurance coverage; financial status; pensions and retirement plans etc. Besides, starting from 2006, HRS randomly assigns half of the core sample to enhanced face-to-face interview. Data from this part is available every wave and is longitudinal every two waves (every four years). After completion of the face-to-face interview, respondents are left with the Leave-Behind Questionnaire, which includes closeness related questions. In the empirical section, I run regressions of person i's retirement choice on i's closeness intersected with spousal retirement choice. This shows more intuition about how we should think about the dynamic of couples' taste for joint leisure or the complementary of leisure and its effects on joint retirement.

HRS data contains 26,596 households, each of which can comprise one or more than one respondents. Because the group of people that are studied in this paper are dual career couples and the behaviors of interest are their retirement choices, respondents who never had a spouse during the interview periods are dropped. Only households of dual career couples are kept and I drop all the households within which either husband or wife or both of them were self employed or homemakers or never had a formal job. This leaves me with 21,280 households. Those households within which husband and wife never reported their retirement status are also dropped from the sample. After this process, 19,029 households are left. For concerns that retirement decisions for households with disabled husband or wife may be determined by different mechanisms as they have other outside options like

Social Security disability insurance (SSDI) which cannot be explained by my model, those households who ever received SSDI or who ever reported being disabled are excluded from the sample. This reduces the total household number to 14,081.

Referring to Social Security retirement benefits, as I do not have the restricted Social Security Administration (SSA) data to obtain the accumulated earnings history and as HRS is designed for people above age 50 and cannot provide information about their earning path at younger age, I can only use samples who reported Social Security retirement benefits if benefits had already been claimed, or who reported Social Security expectation if benefits had not been claimed. Moreover, focusing on dual career couples' joint retirement decisions also means that a household will be excluded if it lacks this information for either husband or wife. Besides, as I use Social Security history or expectation data to extrapolate the Social Security path between ages 62 to 70, which will be described in detail in the following data construction section, records are usable only if both the Social Security amount (or expected amount) and age received (or age to receive) the benefits are available. This rigorous process causes huge shrinkage of sample size and I am left with 3,312 households afterwards.

Due to the simplification of my model, which shuts down the channel of divorce and remarriage, I delete those who ever separated or divorced or widowed or never married during their interviewed periods. This process does not eliminate those who had experienced more than one marriage before the interview; they are kept in the sample as long as they were with the same spouse during all the interviewed periods. Because Social Security spouse's benefit system does not take partners into account, I further drop those who had a partner but no spouse, even though they had never separated during all the interviews. The final household number is 2,682.

Due to model concerns, I further manage the data in the following ways. I drop samples who lack information for state variables, like education/ age/ age difference etc., in all the periods and therefore are unable to be filled anyway. Without those state variables, I am unable to deduct people's labor participation probability path. Since education choice is not something I consider in the model, I delete those whose education level had changed during the interviewed periods. Fifty-three households are eliminated in this process. Moreover, as my main focus is couples' retirement behavior during age 50 to age 75, I only keep those observations within which couples are both above age 50, and either husband or wife is younger than age 75. Otherwise, for instance, if both husband and wife are above age 75, this record contributes nothing to my model which assumes people all quit the labor market after age 75. I end up with 2,587 households and this is the data for both empirical and model analysis.

3.1 Variable Construction

One objective of this subsection is to provide more explanations for key variables before diving into a statistical summary for the whole data set. The other purpose is to describe what I specifically do to construct some of the variables for empirical regression as well as model estimation.

3.1.1 Variables used both in empirical regression and theoretical model

Retirement Indicator

Retirement indicator is set to be one if the respondent considers himself/herself as "partly retired" or "completely retired", and zero if the respondent considers himself/herself as "not retired". This indicator does not determine when to claim Social Security benefits and is not determined by Social Security benefits in the model. In the model which will be discussed in detail later, it can be possible that person i retires at period t but hasn't received benefits yet or person i receives benefits but is still working. In my paper, for simplification, retirement and labor participation are the two sides of the same coin. If the retirement indicator equals to zero, that indicates the person is working full time, and if the indicator equals to one, that indicates the person has quit the labor market. Intermediate state, where people can work part time, is not considered in my model.

Health Indicator

There are two indicators to reflect respondents' health condition. One indicator is whether a respondent's health limits his/her work at the interviewed period, $\mathbf{I}$(*Health Limits Work*). The other indicator, $\mathbf{I}$(*Health*), is based on respondents' self-reported health condition. It equals one if a respondent's self-reported health condition is "Excellent", "Very Good" or "Good", and equals zero if reported health condition is "Fair" or "Poor". Comparing with whether health limits work, the second indicator may capture more information about chronic diseases. Both indicators are used in the empirical analysis, and only $\mathbf{I}$(*Health Limits Work*) is used in the model.

3.1.2 Variables used only in empirical regression

Closeness

Distinct from other variables, the closeness question is longitudinal every two waves, or every four years, which makes it have a much smaller sample size. The question is asked as "How close is your relationship with your partner or spouse?". Answers contain four levels: "1. Very Close", "2. Quite Close", "3. Not that Close", and "4. Not at all Close". In the empirical analysis, indicator $\mathbf{I}$(*Very Close*) is defined as 1 if the answer is "Very Close" and

0 otherwise.

3.1.3 Variables used only in theoretical model

Variables listed below are only used for model estimation.

Hours per Week, Weeks per Year, Hours per Year, Hourly/Weekly Wage

Hours worked per week and weeks worked per year are reported by respondents and hours worked per year is calculated as the product of these two variables. Those variables are set as missing if respondents report "partly retired" or "completely retired" and summaries of those variables in Table 3 are only for respondents who have "not retired" yet. These data are primarily used to derive respondents' yearly wage if they work full time.

Yearly Wage

In the theoretical model, a person who does not retire is assigned with the median hours worked per week, 40 hours, and median weeks worked per year, 52 weeks. As it is shown in later summary statistics that the median is the same for both man and woman, I calculate man's and woman's yearly wage in the same way as follows. Values are rescaled by 10,000.

$$\text{Yearly Wage} = \max\{40 * 52 * \text{hourly wage}, 52 * \text{weekly wage}\}/10,000$$

Social Security Path

Social Security path is calculated based on questions listed in Table 1. Benefits, as a percentage of Primary Insurance Amount (PIA), payable at ages 62 to 70 are calculated based on the rule from Social Security Administration's website, "In the case of early retirement, a benefit is reduced 5/9 of one percent for each month before normal retirement age, up to 36 months. If the number of months exceeds 36, then the benefit is further reduced 5/12 of one percent per month.$\cdots$ Delayed retirement credits increase a retiree's benefits." Table 2 shows detailed information about percentage of PIA people can get based on their year of birth and claiming age. I use rule of this table, respondent's birth year, and respondent's reported or expected Social Security benefits to compute their yearly payable Social Security benefits if claiming at ages 62 to 70. For example, if person i born in 1944 reported in wave 5 that he/she expected to receive Social Security benefits at age 65 with an amount of 24,000; reported in wave 7 that he/she expected to receive Social Security benefits at age 62 with an amount of 11400; and reported in wave 10, year 2010, that he/she had already retired and received Social Security benefits at age 65 with an amount of 14,400; then from the table, person i's normal retirement age is 66 and I use all those three values to calculate the Social Security path for ages 62 to 70 separately and use the average amount at each age as the true Social Security value they will get if claiming at that age.

After obtaining the Social Security benefits path for a couple within a household, individual i's Social Security amount is set to be the maximum between i's own benefits and 1/2 spouse's benefits. This is the simple setting for spouse's benefits, which is based on the Social Security policy that is listed on the website of Social Security Administration, "the full spouse's benefit could be up to one-half the amount your spouse is entitled to receive at their full retirement age".

3.2 Summary Statistics

Table 3 presents the statistical summary. Within the table, the left part is referred to as "sample data" and it displays the summary for all the respondents that are left for empirical regression and theoretical model. The right part of the table summarizes the raw data with nothing other than simple trimming applied to the raw data before summary. In the sample data, I only keep the record if the respondent and his/her spouse are both older than age 50 and are not both older than age 75. In the raw data, I perform the same thing for couples, and restrict the age to be between 50 and 75 for singles. Men in the sample are relatively older than men in the raw data. It is shown in the table that mean education level for men and women respondents are about the same in the sample data, and are slightly higher than those in the raw data, while distribution of education for women is less dispersed. Comparing with respondents in the raw data set, respondents are much healthier and less limited to work in the sample data, and this is true for both men and women. This is reasonable, as in the sample data, respondents who are disabled or receive SSDI are excluded. Due to the fact that respondents are relatively older in the sample data, they are more likely to have already retired in the sample data than in the raw data. For those who have not retired yet, men on average work longer than women both in terms of hours worked per week and weeks worked per year, while the median is the same for both men and women. This is true both in the sample data and in the raw data, and features of those variables are similar in the two data samples. It is also shown in the table that men earn higher wages than women. Though closeness is an ordinal variable and mean of closeness does not contain much information, as the lower the number the closer the relationship, it reveals that men are relatively more positive about their closeness with spouse. This is true in both data sets. It is also shown that, on average, men are approximately three years older than the spouse.

In conclusion, for comparison between the raw data and the sample data, as the sample data only focuses on spouses who did not divorce or separated or widowed during interviewed periods, it is not surprising to see that the sample observations have closer relationship with their spouse. What's more, as the sample data excludes those who are disabled or receive

SSDI, it on average also has lower rate of health limitation, higher rate of health and higher rate for retirement. Other than those differences, means for other variables look similar but are less dispersed in the sample data, compared with the raw data.

4 Empirical Analysis

Before moving on to the theoretical joint retirement model, this section uses both summary statistics and logit regressions to show data patterns of the model's key aspect, heterogeneous and unstable leisure complementarity, and to show how different preference for joint leisure can influence couples' retirement behavior. In the empirical analysis, I utilize all the available data from both husband and wife for each household.

4.1 Features of closeness

Reported "Closeness" is utilized as analog to couples' taste for joint leisure. Thinking from the angle that the closer the feeling, the more willing people are to enjoy leisure with his/her spouse, closeness type of questions can reveal information about attributes of leisure complementarity over time. As an ordinal variable, the smaller the number, the closer the relationship is between respondent and spouse. Table 4 shows the distribution of this variable in all waves. As I focus on those who never divorced during the interview, it is not surprising to see that there are very few people choosing "Not at all Close". Table 5 implicitly reveals that taste for joint leisure is not one hundred percent coordinated between husband and wife, and a couple can have separate taste at the same time. As is shown in the table, the proportion of husbands who chose the first option "Very Close" or the first two options "Very Close" and "Quite Close" are higher than the proportion of wives. Husbands are relatively more positive about their relationship with their spouse. Not only is closeness inconsistent within couples, it also fluctuates over time, and a related example is shown in Table 6, which is the closeness transfer matrix from wave 9(year 2008) to wave 11(year 2012).

4.2 How joint retirement can be affected by closeness

To get more sense about how this unstable taste can further affect couples' retirement decisions, I run logit and conditional logit regressions of respondent retirement decision on spouse's retirement decision interacted with closeness.

Since for many people retirement is a one time choice and an absorbing state, in the regression I do not control for individual fixed effects. Also since retirement is complicated and is highly likely to be nonlinear with age, I control respondent r's and spouse s's age fixed effects and respondent r's birth year fixed effects. Two main logit regressions are run as follows: 1) Not conditional on labor participation history, how r's retirement choice at current period t is affected by spouse s's choice when taking closeness into consideration. 2) Conditional on respondent r hadn't retired at last period *t-1*, how r's retirement choice at current period t is determined.

There are several reasons why I use logit model instead of linear probability model. One reason is that linear probability model does not guarantee predicted or fitted values to be within zero and one and has homoscedastic errors. Another reason is that partial effects in linear probability model are constant which does not make sense when the probability is near zero or one. For instance, because all respondents in the sample are between ages 50 and 75, conditional on still working last period, people at their younger age of 50s are less likely to retire at this period and the probability may be very close to zero. As it is more reasonable to let dependent variable $\boldsymbol{X}$ have a non-constant partial effects near the edge, logit model is a better choice than linear probability model. Moreover, another closely related advantage of using logit model is that when using logit model with age fixed effect, those very young or very old age groups within which all the observations have retired or all the observations are working will not enter the regression. The following equations are estimated.

$$\begin{aligned}\mathbf{y}_{it} = \quad & G\Big[\beta_1 \mathbf{I}(r\_Very\ Close)_{i,t} \times \mathbf{I}(s\_Retired)_{i,t} + \beta_2 \mathbf{I}(r\_Very\ Close)_{i,t} + \beta_3 \mathbf{I}(s\_Retired)_{i,t} \\ & + \beta_4 \mathbf{I}(s\_Retired)_{i,t-1} + Age_r + Age_s + \delta_t + \gamma' \boldsymbol{Z}_{i,t}\Big], \end{aligned} \tag{1}$$

$\mathbf{y}_{it}$ is $Pr\Big(\mathbf{I}(Retired)^{\mathbf{r}}_{i,t} = 1 \Big| \boldsymbol{X}_{i,t}\Big)$ or $Pr\Big(\mathbf{I}(Retired)^{\mathbf{r}}_{i,t} = 1 \Big| \boldsymbol{X}_{i,t},\ \mathbf{I}(Retired)^{\mathbf{r}}_{i,t-1} = 0\Big)$. $G[\cdot]$ is the logistic CDF. $\mathbf{I}(r\_Very\ Close)_{i,t}$ is an indicator which indicates whether person i's reported closeness falls into the first closeness group or not. $\mathbf{I}(s\_Retired)_{i,t}$ is indicator of whether s retires at this period and $\mathbf{I}(s\_Retired)_{i,t-1}$ is indicator of whether s retired at last period. Independent variable $\boldsymbol{Z}_{i,t}$ contains a set of controls for respondent's gender, respondent's and spouse's years of education/ health limits work indicator/ health condition and constant term. Age_r represents respondent's age fixed effects, Age_s represents spouse's age fixed effects and δ_t denotes respondent's birth year fixed effects.

In regressions, I use a simple indicator $\mathbf{I}(r\_Very\ Close)$ to divide closeness into two groups, "Very Close" group and the others. The reason for dividing closeness in this way is because there are too few observations in the last two closeness categories. Concerning that people may not be convinced that the last two closeness categories, "Not that Close" and "Not at all Close", can be grouped together with "Quite Close", I run a second version regression for robustness check, within which only those reported "Very Close" and "Quite Close" are kept for regression. Similar results are shown in Table 8. As consistent results are shown in both versions, I use the first version to conduct empirical analysis.

Because the main focus of this section is to show the data patterns before moving on to the model, when describing the estimations I primarily concentrate on interpreting the direction or sign, instead of putting efforts on explaining the magnitude. Discussion about the magnitude will be left after estimating the theoretical model.

Table 7 reports the estimation results for equation (1). Outputs from both column (1) and column (2) show that for a representative respondent r, r is more likely to retire at current period if r's spouse retires at this period, or r has less education, or r's health limits work, or spouse s is in good health. The results from this table further show that health can be one of the key features that influence older population's retirement decisions. It is necessary and vital to take health shock into consideration when doing joint retirement analysis.

More importantly, for the intersection term between r's closeness feeling and s's retirement choice, it is shown that compared with those who feel less close, r in closer relationship values his/her leisure more once the spouse has retired and has more tendency to retire together with the spouse s. This finding indicates that closeness has the ability to influence joint retirement behavior, and people may behave differently when under different preference for joint leisure. Even under the condition where retirement is thought to be durable or one time choice, column (2) sheds lights on those conditions and provides similar results. Besides, effects of closeness are amplified in the conditional regression.

All in all, data patterns in this section show that preference for joint leisure can be unstable and heterogenous between husband and wife, and it can potentially influence couples' joint retirement behavior. In order to better understand couples' joint retirement choices, these features are added in my current theoretical model.

5 Theoretical Model

In this section, I propose a dynamic life-cycle model of dual career couples' retirement choices (or labor supply decisions) at their older age.

Based on the data patterns presented in the Empirical Analysis section, unstable and heterogeneous leisure complementarity is added. In addition, conditional on the results from the logit regression and based on the conclusions from Wu (2003) and Bound et al. (2010), uncertainty for health shock is embedded. At the start of each period, with a certain probability, a representative person will end up with bad health condition and the person's work ability will be limited. While it is shown in Rogowski and Karoly (2000) that health insurance can affect older worker's retirement behavior, Blau and Gilleskie (2006) showed that health insurance has a moderate effect on older couples' labor participation behavior.

Due to this reason and for simplification, my model does not incorporate medical expenditure in household joint budget constraint.

Since Rust and Phelan (1997) showed that Social Security policy has a large impact on individual's retirement behavior, Social Security retirement benefits are built in the model. Though French (2005) found that taxation and unfairness of the Social Security system are vital in explaining job exit at ages 62 and 65, at the current stage, for model simplification, those tax features are not embedded. I start with a simplest version with no tax or earnings test and a model within which Social Security path is known and is not influenced by current labor participation decisions for people who are above their age 50, and all people claim their Social Security benefits at age 65.

In the model, each household contains husband and wife, and divorce and remarriage are not considered in my model; people will only be back to single if one of the spouses dies. At each discrete period t, based on all the information they have, couples make optimal decisions on whether to retire or not (or in other words whether to not participate in the labor force or to participate).

Based on Gustman and Steinmeier (2000) and Gustman and Steinmeier (2004), the model constructed here is a non-cooperative bargaining model, in which each individual maximizes his/her own utility instead of household utility. Couples can impact each other's decision making process through household consumption and leisure complementarity. Comparing with what Gustman and Steinmeier did in their paper, in my model, I allow uncertainties of different dimensions, especially uncertainty of leisure complementarity which is rarely considered in previous papers. Retirement is not assumed as an absorbing state in my model, which is to say it is possible for people to go back to work after retirement as long as it is optimal.

5.1 Choice Set

At each discrete time period t, based on all the information observed, husband and wife make their own decisions on whether to fully retire from the labor market and enjoy their leisure. In my model, retirement is the opposite side of participating in the labor force and people work full time if they do not retire. This means choices are simplified as binary choice and there are only two elements, either retire or not retire, in the choice set.

$$L_t^i = \begin{cases} 0, & \text{leisure equals to 0 if } i \text{ works full time} \\ 1, & \text{leisure equals to 1 if } i \text{ fully retires} \end{cases}$$

where L denotes leisure, h denotes husband, w denotes wife and $i \in \{h, w\}$. Though trinary discrete choices which also include *partly retired* as one option are more reasonable, for the sake of simplicity, my model does not include any choices other than *completely retired* and *not retired.* The option of *partly retired* is excluded from my model and is not distinct from *completely retired.*

Retirement is not assumed as an absorbing state in my model, this is to say, people can go back to work whenever they want even after they once quit the labor market. For computational concerns and to save state variables, there is no extra fixed cost attached to back to work behavior in the model. Among all those 2,587 households that are left for analysis, 184(around 7.11%) of the husbands once had back to work behavior after retirement when their ages were between 50 and 75. 200(around 7.73%) of the wives once went back to work after retirement. In total, 364(14.07%) of the household, either husband or wife, once went back to work after retirement. Based on theses facts, flexible labor choice at each period seems not too bad a setting to make.

Another reason why it may be safe to assume couples make labor choices repeatedly, comes from the facts presented by empirical analysis. When comparing the conditional and unconditional case, it implicitly reveals that assuming labor participation as repeated games will underestimate the effects from preference for joint leisure and may provide a lower bound to estimation.

In current model, retire or not is the only choice people make, and it does not determine and is not determined by when to claim Social Security benefits. Instead, it is assumed that all people will receive their Social Security benefits at age 65, which is one of the two pronounced retirement peaks deeply discussed in Rust and Phelan (1997). Social Security retirement benefits claiming process is an absorbing state in the model, which means that once the benefits are received, people will get the same amount of benefits after that.

Regarding of Social Security benefits, people who were born in 1929 or later need 40 credits (10 years of work) to get retirement benefits and the benefits amount will be based on how much people earned during working career. As all the respondents that I have are above age 50, I assume that those, who are kept at current data sample and report that they expect to receive Social Security benefits in the future, already have enough credits for Social Security. I further assume that their current labor choices won't have tremendous influences on their life time earnings and won't affect the Social Security benefits that they will get in the future. This is to say that Social Security path, which is calculated based on their reported age to receive Social Security and amount they will get at that age, will be fixed over time after age 50. As Social Security calculates the average indexed monthly earnings during the 35 years in which the person earned the most, in reality it is possible that people's labor choices after age 50 still contribute to their future retirement benefits. But in the model the Social Security path is calculated based on people's expectation; expectation may have already included those concerns and may provide precise enough future information and be barely affected by later labor choices. In conclusion, it can be safe to assume Social Security benefits are exogenous after age 50 in the model, given that it is not a major focus of my model.

5.2 State Variables

$$s_t = \{\underbrace{g_t^h, g_t^w, h_t^h, h_t^w}_{\textbf{observable}}, \underbrace{\theta_t^h, \theta_t^w \overbrace{\xi_t^h, \xi_t^w}^{\textbf{self known}}}_{\textbf{unobservable}}\}.$$

At each time period t, state variables consist of three components: variables that are observable to both economists and household members, variables that are observable only to household members, and variables that are observable only to husband himself or to wife herself. In the following descriptions, $i \in \{h, w\}$

Observable Variables: For observable variables, g_t^i is i's age, h_t^i is indicator for whether i's health limits his/her work at the beginning of period t.

Unobservable Variables: θ^i is i's taste for joint leisure with his/her spouse, which follows a discrete-time time-homogeneous Markov chain. $\theta^i \in \{\theta_{low}^i, \theta_{high}^i\}$, where θ_{low}^i denotes low complementary of leisure and θ_{high}^i denotes high complementary of leisure. Leisure complementarities for husband and wife fellow heterogeneous Markov chains.

Unobservable and only self-known variables: Preference or utility shock to work(or not work) ξ_t^i is self known, in other words husband and wife do not know each other's taste shock at the time when they make retirement decisions.

Besides these variables, in the model, couples' education edu_t^i, gender $Gender^i$, birth year $BirthYear^i$, and Social Security path are given and do not change over time.

5.3 Uncertainties Considered

Three main uncertainties are considered in the model: 1) Uncertainties of whether husband h's or wife w's health will limit work in the next period. 2) Uncertainties from preference shocks. 3) Uncertainties from husband h's and wife w's preference for joint leisure, θ^h and θ^w, which are binary discrete-time time-homogeneous Markov chain. Among those uncertainties, (1) and (2) are commonly included in other papers while there is almost no discussion for (3).

5.4 Husband's and wife's preference

Husband h's preference at time t:

$$u_t^h(s_t) = C_t + \exp(\beta_0 + \beta_1 g_t^h + \beta_2 h_t^h + \theta_t^h L_t^w) L_t^h \tag{2}$$

Wife w's preference at time t is symmetric

$$u_t^w(s_t) = C_t + \exp(\beta_0 + \beta_1 g_t^w + \beta_2 h_t^w + \theta_t^w L_t^h) L_t^w \tag{3}$$

Joint budget constraint for both husband and wife,

$$C_t = (1 - L_t^h) w_t^h + (1 - L_t^w) w_t^w + \mathbf{I}(g_t^h \geq c^h) ss_c^h + \mathbf{I}(g_t^w \geq c^w) ss_c^w \tag{4}$$

I assume that all people claim their social security at age 65, claiming age $c^h = c^w = 65$. Wage path is assumed to have the following functional form in equation (5) and health shock arrives based on functional form (6).

$$\begin{aligned} \ln w_t^i &= \pi_0 + \pi_1 g_t^i + \pi_2 {g_t^i}^2 + \pi_3 h_t^i + \pi_4 h_t^i g_t^i \\ &\quad + \pi_5 BirthYear^i + \pi_6 \mathbf{I}(female)^i + \sum_{cat. \neq 1} \kappa_{cat.} \mathbf{I}(edu^i)_{cat.} \qquad {}^2 \\ &\equiv X(g_t^i, edu_t^i, h_t^i, BirthYear^i, Gender^i), \quad i \in \{h, w\} \end{aligned} \tag{5}$$

$$\begin{aligned} Pr(h_t^i = 1 | \mathbf{X}_t^i) &= G\big[\alpha_0 + \alpha_1 g_t^i + \alpha_2 edu^i + \alpha_3 {edu^i}^2 + \alpha_4 BirthYear^i + \alpha_5 \mathbf{I}(female)^i\big] \\ &\equiv Y(g_t^i, edu_t^i, Gender^i, BirthYear^i), \quad i \in \{h, w\}, \end{aligned} \tag{6}$$

$G[\cdot]$ is logistic CDF. Inside the equation, π_6 and α_5 capture gender fixed effects.

To keep things simple, I do not consider anything about saving and borrowing as well as medical expenditure. People will therefore consume everything they have by the end of each period. Though no medical expenditure appears in the budget constraint, people do care about their health through its effects on wage and through the interaction with leisure, which allows the possibility that people may enjoy their leisure more when they are in good health. From the previous Data and Empirical Analysis sections, there are two measurements of health, one is health condition $\mathbf{I}(Health)_t^i$ and another is whether health limits work $\mathbf{I}(Health\ Limits\ work)_t^i$. As bad health condition is usually accompanied with higher medical expenditure, which is not included in my current model, and whether health

[2] Education is divided into six categories: (1)lower than high school; (2)some high school; (3)high school degree; (4)some college; (5)college degree; (6)college+. The default group is category one.

limits work is usually highly correlated with whether to retire, I only use whether health limits work as the standard to depict health h_t^i.

In my model, there are no government transfers inside equation (4), which implies that the household will consume zero if both husband and wife are not in the labor market and receive no benefits from Social Security at that period. As in the utility function consumption shows up as linear form instead of CRRA form, from model solving perspective of view, this will not cause a problem.

In the model, labor supply is jointly decided through several channels. Firstly, C_t is family consumption instead of individual consumption and is financed by earnings from both husband h and wife w. Therefore both own leisure choice as well as spouse's leisure choice can affect person i's consumption. Second, husband h's leisure choice L_t^h can be affected by wife w's leisure choice L_t^w. Moreover, if taste for joint leisure θ_t^h is positive, husband h will value his leisure more if wife w has retired, and the same logic applies for wife w.

Besides, a strong assumption made here is that people will stay with the same spouse all over the rest of their life and never divorce. The only situation under which they will be back to single is that their spouse does not survive in that period. In my model, I assume that women live to age 83 and men live to age 79, which are derived from life expectancy at age 50 for women and men reported by CDC in 2020.
When the person is back to single, individual i's preference, $i \in \{h, w\}$:

$$u_t^i(s_t) = C_t + \exp(\beta_0 + \beta_1 g_t^i + \beta_2 h_t^i) L_t^i \tag{7}$$

Budget constraint for individual i,

$$C_t = (1 - L_t^i) w_t^i + \mathbf{I}(g_t^i \geq c^i) ss_c^i \tag{8}$$

Again, Social Security benefits claiming age for person i is assumed to be age 65, $c^i = 65$, there are no outside transfers, and wage and health shock follow the previous functional forms in equation (5) and (6).

6 Solving the Model

To estimate the model, I use MLE method and maximize the likelihood function which is described in detail in this section. All other detailed steps in solving the model are described in Appendix B.

6.1 Timing

1. At the beginning of each period, both husband h's and wife w's health conditions and preferences for joint leisure are achieved and mutually known, while taste shocks ξ_t^h and ξ_t^w are self known and unknown to each other.

2. Based on those conditions, household labor supplies are made in a sequential process. In each period t, husband h moves first and wife w knowing the choice of her husband moves next to maximize their own utility.

The reason for solving the model in a sequential way is because under the situation where they move simultaneously, Nash equilibrium may not exist for some cases when couples have opposite taste for joint leisure. In the Appendix A, Figure 11 depicts the rough idea of this.

Due to this reason, I need to assign someone to move first. For simplicity, in the model I pick husband as the first mover and wife as the second mover. It is hard to say whether there is first mover advantage. Though husband moves first, he has less information about his wife's current period labor participation and can only make choices based on his expectation. Despite wife moves next, she is with more information about first mover's behavior. More complicated extension for current version can be to let both husband and wife have half of the probability to move first at each period.

To simplify the expression, denote $t+1$ as t'. Instead of using husband h and wife w to denote two members inside the same household, for notation simplicity and as this is a sequential game, I use F to represent first mover and S to represent second mover at each period t within the same household for the rest of the section.

6.2 At period $t \leq T$

For computational tractability, in the model I assume people only make labor participation choices before age 75. This is to some extent consistent with the current sample within which among those who have not retired, only less than 1 percent are above age 75. Therefore, each person's T is his/her age 75. After age 75, their leisure choices $L_t^i = 1,\ i \in \{F, S\}$. The model is solved by backward induction.

6.2.1 If both husband and wife survive till that period

For the sake of convenience in writing, following simplifications are implemented. For $x, y \in \{0, 1\}$, leisure choice $L_t^F = x$ is simplified as Fx and $L_t^S = y$ is simplified as Sy. Consumption amount C_{txy} denotes $C_{t, L_t^F = x, L_t^S = y}$. For instance, C_{t00} is the amount household can consume when both first mover and second mover choose to work. And conditional probability of leisure choice $P(L_t^S = y|s_t, L_t^F = x)$ is simplified as $P_t(Sy|s_t, Fx)$. For example, $P_t(S0|s_t, F1)$ is the probability for second mover S to work conditional on first mover F chooses to retire.

First Mover *F* (husband)

As F does not know the value of the second mover S's preference shock ξ_t^S, F needs to anticipate what S is going to do if F makes different choices. For instance, when considering to fully retire $L_t^F = 1$, F has the correct belief that based on he retires at current period, with probability $P_t(S0|F1, s_t)$, S will work full time at the same period and with probability $P_t(S1|F1, s_t)$, S will also choose to retire now. In contrast, when considering working full time $L_t^F = 0$, F knows that based on he works at current period, with probability $P_t(S0|F0, s_t)$, S will work full time at the same period and with probability $P_t(S1|F0, s_t)$, S will choose to retire now. In the following equation, $\mathbf{A}$ is the utility F can get if F chooses to work and $\mathbf{B}$ is the utility F can get if F chooses to retire. Calculation details are shown in Appendix B.

$$V_t^F(s_t) = \max_{L_t^F}\{\underbrace{E_t\big[U_t^F(s_t, F0) + \delta E_t V_{t'}^F(s_{t'}|s_t)\big]}_{\mathbf{A}} + \widetilde{\xi_t^F}\ , \underbrace{E_t\big[U_t^F(s_t, F1) + \delta E_t V_{t'}^F(s_{t'}|s_t)\big]}_{\mathbf{B}} + \widehat{\xi_t^F}\} \tag{9}$$

$$\begin{aligned} &= \max_{L_t^F}\big\{P_t(S0|F0, s_t)\big[U_t^F(s_t, F0, S0) + \delta E_t V_{t'}^F(s_{t'}|s_t)\big] \\ &\qquad\qquad + P(S1|F0, s_t)\big[U_t^F(s_t, F0, S1) + \delta E_t V_{t'}^F(s_{t'}|s_t)\big] + \widetilde{\xi_t^F}\ , \\ &\qquad P_t(S0|F1, s_t)\big[U_t^F(s_t, F1, S0) + \delta E_t V_{t'}^F(s_{t'}|s_t)\big] \\ &\qquad\qquad + P_t(S1|F1, s_t)\big[U_t^F(s_t, F1, S1) + \delta E_t V_{t'}^F(s_{t'}|s_t)\big] + \widehat{\xi_t^F}\Big\} \end{aligned} \tag{10}$$

First mover F chooses to work at time t, $L_t^F = 0$, only if

$$\widetilde{\xi_t^F} - \widehat{\xi_t^F} > \mathbf{B} - \mathbf{A} \tag{11}$$

where $\xi_t^i \sim T1EV(0,1)$, $\widetilde{\xi_t^i} - \widehat{\xi_t^i} \sim logistic(0,1)$. Based on the frame work of McFadden et al. (1973) and Rust (1987), under the assumption that ξ_t^F obeys type one extreme value distribution, conditional probability of first mover working and conditional expectation are as follows:

$$P_t(F0|s_t) = \frac{exp(\mathbf{A} - \mathbf{B})}{1 + exp(\mathbf{A} - \mathbf{B})} \tag{12}$$

$$E_{t-1}V_t^F(s_t|s_{t-1}) = E_{t-1}\Big\{\gamma + log\big(exp(\mathbf{A}) + exp(\mathbf{B})\big)\Big\}, \tag{13}$$

where γ is Euler constant.

Second Mover *S* (wife)

Second mover will make choices depending on first mover's behavior and will potentially face two cases.

a. Under the condition where first mover *F* works full time $L_t^F = 0$

$$V_t^S(s_t, F0) = \max_{L_t^S}\{\underbrace{U_t^S(s_t, F0, S0) + \delta E_t V_{t'}^S(s_{t'}|s_t)}_{\mathbf{C0}} + \widetilde{\xi}_t^S\ , \underbrace{U_t^S(s_t, F0, S1) + \delta E_t V_{t'}^S(s_{t'}|s_t)}_{\mathbf{D0}} + \widehat{\xi}_t^S\} \tag{14}$$

C0 is what S can get if working full time and **D0** is what S can get if choosing to retire.

As the second mover S has already seen first mover F's choice, S knows for sure what she will receive if working or if retiring for current period, things she does not know are about next period. S chooses to work at time t, $L_t^S = 0$, when

$$\widetilde{\xi}_t^S - \widehat{\xi}_t^S > \mathbf{D0} - \mathbf{C0} \tag{15}$$

With ξ_t^S follows type one extreme value distribution, we can get conditional probability of working and conditional expectation as follows:

$$P_t(S0|s_t, F0) = \frac{exp(\mathbf{C0} - \mathbf{D0})}{1 + exp(\mathbf{C0} - \mathbf{D0})} \tag{16}$$

$$E_{t-1}V_t^S(s_t|s_{t-1}, F0) = E_{t-1}\Big[\gamma + log\big(exp(\mathbf{C0}) + exp(\mathbf{D0})\big)\Big] \tag{17}$$

b. Under the condition where first mover retired $L_t^F = 1$

$$V_t^S(s_t, F1) = \max_{L_t^S}\{\underbrace{U_t^S(s_t, F1, S0) + \delta E_t V_{t'}^S(s_{t'}|s_t)}_{\mathbf{C1}} + \widetilde{\xi}_t^S\ , \underbrace{U_t^S(s_t, F1, S1) + \delta E_t V_{t'}^S(s_{t'}|s_t)}_{\mathbf{D1}} + \widehat{\xi}_t^S\} \tag{18}$$

Second mover S chooses to work at time t, $L_t^S = 0$, only if

$$\widetilde{\xi}_t^S - \widehat{\xi}_t^S > \mathbf{D1} - \mathbf{C1} \tag{19}$$

Again, with ξ_t^S follows type one extreme value distribution, we can get

$$P_t(S0|s_t, F1) = \frac{exp(\mathbf{C1} - \mathbf{D1})}{1 + exp(\mathbf{C1} - \mathbf{D1})} \tag{20}$$

$$E_{t-1}V_t^S(s_t|s_{t-1}, F1) = E_{t-1}\Big[\gamma + log\big(exp(\mathbf{C1}) + exp(\mathbf{D1})\big)\Big] \tag{21}$$

From (17) and (21),

$$E_{t-1}V_t^S(s_t|s_{t-1}) = P_t(F1|s_t)E_{t-1}V_t^S(s_t|s_{t-1}, F1) + P_t(F0|s_t)E_{t-1}V_t^S(s_t|s_{t-1}, F0) \tag{22}$$

6.2.2 If only person i survives till that period, $i \in \{husband, wife\}$

Under this condition, based on the assumption that people do not get remarried after this, individual i is the only mover in the game.

$$V_t^i(s_t) = \max_{L_t^i}\{\underbrace{U_t^i(s_t, i0) + \delta EV_{t'}^{single}(s_{t'}|s_t)}_{\mathbf{E}} + \widetilde{\xi}_t^i \ , \ \underbrace{U_t^i(s_t, i1) + \delta EV_{t'}^{single}(s_{t'}|s_t)}_{\mathbf{F}} + \widehat{\xi}_t^i\} \tag{23}$$

i chooses to work, $L_t^i = 0$, only if

$$\widetilde{\xi}_t^i - \widehat{\xi}_t^i > \mathbf{F} - \mathbf{E} \tag{24}$$

With ξ_t^i follows type one extreme value distribution,

$$P_t(i0|s_t) = \frac{exp(\mathbf{E} - \mathbf{F})}{1 + exp(\mathbf{E} - \mathbf{F})} \tag{25}$$

$$E_{t-1}V_t^{single}(s_t|s_{t-1}) = E_{t-1}\Big[\gamma + log\big(exp(\mathbf{E}) + exp(\mathbf{F})\big)\Big] \tag{26}$$

6.3 The Likelihood Function

To make the model computational feasible, I refer to the hidden Markov model in Christensen et al. (2022).

Based on the setting in my paper, leisure complementarity of husband and wife has four possible combinations or states, which are listed in the following chart.

Possible states

states	1	2	3	4
θ (husband, wife)	$\theta^h_{low}\theta^w_{low}$	$\theta^h_{low}\theta^w_{high}$	$\theta^h_{high}\theta^w_{low}$	$\theta^h_{high}\theta^w_{high}$
abbreviated as	ll	lh	hl	hh

For the sake of notation convenience, denote joint leisure complementarity as latent state θ. θ can take the four states listed above and is abbreviated as $\theta \in \{ll, lh, hl, hh\}$. For a representative individual, L_t is the leisure choice in period t. Define $p_{t\theta}$ as the probability of this observation when joint leisure complementarity is θ. Let π_θ be the probability that the initial state is θ, and let $\pi = (\pi_\theta)$ be a 1 by 4 row vector. and I take the steady state probability as the initial probability. $A = (A_{ij})$ is the 4 by 4 transition probability matrix and A_{ij} is the probability of transiting from state i to state j, where $i, j \in \{ll, lh, hl, hh\}$. The likelihood is

$$L = \pi D_1 \prod_{t=2}^{T}(AD_t)\iota = \pi D_1 \prod_{t=2}^{T} C_t \iota, \tag{27}$$

where $D_t = (p_{t\theta})$ is a 4 by 4 diagonal matrix with $(p_{thh}, p_{thl}, p_{tlh}, p_{tll})$ on the diagonal, $C_t = AD_t$ and ι is a 4 by 1 column vector of ones.

7 Model Estimates

Model is estimated using a two-step strategy. Parameters for the wage process and the probability of health shock process are estimated in the first step. After getting estimations from the first-step, all the other 11 parameters are estimated by the model.

7.1 First-Step Estimation

wage

For wage process, it is assumed in the model as a function of individual's gender, birth year, age, years of education and health shock (whether health limits work). Estimators for this part are provided by the following linear regression of $ln(wage)$ on all the other variables mentioned above.

$$\begin{aligned} ln(w_{it}) =& \pi_0 + \pi_1 g_{it} + \pi_2 g_{it}^2 + \pi_3 h_{it} + \pi_4 h_{it} g_{it} \\ & + \pi_5 BirthYear_i + \pi_6 \mathbf{I}(female)_i + \sum_{cat. \neq 1} \kappa_{cat.} \mathbf{I}(edu_i)_{cat.} + \zeta_i + \epsilon_{it} \end{aligned} \tag{28}$$

where w_{it} is yearly wage and is rescaled by 10,000. g_{it} is age. edu_i is years of education and is divided into six categories: (1)lower than high school; (2)some high school; (3)high school degree; (4)some college; (5)college degree; (6)college+. The default group is category one. $\kappa_2 - \kappa_6$ capture education categories' fixed effects. h_{it} is an indicator which equals 1 if person i's health limits work and 0 if not. $BirthYear_i$ is person i's year of birth. π_6 captures the wage difference between male and female.

Concerning about the selection problem, individual fixed effect ζ_i is added in the first-step estimation for more precise estimates of π and κ. And this individual fixed effect will not directly enter the model.

To estimate $\pi_0 - \pi_6$ and $\kappa_2 - \kappa_6$, records for all husbands and wives from those 2,587 households are used. Based on the model assumption, people will retire for sure after age 75, only those observations whose age are between ages 50 and 75 are used in the regression. Estimates for the wage process are presented in Table 9.

health shock

It is assumed in the model that the probability of health shock at the beginning of each period is a function of person i's age g_{it}, education edu_{it}, birth year $BirthYear_i$ and gender $gender_i$. Parameters are estimated by the following logit regression.

$$Pr(h_{it} = 1 | \mathbf{X}_{it}) = G\big[\alpha_0 + \alpha_1 g_{it} + \alpha_2 edu_i + \alpha_3 {edu_i}^2 + \alpha_4 BirthYear_i + \alpha_5 \mathbf{I}(female)_i\big] \tag{29}$$

Conditional on the model assumption that life expectancy for male is 79 and for female is 83, only males younger than age 80 and females younger than age 84 is utilized to run the regression. The estimates are displayed in Table 10.

Preset Parameters

There are two parameters that are preset and drawn from the literature. Annualized discount factor α is set to be 0.95, and Euler constant γ takes the value of 0.5772.

7.2 Second-Step Estimation Results

Three versions of the model are estimated and results are presented in Table 11. Subscript h and w denote husband and wife, and subscript *low*(or *high*) denotes leisure is less(or more) attractive when their spouse has retired.

The first column shows results for the benchmark model where there is no value added for joint leisure (or joint retirement). This is under a condition where people value their leisure time in the same way no matter whether their spouse has retired or not. Benchmark results show that people value their leisure time and preference for leisure increases with age. Besides, people enjoy leisure more when their health limits their work ability. The second column displays the results for a situation where people's preference for leisure can be affected by their spouse's retirement decision. This version, comparing with the benchmark version, adds room for leisure complementarity θ^i, which is assumed to be heterogeneous between husband and wife but constant overtime. Under this version, similar conclusions are drawn as in benchmark version. What's more, it provides consistent results as in Gustman and Steinmeier (2000), that couples value their leisure more once their spouse has retired and this is particularly true for husbands. The third column assumes that the worst condition for joint leisure is that the individual does not value their joint leisure with their spouse at all. This is to say that when the individual is with low preference for joint leisure, he/she will value the leisure in the same way no matter whether their spouse has retired or not.

The estimations for the key model that is discussed in detail in previous sections are listed in the last column. In this key version, husband and wife value their leisure heterogeneously when their spouse retired, which is captured by the $\theta^i,\ i \in \{h, w\}$. θ^i fluctuates over time and follows a discrete-time time-homogeneous Markov process. Therefore, not only how husband and wife value their leisure when their spouse has retired but also how their tastes jump between different status can be heterogeneous.

The estimators for this version of the model reveal several things. Firstly, it can be possible that retirement is less enjoyable when their spouse has retired. This is true both for husband and wife, while the magnitude is much smaller for husband than for wife. Though the numbers are small, it is -0.070 for θ^h_{low} and -0.718 for θ^w_{low}, this term is inside exponent and ahead of own leisure term L^i_t, and can potentially have large effect. If it is under this low preference condition, leisure can be much less enjoyable when their spouse has retired than when their spouse is still working. For example, when husband is under this low preference condition θ^h_{low}, $e^{-0.070}$ is 0.932, which indicates that when his wife has retired, leisure is only 0.932 as enjoyable as when his wife has not retired. Similarly, when wife is under the low preference condition θ^w_{low}, $e^{-0.718}$ is 0.488, which is to say that leisure is about half as enjoyable when her husband has retired as when her husband has not retired. When husband is under high preference for leisure, θ^h_{high} is 1.491; and when wife is under high preference for leisure, θ^w_{high} is 1.778. The magnitude is about the same. Under this condition, husband(wife) values his(her) leisure more when the spouse has retired than when the spouse has not retired. Inside the model, there is no restriction that couples have the same preference, i.e. both enjoy their leisure more when their spouse has retired or leisure is less enjoyable for both husband and wife when their spouse has retired. This is to say that it is possible that leisure is more enjoyable for husband while wife has retired, but is less enjoyable for wife while husband has retired, or vise versa.

Second finding is based on the estimated probability for status change of θ^i. $P^w_{high,high}$ is 0.959 and $P^h_{high,high}$ is 0.134, and this explicitly indicates that high preference is much more likely to persist longer for wife than for husband. As $P^w_{low,low}(0.935)$ and $P^h_{low,low}(0.135)$, low preference also lasts longer for wife than for husband. In steady state, the proportion of wife who enjoys her retirement more when her husband has retired is around 61.17%, and the proportion of husband who enjoys his retirement more when his wife has retired is around 11% lower and is approximately 50%.

8 Model Fit

Figure 1 and Figure 2 report how the simulated data fits the true data for both husband and wife. In all figures, blue dash-dot lines are for the model simulated data and solid lines are for the true data. In Figure 1, the first row displays retirement behavior for all husbands, husbands with less than or equal to 12 years of education, husbands with higher than 12 of years education. The second row displays retirement behavior for husbands whose wife has retired and the third row is for husbands whose wife has not retired at the same period. In those two rows, different education groups are divided and presented in the same way as before. I do similar constructions for wife's figures and results are displayed in Figure 2.

Due to data construction, there are zigzag shapes for the true data in some of the sub-figures. For example, the zigzag for the sub-figures on the second row of Figure 1 is caused by the following reasons. As I only keep those observations whose husband and wife are both above age 50, and based on the facts displayed in summary statistics in Table 3 that husbands on average are three years older than wives, therefore, sample size for husbands who are around their age 50 is smaller than sample size for other age groups. Age differences between husbands and wives can also explain the zigzag for the true data in the third row of Figure 2. When wives are round age 70, husbands on average are older and more likely to have already retired, this will lead to a small sample size for "wife is around age 70 and husband is still working" group.

There are some features in the true data that can not be explained by my model. Firstly, as my model assumes that retirement is not a one-time choice and everyone claim their Social Security benefits at age 65, and as my model does not include medical expenditure as well as Medicare, the model lacks mechanisms to explain the retirement spike at age 62(Social Security early retirement age) and age 65(Social Security normal retirement age and Medicare eligible age). In addition, as I assume there is no back to work cost once people has retired, it also leads to the smoothness of retirement ratio change. Secondly, my model overestimates retirement ratio for the younger low education group and underestimates retirement ratio for the older high education group. This can be because there is no saving in the budget constraint. Facts listed in Appendix C reveal that the high education group tends to have more savings than the low education group. Comparing with the model, in reality, people with lower education may tend to work more when they are young as they do not have enough savings for their later life, and people with higher education may choose to retire earlier as they have already saved enough.

9 Counterfactual Behavior Analysis

In this section, with all the parameters estimated, I conduct counterfactual behavior analysis for husband(first mover) and wife(second mover) in a representative household. Other households are with similar patterns. Figures displayed in Section 13 present all the counterfactual simulations that I perform. The figures are organized in the following order: I will present behavior analysis figures for the husband(first mover) first; then I will present behavior analysis figures for the wife(second mover); and in the last subsection, I will make comparasion between two models, one with uncertain leisure complementarity and one without uncertain leisure complementarity.

9.1 Husband(First Mover)

As my model considers two uncertainties, health shock uncertainty and joint leisure preference uncertainty, in Figure 3 I control health shock uncertainty and do analysis for the other one. When comparing situation with low and situation with high preference for joint leisure, simulation indicates that conditional on health never limits ability to work, working probability for the husband when he is with low preference for joint leisure θ_{low} is much higher than when he is with high preference for joint leisure θ_{high} and the magnitude is not negligible. In Figure 4, I further add the dash lines which are under the condition that the husband's health always limits his ability to work. The dash lines show similar patterns that working probability for the husband when he is with θ_{low} is much higher than when he is with θ_{high}. Comparing the solid lines with the dash lines in Figure 4, another conclusion is that conditional on preference for joint leisure being fixed, the husband is less likely to work when he is with bad health condition.

As husband is the first mover by assumption, his behavior does not depend on wife's choice at each period. However, his behavior does depend on how he expects his wife will behave. I take husband expected $Pr(wife\ retires|husband\ has\ retired)$ as an example and conduct this counterfactual simulation for husband at his age 60. Simulated results are displayed in Figure 5 and Figure 6. (Similar counterfactual simulation can be implemented for husband expected $Pr(wife\ retires|husband\ is\ working)$.). Figure 5 is conditional on the husband's health never limits his ability to work, and Figure 6 adds the other condition where his health always limits his ability to work. As long as the husband expects his wife will retire with non-zero probability, simulated line for θ^h_{low} will not coincide with the line for θ^h_{high}. While if the husband expects his wife will work (or will not retire) for sure, $L^w = 0$, $\theta^h L^h L^w$ will be eliminated from his utility function and θ^h does not affect his choice. This exercise suggests that if the husband enjoys his leisure more when his wife has retired, his probability of retiring is positively correlated with wife's probability of retiring. While if the husband values his leisure less when his wife has retired, this correlation is negative.

9.2 Wife (Second Mover)

For wife, we can have the same analysis. While as wife is the second mover by assumption, the wife's behavior depends on her husband's choice. The figures for the wife are constructed in similar ways, the solid lines are under the condition where the wife's health never limits her ability to work, and the dash lines are under the condition where the wife's health always limits her ability to work. Conditional on the husband has retired at current period, the wife's probability of working is presented in Figure 7. This figure shows similar patterns as before and working probability for the wife when she is with θ_{low} is much higher than when she is with θ_{high}. Conditional on the husband is still working, the wife's current preference for joint leisure θ^w will not enter her utility function and therefore does not affect her labor participation, while the wife's bad health can still impede her from working as is shown in Figure 8.

9.3 Comparing With and Without Uncertainty Models

In order to compare how the model with uncertain leisure complementarity differs from the model without this type of uncertainty, I further implement similar behavior analysis under the two different models. To make the figure neat and clean, the following analysis is conditional on the husband's and the wife's health never limits their ability to work. Figures for the situation where health always limits work look similar and are with smaller magnitude. Figure 9 is for the husband and Figure 10 is for the wife. The solid lines are for the model with uncertain preference for joint leisure(current model), and the dash-dot-dot lines are for the model without uncertainty for joint leisure but with heterogenous preferences between the husband and the wife. Comparing those two models, Figure 9 and Figure 10 implicitly reveal that labor participation at older age is highly likely to be caused by disutility from joint leisure and the model without uncertainty lakes mechanism to explain this feature.

From policy design point of view, this can be potentially important. Take policy design for Social Security benefits as an instant and consider push the normal retirement age back to age 70. Two channels can affect the husband's behavior: 1) effects from the changed budget constraint; 2) his spouse may incline to work longer due to similar reason. Under the setting where there is no uncertainty for θ^h, as θ^h is positive, the second channel tells us that the husband's probability of working will always be higher knowing that his spouse tends to push back retirement plan. However, under the setting where θ^h is uncertain, the second channel can either bump up or reduce the husband's probability of working. The model without uncertainty may overestimate or underestimate the policy effects on labor participation for older population.

10 Conclusion

In this paper, I conduct empirical analysis and build a dynamic life-cycle model to study dual career couples' joint retirement decisions.

In empirical section, I use HRS data from 1992 to 2018 and use couples' reported "Closeness" as analog to preference for joint leisure to do the analysis. Results from this part show that leisure complementarity can be unstable and heterogenous between husband and wife. And people are more likely to retire together with their spouse when they are in closer relationship than when they are in relatively less close relationship. Conclusions from this section are further used as guidance to build theoretical model.

The prototype of the theoretical model is from Gustman and Steinmeier (2000), while my model is dynamic life-cycle model with two uncertainties, uncertainty from health shock and uncertainty from unstable preference for joint leisure. Among those two, uncertain health shock is commonly considered in previous papers, but the second one is rarely analysed. The model is solved by MLE method and through backward induction.

Several conclusions can be drawn from estimations of the model and counterfactual behavior analysis. Firstly, unlike conclusions from previous papers that people always value their retirement more once their spouse has retired, in my model and under certain situations, it is possible that people value their retirement less when their spouse has retired. This is true for both husband and wife, and magnitude for wife is larger. Secondly, both the range and the frequencies of leisure preference fluctuation are not small. Thirdly, both high and low preference for joint leisure persist longer for wife than for husband. In other words, preference fluctuates in relatively higher frequency for husband than for wife. Lastly, people's working probability gap between when they are always with a high preference for joint leisure θ_{high} and when they are always with a low preference for joint leisure θ_{low} can be large. And people's labor participation at older age can be potentially caused by the disutility from joint leisure. When considering intervention for policy design and when the main focus is people's labor participation behavior at older age, this fluctuating leisure complementarity may be one of the vital features that need to be considered.

The extension of the model can be to add Social Security claiming decisions into the choice set. By doing so, more interesting counterfactual policy interventions can be implemented, for example pushing back early/normal/late retirement age. With the extended version of the model, I can further compare the counterfactual results from this model with the results from previous papers. More conclusions therefore can be drawn on whether a model without uncertain preference for joint leisure will over/underestimate the policy effects.

11 Tables

Table 1: Social Security related questions in HRS

1.	Interviewee receives Social Security in any wave.
2.	Age when started to receive Social Security.
3.	Do you expect to receive Social Security benefits at some time in the future?
4.	Age expect to collect Social Security benefits
5.	If you start collecting Social Security benefits then, about how much do you expect the payments to be in today's dollars?
6.	If claiming at 62, what is the Social Security value?
7.	If claiming at normal retirement age, what is the Social Security value?
...	

Table 2: Benefit, as a percentage of Primary Insurance Amount (PIA), payable at ages 62-70

Year of Birth	Normal Retirement Age (NRA)	Credit for each year of delayed retirement after NRA (percent)	62	63	64	65	66	67	68	69	70
1917-1924	65	3	80	86.67	93.33	100	103	106	109	112	115
1925-1926	65	3.5	80	86.67	93.33	100	103.5	107	110.5	114	117.5
1927-1928	65	4	80	86.67	93.33	100	104	108	112	116	120
1929-1930	65	4.5	80	86.67	93.33	100	104.5	109	113.5	118	122.5
1931-1932	65	5	80	86.67	93.33	100	105	110	115	120	125
1933-1934	65	5.5	80	86.67	93.33	100	105.5	111	116.5	122	127.5
1935-1936	65	6	80	86.67	93.33	100	106	112	118	124	130
1937	65	6.5	80	86.67	93.33	100	106.5	113	119.5	126	132.5
1938	65, 2 mo.	6.5	79.17	85.56	92.22	98.89	105.42	111.92	118.42	124.92	131.42
1939	65, 4 mo.	7	78.33	84.44	91.11	97.78	104.67	111.67	118.67	125.67	132.67
1940	65, 6 mo.	7	77.5	83.33	90	96.67	103.5	110.5	117.5	124.5	131.5
1941	65, 8 mo.	7.5	76.67	82.22	88.89	95.56	102.5	110	117.5	125	132.5
1942	65, 10 mo.	7.5	75.83	81.11	87.78	94.44	101.25	108.75	116.25	123.75	131.25
1943-1954	66	8	75	80	86.67	93.33	100	108	116	124	132
1955	66, 2 mo.	8	74.17	79.17	85.56	92.22	98.89	106.67	114.67	122.67	130.67
1956	66, 4 mo.	8	73.33	78.33	84.44	91.11	97.78	105.33	113.33	121.33	129.33
1957	66, 6 mo.	8	72.5	77.5	83.33	90	96.67	104	112	120	128
1958	66, 8 mo.	8	71.67	76.67	82.22	88.89	95.56	102.67	110.67	118.67	126.67
1959	66, 10 mo.	8	70.83	75.83	81.11	87.78	94.44	101.33	109.33	117.33	125.33
1960 and later	67	8	70	75	80	86.67	93.33	100	108	116	124

Table 3: Summary statistics

	Data used in regression and model						Raw data+					
Men												
Variable	Obs	Mean	Std.Dev.	Min	Max	Med.	Obs	Mean	Std.Dev.	Min	Max	Med.
Age	15,667	66.21	7.333	50	92	66	84,095	64.45	7.829	50	100	64
Years of Education	15,667	12.88	3.082	0	17	12	83,864	12.49	3.470	0	17	12
I(Health Limit Work)*	13,376	0.178	0.382	0	1	0	77,861	0.284	0.451	0	1	0
I(Health)	13,890	0.836	0.370	0	1	1	84,047	0.729	0.445	0	1	1
I(Retired)**	12,559	0.676	0.468	0	1	1	73,082	0.594	0.491	0	1	1
Hours Worked per Week	4,540	43.40	9.111	6	80	40	30,511	43.79	11.07	6	80	40
Weeks Worked per Year	4,556	50.93	3.938	15	52	52	30,560	50.29	4.993	15	52	52
Hours Worked per Year	4,525	2212	508.3	200	4160	2080	30,061	2212	612.4	176	4160	2080
Hourly Wage	4,163	21.73	14.02	1.040	115.4	18.43	27,246	22.49	16.64	0.839	115.4	17.86
Weekly Wage	4,168	941.3	602.8	19.23	4375	800	27,341	965.9	714.7	19.23	4500	769.2
Yearly Wage	4,168	50065	32888	1560	260000	41998	27,366	52426	39591	1440	265149	41080
Closeness	2,484	1.336	0.589	1	4	1	13,431	1.454	0.693	1	4	1
Age Difference***	15,667	2.996	4.204	-12	22	3	67,529	3.111	4.774	-12	22	3
Women												
Variable	Obs	Mean	Std.Dev.	Min	Max	Med.	Obs	Mean	Std.Dev.	Min	Max	Med.
Age	13,471	62.57	6.995	50	84	62	108,707	62.40	7.197	50	97	62
Years of Education	13,471	12.82	2.678	0	17	12	108,468	12.41	3.106	0	17	12
I(Health Limit Work)	11,729	0.171	0.376	0	1	0	100,237	0.298	0.457	0	1	0
I(Health)	12,083	0.850	0.357	0	1	1	108,645	0.722	0.448	0	1	1
I(Retired)	9,927	0.545	0.498	0	1	1	89,644	0.519	0.500	0	1	1
Hours Worked per Week	4,102	37.28	9.894	6	80	40	37,482	37.76	10.91	6	80	40
Weeks Worked per Year	4,075	49.43	5.646	15	52	52	37,212	49.60	5.613	15	52	52
Hours Worked per Year	4,054	1851	555.5	174	4160	2080	36,696	1880	599.8	170	4160	2080
Hourly Wage	3,848	16.70	11.40	1.010	99.64	13.46	34,882	16.85	12.56	0.855	115.4	13
Weekly Wage	3,850	641.2	503.7	20	4327	506.4	35,029	647.4	536.2	19.23	4500	488.6
Yearly Wage	3,849	36767	27215	1430	253500	29120	34,972	37169	29181	1404	264000	28000
Closeness	2,620	1.474	0.656	1	4	1	14,389	1.630	0.801	1	4	1
Age Difference	13,471	3.022	4.183	-11	22	2	67,969	3.085	4.765	-12	22	3

+ Raw data is the data before any management, and the only management conducted here is trimming on those variables discussed in previous subsection.

* Indicator of whether health limits work.

** Indicator of whether this person has retired at time t or not.

*** Age difference denotes husband is how many years older than wife.

Table 4: Closeness Summary

how close are you with your spouse?			
	Freq.	Percent	Cum.
1.Very Close	3,873	68.77	68.77
2.Quite Close	1,434	25.46	94.23
3.Not that Close	293	5.200	99.43
4.Not at all Close	32	0.570	100
Total	5,632	100	

Table 5: Husband's and wife's reported closeness

		Wife's Reported Closeness						
		1.Very	2.Quite	3.Not that	4.Not at all	Total	Percent	Accum.
Husband Reported Closeness	1.Very	722	190	15	0	927	73.75	73.75
	2.Quite	116	124	25	1	266	21.16	94.91
	3.Not that	9	20	22	4	55	4.380	99.29
	4.Not at all	0	1	8	0	9	0.720	100
	Total	847	335	70	5	1,257	–	–
	Percent	67.38	26.65	5.570	0.400	–		
	Accum.	67.38	94.03	99.6	100	–		

Table 6: Closeness transfer matrix (%)

		Closeness in Wave 11					
		1.Very	2.Quite	3.Not that	4.Not at all	Total (%)	Total obs.
Closeness in Wave 9	1. Very	86.90	12.46	0.64	0.00	100	313
	2. Quite	34.91	55.66	8.49	0.94	100	106
	3. Not that	15.00	50.00	35.00	0.00	100	20
	4. Not at all	0.00	50.00	50.00	0.00	100	2
	Total obs.	312	109	19	1		441

Table 7: Retirement decisions on closeness

VARIABLES	(1) $Pr\Big(\mathbf{I}(r\_Retired)_{it} = 1\Big\vert\mathbf{X}_{it}\Big)^{*}$ Coef.	Odds Ratio	(2) $Pr\Big(\mathbf{I}(r\_Retired)_{it} = 1\Big\vert\mathbf{X}_{it}, \mathbf{I}(r\_Retired)_{it-1} = 0\Big)$ Coef.	Odds Ratio
$\mathbf{I}$(r_Very Close)$_{it}\times$ $\mathbf{I}$(s_Retired)$_{it}$	0.602**	1.826**	1.130**	3.096**
	(0.285)	(0.520)	(0.464)	(1.437)
$\mathbf{I}$(r_Very Close)$_{it}$	0.123	1.131	-0.114	0.892
	(0.238)	(0.269)	(0.366)	(0.326)
$\mathbf{I}$(s_Retired)$_{it}$	0.640***	1.897***	0.710*	2.033*
	(0.247)	(0.469)	(0.414)	(0.843)
$\mathbf{I}$(s_Retired)$_{it-1}$	0.683***	1.980***	-0.471*	0.624*
	(0.179)	(0.354)	(0.273)	(0.170)
r_Gender$_i$	-0.086	0.917	0.199	1.220
	(0.208)	(0.191)	(0.270)	(0.330)
r_Years of Education$_{it}$	-0.074**	0.928**	-0.095**	0.910**
	(0.037)	(0.035)	(0.046)	(0.042)
s_Years of Education$_{it}$	0.072**	1.075**	0.046	1.047
	(0.032)	(0.035)	(0.047)	(0.049)
$\mathbf{I}$(r_Health Limit Work)$_{it}^{**}$	1.180***	3.254***	0.924***	2.519***
	(0.219)	(0.714)	(0.339)	(0.855)
$\mathbf{I}$(s_Health Limit Work)$_{it}$	-0.147	0.864	0.363	1.437
	(0.180)	(0.156)	(0.275)	(0.396)
$\mathbf{I}$(r_Health)$_{it}$	-0.027	0.973	-0.094	0.910
	(0.228)	(0.222)	(0.343)	(0.312)
$\mathbf{I}$(s_Health)$_{it}$	0.542***	1.719***	0.965***	2.625***
	(0.206)	(0.354)	(0.323)	(0.848)
r_Age Fixed Effects	Y	Y	Y	Y
s_Age Fixed Effects	Y	Y	Y	Y
Year of Birth Fixed Effects	Y	Y	Y	Y
Constant	1.396	4.038	-0.606	0.546
	(2.007)	(8.103)	(2.148)	(1.172)
Observations	2,617	2,617	840	840

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

[*] Indicator of whether r has retired at time t or not. r represents "respondent" and s represents "respondent's spouse".

[**] Indicator of whether health limits work at time t.

Table 8: Retirement decisions on closeness | Closeness is "Very" or "Quite Close"

VARIABLES	(1) $Pr\big(\mathbf{I}(r\_Retired)_{it}=1 \big| \mathbf{X}_{it}\big)^*$		(2) $Pr\big(\mathbf{I}(r\_Retired)_{it}=1 \big| \mathbf{X}_{it}, \mathbf{I}(r\_Retired)_{it-1}=0\big)$	
	Coef.	Odds Ratio	Coef.	Odds Ratio
$\mathbf{I}$(Very Close)$_{it}$ $\times\mathbf{I}$(s_Retired)$_{it}$	0.507*	1.659*	1.130**	3.095**
	(0.301)	(0.500)	(0.480)	(1.484)
$\mathbf{I}$(Very Close)$_{it}$	0.120	1.128	-0.239	0.788
	(0.254)	(0.287)	(0.371)	(0.292)
$\mathbf{I}$(s_Retired)$_{it}$	0.698***	2.010***	0.640	1.896
	(0.270)	(0.543)	(0.434)	(0.822)
$\mathbf{I}$(s_Retired)$_{it-1}$	0.705***	2.023***	-0.423	0.655
	(0.183)	(0.371)	(0.278)	(0.182)
r_Gender$_i$	-0.002	0.998	0.222	1.248
	(0.216)	(0.216)	(0.274)	(0.341)
r_Years of Education$_{it}$	-0.083**	0.920**	-0.111**	0.895**
	(0.040)	(0.037)	(0.048)	(0.043)
s_Years of Education$_{it}$	0.073**	1.075**	0.048	1.049
	(0.034)	(0.037)	(0.047)	(0.049)
$\mathbf{I}$(r_Health Limit Work)$_{it}^{**}$	1.074***	2.926***	0.836**	2.308**
	(0.229)	(0.669)	(0.348)	(0.802)
$\mathbf{I}$(s_Health Limit Work)$_{it}$	-0.126	0.881	0.460	1.584
	(0.188)	(0.166)	(0.289)	(0.458)
$\mathbf{I}$(r_Health)$_{it}$	0.051	1.053	-0.159	0.853
	(0.236)	(0.248)	(0.353)	(0.301)
$\mathbf{I}$(s_Health)$_{it}$	0.481**	1.617**	1.030***	2.800***
	(0.221)	(0.358)	(0.341)	(0.956)
r_Age Fixed Effects	Y	Y	Y	Y
s_Age Fixed Effects	Y	Y	Y	Y
Year of Birth Fixed Effects	Y	Y	Y	Y
Constant	1.363	3.908	0.194	1.214
	(2.045)	(7.992)	(2.408)	(2.923)
Observations	2,461	2,461	781	781

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

* Indicator of whether r has retired at time t or not. r represents "respondent" and s represents "respondent's spouse".

** Indicator of whether health limits work at time t.

Table 9: First-step parameters of the income process

Parameters ahead of	Symbols	Estimates	Standard errors
Constant	α_0	-81.449	(3.708)
Age_{it}	α_1	0.150	(0.015)
Age_{it}^2	α_2	-0.001	(0.000)
$\mathbf{I}(\text{HealthLimitsWork})_{it}$	α_3	-0.253	(0.179)
$\mathbf{I}(\text{HealthLimitsWork})_{it} \times \text{Age}_{it}$	α_4	0.003	(0.003)
Birth Year_i	α_5	0.040	(0.002)
$\mathbf{I}(\text{female})_i$	α_6	-0.392	(0.010)
$\mathbf{I}(\text{some high school})_i$	κ_2	-0.020	(0.034)
$\mathbf{I}(\text{high school degree})_i$	κ_3	0.114	(0.031)
$\mathbf{I}(\text{some college})_i$	κ_4	0.256	(0.032)
$\mathbf{I}(\text{college degree})_i$	κ_5	0.433	(0.036)
$\mathbf{I}(\text{college+})_i$	κ_6	0.632	(0.037)

Table 10: First-step parameters of the health shock process

Parameters ahead of	Symbols	Estimates	Standard errors
Constant	α_0	-26.599	(7.146)
Age_{it}	α_1	0.080	(0.003)
$\text{Years of Education}_i$	α_2	0.014	(0.039)
$\text{Years of Education}_i^2$	α_3	-0.003	(0.002)
Birth Year_i	α_4	0.010	(0.004)
$\mathbf{I}(\text{female})_i$	α_5	0.190	(0.050)

Table 11: Model estimates with husband as the first mover

	Benchmark		Constant Taste		Uncertain Taste		Uncertain Taste	
	(1)		(2)		(3)		(4)	
	estimates	SE	estimates	SE	estimates	SE	estimates	SE
Shared params:								
β_0	-4.145	(0.030)	-3.956	(0.000)	-7.171	(0.000)	-7.458	(0.000)
β_1	0.087	(0.000)	0.076	(0.000)	0.124	(0.000)	0.130	(0.000)
β_2	0.236	(0.007)	0.231	(0.001)	0.446	(0.001)	0.479	(0.001)
Husband's params:								
θ^h			0.669	(0.012)				
θ^h_{low}					0	–	-0.070	(0.012)
θ^h_{high}					1.576	(0.008)	1.491	(0.011)
$P^h_{low,low}$					0.107	(0.012)	0.135	(0.013)
$P^h_{high,high}$					0.166	(0.010)	0.134	(0.010)
Wife's params:								
θ^w			0.469	(0.009)				
θ^w_{low}					0	–	-0.718	(0.026)
θ^w_{high}					2.003	(0.018)	1.778	(0.017)
$P^w_{low,low}$					0.961	(0.004)	0.935	(0.005)
$P^w_{high,high}$					0.959	(0.004)	0.959	(0.003)
Log likelihood	-16471.254		-15578.305		-12445.216		-12267.405	

* $\theta^i,\ i \in \{h, w\}$, follows a discrete-time time-homogeneous Markov chain. In "Uncertain Taste" version, husband and wife have heterogeneous θ^i and the corresponding Markov chain.

12 Figures – Model Fit

Table 12: Notes for Figure 1

	all husbands	husband's edu≤12	husband's edu>12
all husbands	Fig 1(1)	Fig 1(2)	Fig 1(3)
wife has retired	Fig 1(4)	Fig 1(5)	Fig 1(6)
wife is working	Fig 1(7)	Fig 1(8)	Fig 1(9)

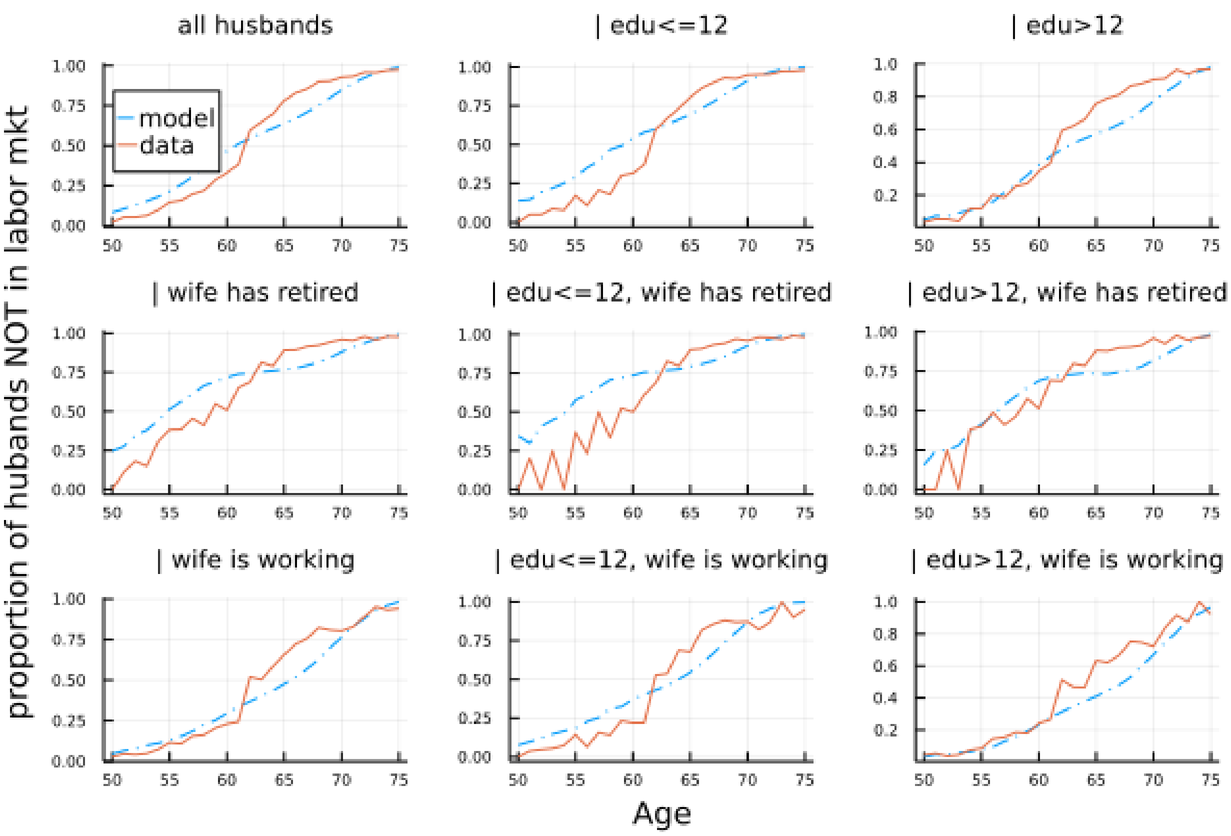


Figure 1: Model fit for husband

Table 13: Notes for Figure 2

	all wives	wife's edu≤12	wife's edu>12
all wives	Fig 2(1)	Fig 2(2)	Fig 2(3)
husband has retired	Fig 2(4)	Fig 2(5)	Fig 2(6)
husband is working	Fig 2(7)	Fig 2(8)	Fig 2(9)

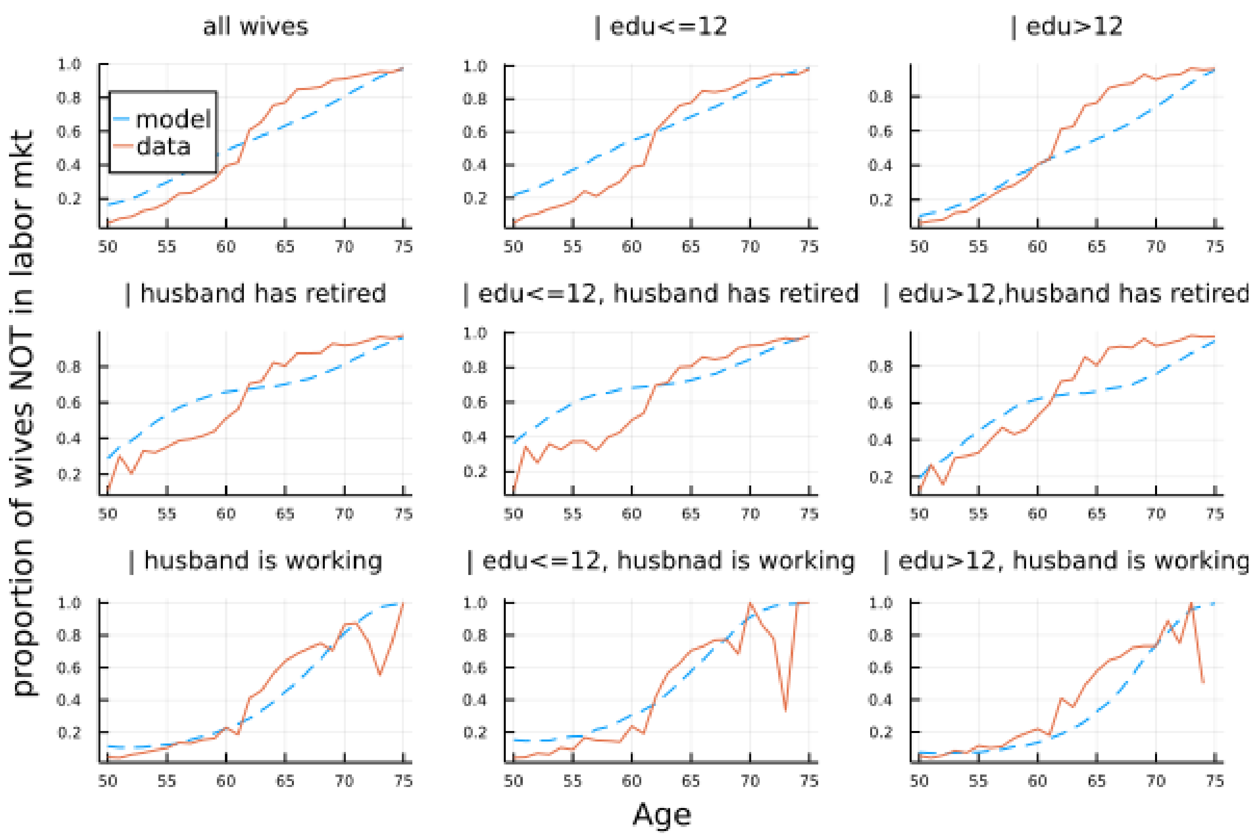


Figure 2: Model fit for wife

13 Figures – Counterfactual Behavior Analysis

13.1 Husband (First Mover)

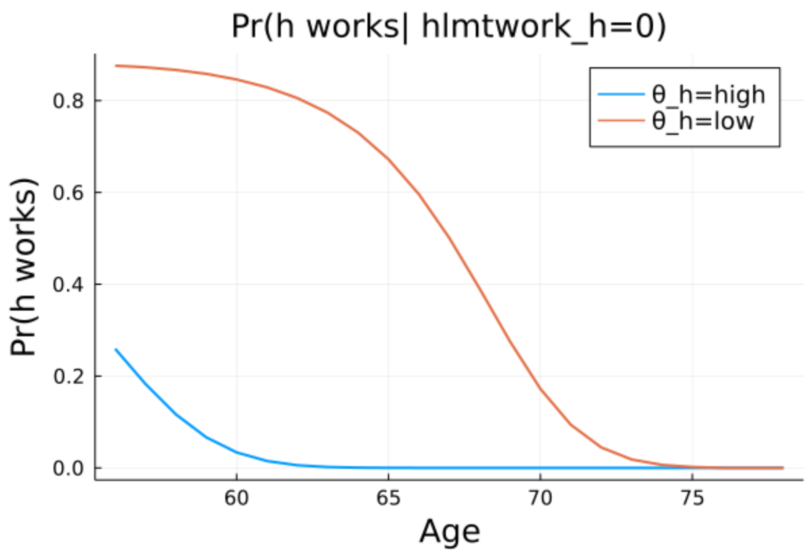


Figure 3: Behavior analysis for husband— hlmtwork=0

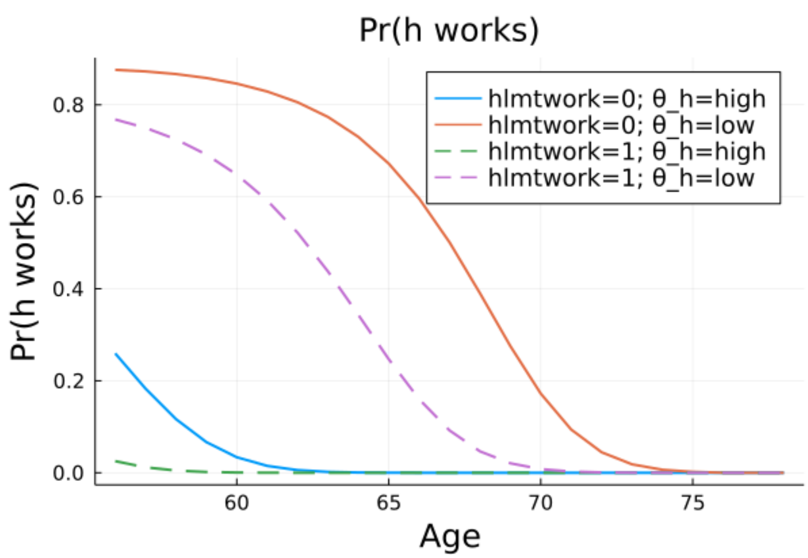


Figure 4: Behavior analysis for husband

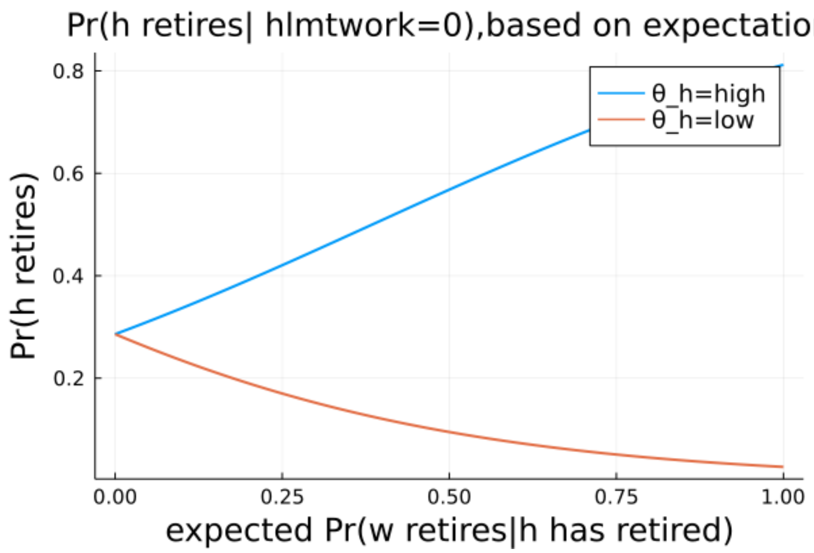


Figure 5: Based on the expectation, behavior analysis for husband— hlmtwork=0

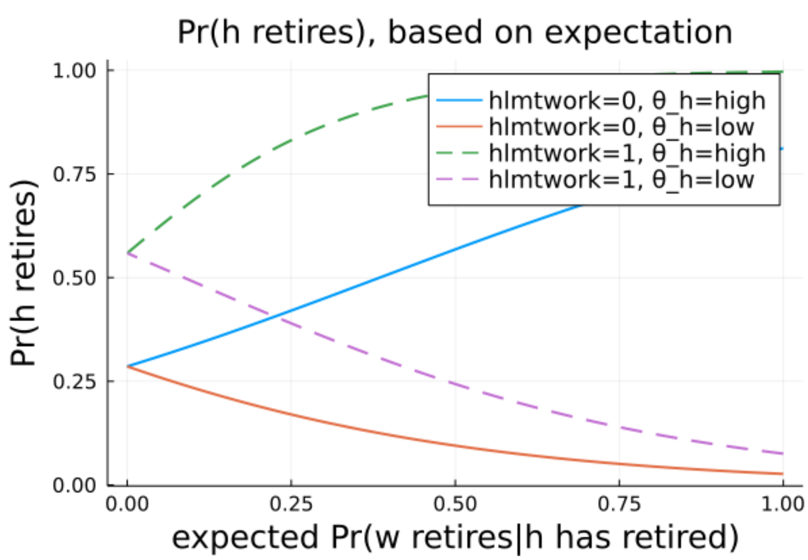


Figure 6: Based on the expectation, behavior analysis for husband

13.2 Wife (Second Mover)

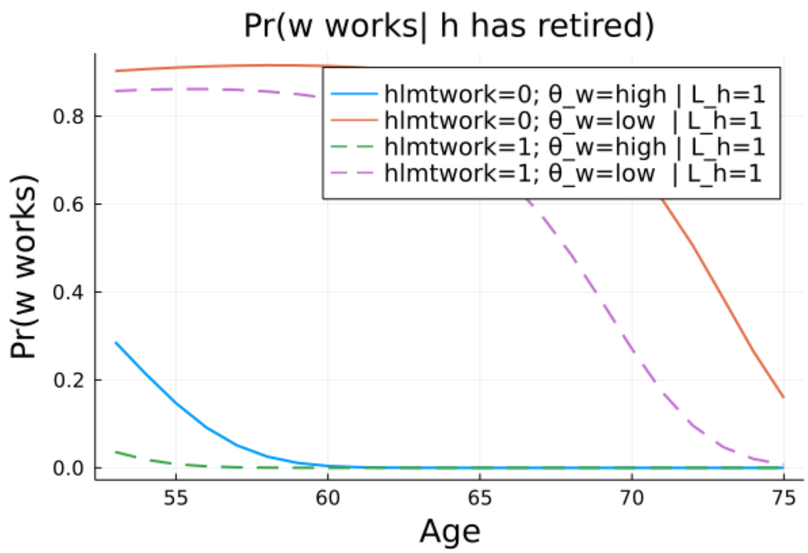


Figure 7: Behavior analysis for wife

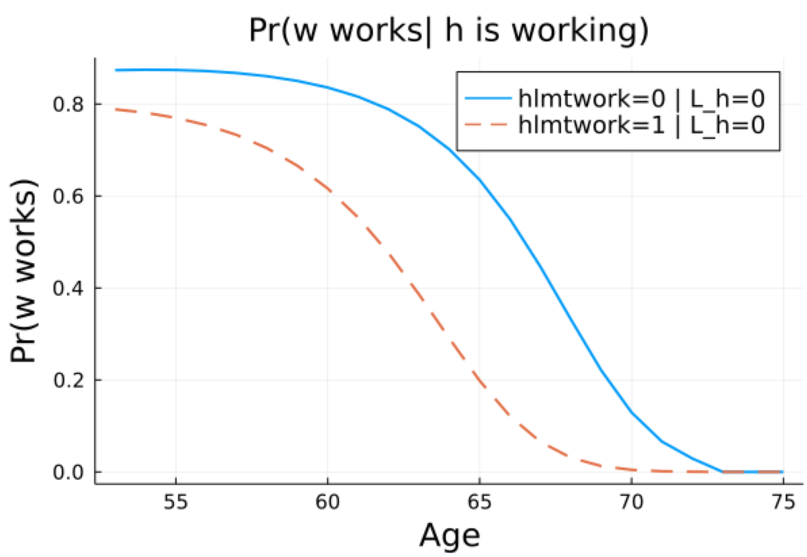


Figure 8: Behavior analysis for husband

13.3 Comparing With and Without Uncertainty Models

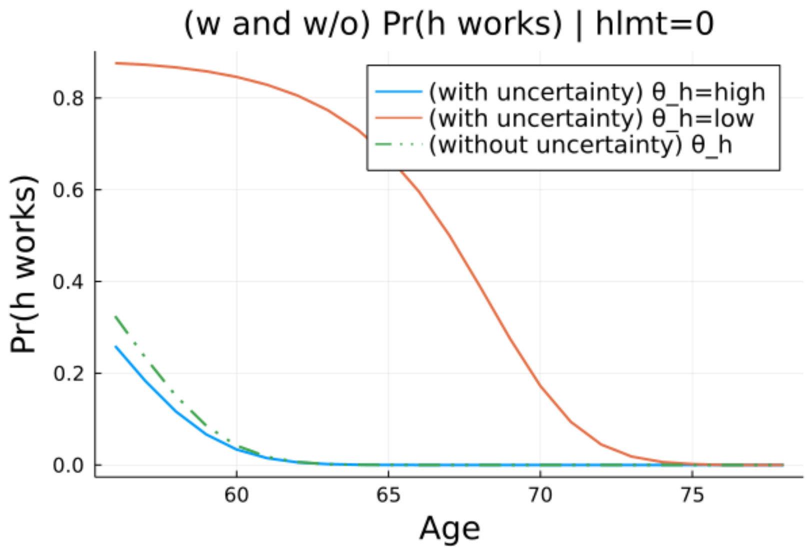


Figure 9: Comparing w and w/o uncertainty model, behavior analysis for husband

Figure 10: Comparing w and w/o uncertainty model, behavior analysis for wife

Appendices

A Example of no Nash equilibrium

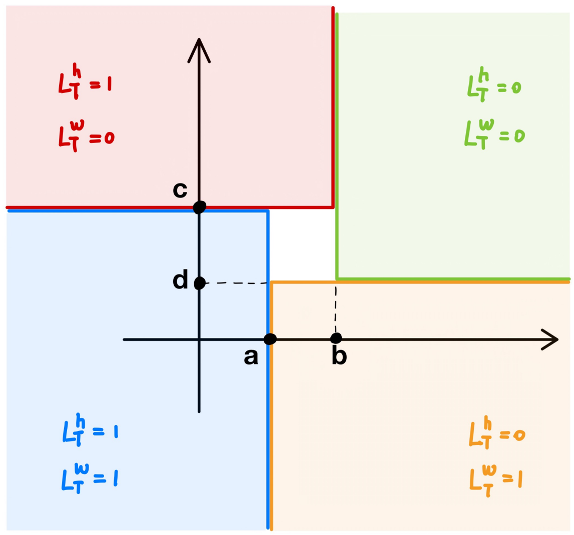


Figure 11: Example when $\theta_t^h > 0, \theta_t^w < 0$

Horizontal axis and vertical axis are husband's and wife's preference shock, ξ_t^h and ξ_t^w. Under the case where taste for joint leisure for husband and wife are in opposite direction, for instance $\theta_t^h > 0$ while $\theta_t^w < 0$, there is no Nash equilibrium for the middle blank area.

B Detailed solutions

First mover F

$$
\begin{aligned}
&V_t^F(s_t) \\
&= \max_{L_t^F}\{E_t\big[U_t^F(s_t, F0) + \delta E_t V_{t'}^F(s_{t'}|s_t)\big] + \widetilde{\xi_t^F}\ ,\ E_t\big[U_t^F(s_t, F1) + \delta E_t V_{t'}^F(s_{t'}|s_t)\big] + \widehat{\xi_t^F}\} \\
&= \max_{L_t^F}\Big\{P_t(S0|F0, s_t)\big[U_t^F(s_t, F0, S0) + \delta E_t V_{t'}^F(s_{t'}|s_t)\big] \\
&\qquad\qquad + P(S1|F0, s_t)\big[U_t^F(s_t, F0, S1) + \delta E_t V_{t'}^F(s_{t'}|s_t)\big] + \widetilde{\xi_t^F}\ , \\
&\qquad P_t(S0|F1, s_t)\big[U_t^F(s_t, F1, S0) + \delta E_t V_{t'}^F(s_{t'}|s_t)\big] \\
&\qquad\qquad + P_t(S1|F1, s_t)\big[U_t^F(s_t, F1, S1) + \delta E_t V_{t'}^F(s_{t'}|s_t)\big] + \widehat{\xi_t^F}\Big\}
\end{aligned}
$$

$$
\begin{aligned}
&= \max_{L_t^F} \Big\{ \big[P_t(S0|F0, s_t)U_t^F(s_t, F0, S0) + P(S1|F0, s_t)U_t^F(s_t, F0, S1)\big] + \delta E_t V_{t'}^F(s_{t'}|s_t) + \widetilde{\xi_t^F} \ , \\
&\qquad \big[P_t(S0|F1, s_t)U_t^F(s_t, F1, S0) + P_t(S1|F1, s_t)U_t^F(s_t, F1, S1)\big] + \delta E_t V_{t'}^F(s_{t'}|s_t) + \widehat{\xi_t^F} \Big\} \\
&= \max_{L_t^F} \Big\{ \big[P(S0|F0, s_t)C_{T00} + P(S1|F0, s_t)C_{T01}\big] + \delta E_t V_{t'}^F(s_{t'}|s_t) + \widetilde{\xi_t^F} \ , \\
&\qquad \big[P_t(S0|F1, s_t)C_{T10} + P_t(S1|F1, s_t)C_{T11} + \theta_t^F\big] + \delta E_t V_{t'}^F(s_{t'}|s_t) + Z_t^F(\cdot) + \widehat{\xi_t^F} \Big\} \\
&= \max_{L_t^F} \Big\{ P_t(S0|F0, s_t)\big[w_t^F + w_t^S + \mathbf{I}(g_t^F \geq c^F)ss_c^F + \mathbf{I}(g_t^S \geq c^S)ss_c^S\big] \\
&\qquad \underbrace{+P_t(S1|F0, s_t)\big[w_t^F + \mathbf{I}(g_t^F \geq c^F)ss_c^F + \mathbf{I}(g_t^S \geq c^S)ss_c^S\big] + \delta E_t V_{t'}^F(s_{t'}|s_t)}_{\mathbf{A}} + \widetilde{\xi_t^F} \ , \\
&\qquad P_t(S0|F1, s_t)\big[w_t^S + \mathbf{I}(g_t^F \geq c^F)ss_c^F + \mathbf{I}(g_t^S > c^w)ss_c^S\big] \\
&\qquad \underbrace{+P_t(S1|F1, s_t)\big[\theta_t^F + \mathbf{I}(g_t^F \geq c^F)ss_c^F + \mathbf{I}(g_t^S \geq c^S)ss_c^S\big] + \delta E_t V_{t'}^F(s_{t'}|s_t) + Z_t^F(\cdot)}_{\mathbf{B}} + \widehat{\xi_t^F} \Big\}
\end{aligned}
\tag{30}
$$

Second mover S

a. Under the condition where first mover F works full time

$$
\begin{aligned}
&V_t^S(s_t, F0) \\
&= \max_{L_t^S}\{U_t^S(s_t, F0, S0) + \delta E_t V_{t'}^S(s_{t'}|s_t) + \widetilde{\xi_t^S} \ , \ U_t^S(s_t, F0, S1) + \delta E_t V_{t'}^S(s_{t'}|s_t) + \widehat{\xi_t^S}\} \\
&= \max_{L_t^S}\{C_{T00} + \delta E_t V_{t'}^S(s_{t'}|s_t) + \widetilde{\xi_t^S} \ , \ C_{T01} + Z_t^S(\cdot) + \delta E_t V_{t'}^S(s_{t'}|s_t) + \widehat{\xi_t^S}\} \\
&= \max_{L_t^S} \Big\{ \underbrace{w_t^F + w_t^S + \mathbf{I}(g_t^F \geq c)ss_c^F + \mathbf{I}(g_t^S \geq c)ss_c^S + \delta E_t V_{t'}^S(s_{t'}|s_t)}_{\mathbf{C0}} + \widetilde{\xi_t^S} \ , \\
&\qquad \underbrace{w_t^F + \mathbf{I}(g_t^F \geq c)ss_c^F + \mathbf{I}(g_t^S \geq c)ss_c^S + Z_t^S(\cdot) + \delta E_t V_{t'}^S(s_{t'}|s_t)}_{\mathbf{D0}} + \widehat{\xi_t^S} \Big\},
\end{aligned}
\tag{31}
$$

b. Under the condition where first mover F retired

$$
\begin{aligned}
&V_t^S(s_t, F1) \\
&= \max_{L_t^S}\{U_t^S(s_t, F1, S0) + \delta E_t V_{t'}^S(s_{t'}|s_t) + \widetilde{\xi_t^S} \ , \ U_t^S(s_t, F1, S1) + \delta E_t V_{t'}^S(s_{t'}|s_t) + \widehat{\xi_t^S}\} \\
&= \max_{L_t^S}\{C_{T10} + \delta E_t V_{t'}^S(s_{t'}|s_t) + \widetilde{\xi_t^S} \ , \ C_{T11} + \theta_t^S + Z_t^S(\cdot) + \delta E_t V_{t'}^S(s_{t'}|s_t) + \widehat{\xi_t^S}\} \\
&= \max_{L_t^S} \Big\{ \underbrace{w_t^S + \mathbf{I}(g_t^F \geq c)ss_c^F + \mathbf{I}(g_t^S \geq c)ss_c^S + \delta E_t V_{t'}^S(s_{t'}|s_t)}_{\mathbf{C1}} + \widetilde{\xi_t^S} \ ,
\end{aligned}
$$

$$\underbrace{\mathbf{I}(g_t^F \geq c)ss_c^F + \mathbf{I}(g_t^S \geq c)ss_c^S + \theta_t^S + Z_t^S(\cdot) + \delta E_t V_{t'}^S(s_{t'}|s_t)}_{\mathbf{D1}} + \widehat{\xi}_t^S \Big\} \tag{32}$$

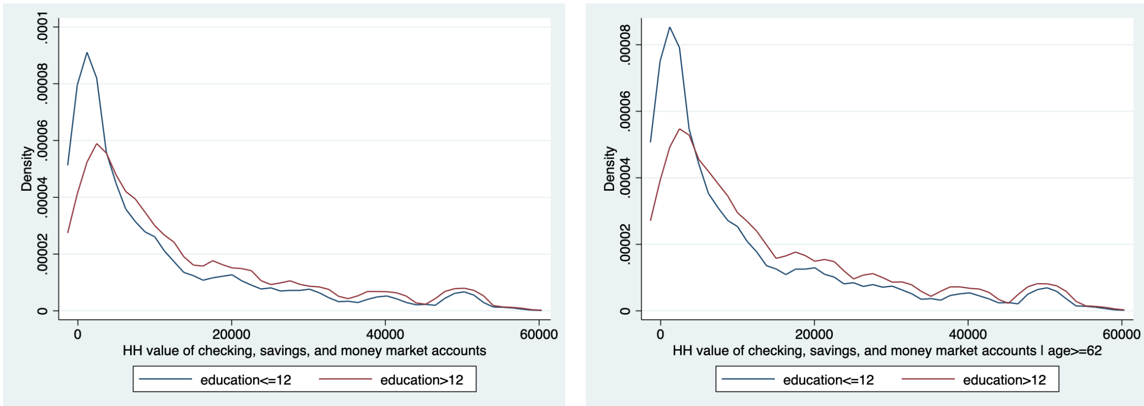
Second mover S's expected utility

$$\begin{aligned}
&E_{t-1}V_t^S(s_t|s_{t-1}) \\
=&P_t(F1|s_t)E_{t-1}V_t^S(s_t|s_{t-1}, F1) + \big(1 - P_t(F1|s_t)\big)E_{t-1}V_t^S(s_t|s_{t-1}, F0) \\
=&P_t(F1|s_t)E_{t-1}\big[\gamma + log\big(exp(\mathbf{C1}) + exp(\mathbf{D1})\big)\big] \\
&\qquad + \big(1 - P_t(F1|s_t)\big)E_{t-1}\big[\gamma + log\big(exp(\mathbf{C1}) + exp(\mathbf{D1})\big)\big]
\end{aligned} \tag{33}$$

If only person i survive till that period, $i \in \{husband, wife\}$

$$\begin{aligned}
&V_t^i(s_t) \\
&= \max_{L_t^i}\{U_t^i(i0|s_t) + \delta EV_{t'}^{single}(s_{t'}|s_t) + \widetilde{\xi}_t^i \ , \ U_t^i(i1|s_t) + \delta EV_{t'}^{single}(s_{t'}|s_t) + \widehat{\xi}_t^i\} \\
&= \max_{L_t^i}\{C_{T0} + \delta EV_{t'}^{single}(s_{t'}|s_t) + \widetilde{\xi}_t^i \ , \ C_{T1} + Z_t^i(g_t^i, h_t^i) + \delta EV_{t'}^{single}(s_{t'}|s_t) + \widehat{\xi}_t^i\} \\
&= \max_{L_t^i}\{\underbrace{w_t^i + \mathbf{I}(g_t^i \geq c)ss_c^i + \delta EV_{t'}^{single}(s_{t'}|s_t)}_{\mathbf{E}} + \widetilde{\xi}_t^i, \\
&\qquad \underbrace{\mathbf{I}(g_t^I \geq c)ss_c^i + Z_t^i(g_t^i, h_t^i) + \delta EV_{t'}^{single}(s_{t'}|s_t)}_{\mathbf{F}} + \widehat{\xi}_t^i\}
\end{aligned} \tag{34}$$

C Savings for different education and age group



(a) All households (b) Households whose husband age $\geq$ 62

Figure 12: Household value of checking, savings, and money market account

Table 14: Saving percentile for different education group

	Household value of checking, savings, and money market accounts											
All households												
	1%	5%	10%	25%	50%	75%	90%	95%	99%	Mean	dev.	Obs
h's edu<=12	0	0	0	1000	6000	20000	53000	95000	190000	19932	36406	11,159
h's edu>12	0	0	1000	4000	12000	36300	90000	140000	250000	31549	48957	9,662
Households whose husband age>=62												
	1%	5%	10%	25%	50%	75%	90%	95%	99%	Mean	dev.	Obs
h's edu<=12	0	0	0	1100	6500	25000	60000	100000	200000	21510	38094	8,506
h's edu>12	0	0	1000	4400	14000	40000	100000	150000	250000	34363	51736	7,093

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