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Aging Population and Household Labor Supply

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by

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ABSTRACT OF THE DISSERTATION

Aging Population and Household Labor Supply

by

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Doctor of Philosophy in Economics

University of California, San Diego, 2017

Professor David Lagakos, Chair

Aging population is a worldwide phenomenon. Households in these aging societies face many challenges with this demographic change and one of them is the increasing parental care responsibilities. This is one of the channels through which aging population potentially affects households' decisions and the labor market. I study how the health conditions of aged parents affect the labor supply and general time-use decisions of their adult children. To do this, I first develop a static household model where parental care responsibilities are reflected in both the time and budget constraints. I allow a market from which households can purchase market care that can substitute home care. The

implications of the model show that households' response to a parental health shock is heterogeneous to the wage of the secondary earner. More specifically, high-wage secondary earners increase their labor supply to purchase care, while low-wage secondary earners' responses depend on which constraint is affected more. If the time constraint is affected more, they work less; if the budget constraint is affected more, they work more. To confirm the predictions of the model, I analyze household-level data from the Health and Retirement Survey (HRS) using a dynamic panel estimation strategy with person-level fixed effects. I derive the impulse responses of female labor force participation status in the data and find that the trend is consistent with the implications of the model. High-wage females are more likely to work after a parental health shock, while the responses of low-wage females are ambiguous. To further explore the effect of parental care responsibilities on female labor supply, the labor market and the care market, I extend the static household model to discuss what happens in general equilibrium. I propose an overlapping generation model where each household in the young generation has two agents that work and take care of the old generation. Agents supply labor to two sectors that produce care and consumption goods. To calibrate the model, I draw data from the Current Population Survey and the Health and Retirement Survey. I calibrate the model the the 2007 labor market and match the responses identified in the empirical analysis. I also conduct a quantitative experiment to predict how the female labor market changes in an aging population. I find that with the presence of the care market, in the aggregate, female labor supply will increase as parental care responsibilities increase.

Chapter 1

A Household Time-Use Model

1.1 Introduction

As the baby boomers step into retirement and old age, caring for this generation poses unique challenges. The aggregate demand for care will be substantial for the society as the baby boomer cohort (76 million in the United States) makes up around 25% of the total population in the United States. Meanwhile, it will also affect the parental care responsibilities in the households, who are partially responsible for providing, arranging and possibly paying for the care. Currently, multiple sources contribute to the increase in care burden for the households. Aged dependency ratio is raising due to low fertility rate. Advancements in technology and medicine significantly extend people's life expectancy (Weil, 1997; Cutler et al., 1990), which possibly increases the number of years an elder needs to be cared for. On the other hand, over the last few decades, institutional changes moved more care burden from hospitals and communities to households. In 1980s, Medicare and Medicaid reimbursement structures started to incentivize shorter hospital stays. Medicare and Medicaid coverage of community based long-term care have also been shrinking (Meyer and Parker, 2011). As people struggle to balance between working and providing care, it is crucial to understand how parental care responsibility affects the labor force supply decision of the household members.

To study the mechanism of how households respond to an increase in elderly care responsibilities, regardless of their caregiving choices, I propose a model that focuses on intra-household allocations of resources when parental care responsibilities involve both time and financial inputs from the household. In essence, this model follows Becker (1965), but it leaves out the quality aspect of the home production. I model a parental health shock as an increase in a binding care-time requirement and medical care expenditures that come out of the budget constraint. However, parental care does not enter the utility function - a major difference from models of this kind. As a result, the reason for a household to engage in care production is to meet the binding constraints and household decisions now respond much more to exogenous factors such as care responsibilities and prices.

To showcase the channel of market care in the model, I model the two agents in a household with heterogeneous wages and a joint utility function. The primary earner will always work because of the comparative advantage in working. The model predicts that when there is a parental health shock, high-wage secondary earners will increase labor supply to purchase market care. For the low-wage secondary earners, it depends on which constraint is affected more in the care process. When the budget constraint is affected more, they work more; when time constraint is affected more, they work less. In both cases, the low-wage secondary earners are providing more care. Though the low-wage secondary earners may respond differently to the parental health shock, in aggregate, we still see a positive and significantly larger response from the high-wage secondary earners.

1.2 The Model Household

I propose a static household time-use model to study how parental care responsibilities affect household decisions. Consider a household with two agents, a primary earner i and a secondary earner j. Both are endowed with 1 unit of time to allocate among work, leisure and producing care at home. The household takes utility in i and j's individual leisure time and their joint consumption:

$$(1-\mu-\nu)ln(c)+\mu ln(l_i)+\nu ln(l_j)$$

with time endowment constraints for both agents:

$$l_i+n_i+h_i=1 \qquad l_j+n_j+h_j=1$$

I model the household's parental care responsibilities as a minimum care-time requirement, $H(\eta)$, and a lump-sum medical expense requirement, $M(\eta)$. For example, time spent in personal care assistance is accounted for in $H(\eta)$ and expenses such as out-of-pocket payments of drugs and procedures not covered by insurance or Medicare are in $M(\eta)$. Let η be a parental health measure that reflects the distance between the parents' actual health condition and the perfect health condition that requires no care from their adult children. Then both $H(\eta)$ and $M(\eta)$ are increasing functions of η, meaning that as health conditions worsen, the aged parents will require more care-time and medical expense. I assume that the production of care is linear in time inputs:

$$h_i+h_j+h_s \geq H(\eta)$$

where h_i and h_j are time inputs from i and j respectively, and h_s is care services (such as home nurse aid and assisted living services) purchased by the household to help fulfill this care-time requirement, $H(\eta)$. Care service is considered a perfect substitute to home care produced by i or j, and is supplied inelastically at market price p. If the household chooses to purchase care services, the cost will be an expense that comes out of the household's budget constraint. As a part of household budget constraint, $M(\eta)$ can be interpreted as the net asset passed down to the household from the parents. Regardless of the parents' wealth, when the parents are in worse health conditions, it potentially affects the budget constraints of their adult children, in the form of less fortune or more debt. Household's joint income finances joint consumption, market care purchase, and medical expense, thus the budget constraint is:

$$w_i n_i + w_j n_j = c + p h_s + M(\eta)$$

where w_i and w_j are exogenous wages. The model is only concerned with partial equilibrium within the household, so the wages and price are exogenous, and are known to the households when decisions are made.

1.3 Corner Solutions

Since all inputs in the production of care derive negative utility from less leisure or consumption, when optimizing, the household will choose to produce the minimal level of care, $H(\eta)$. At the same time, h_i, h_j, and h_s are perfect substitutes, so the household will choose the input with the lowest unit utility cost to provide all the care, resulting in corner solutions. There are 4 possible scenarios the household can choose from to maximize their utility. Since i is the primary earner, $w_i > w_j$ for each household, i will always work and only work given the primary earner's comparative advantage in bringing in income. To fulfill the care-time requirement, either j produces care at home or the household purchases care services, depending on which option is cheaper. The four possible optimal scenarios are:

1. j works, household purchases care services

   $n_i, n_j \geq 0$, $h_i = h_j = 0$, $h_s = H(\eta)$

2. j works and provides home care

   $n_i, n_j \geq 0$, $h_i = h_s = 0$, $h_j = H(\eta)$

3. j does not work, household purchases care

   $n_i \geq 0$, $n_j = 0$, $h_i = h_j = 0$, $h_s = H(\eta)$

4. j does not work and provides home care

   $n_i \geq 0$, $n_j = 0$, $h_i = h_s = 0$, $h_j = H(\eta)$

Optimal labor and consumption allocations can be calculated under each scenario, given the exogenous wages w_i and w_j, price p, care requirement $H(\eta)$ and medical expense $M(\eta)$. By comparing the utilities derived by optimal allocations from each of the four scenarios, a household picks the scenario that yields the highest utility. Appendix A.1.1 shows for detailed solutions for each of these corner solutions.

1.4 A Household's Optimal Choice

By deriving the conditions for a scenario to yield higher utility than another, the model reveals the factors that affect households' labor supply and care decisions. Let the maximum utility of scenario i be U_i, $i = 1,2,3,4$. First, I show that the choice of the corner solutions depends on the ratios of w_i,w_j and p.

Proposition 1. *A household's optimal corner solution can be identified through the households' relative prices,* $\frac{w_i}{w_j}$ *and* $\frac{w_i}{p}$*. More specially, the secondary earner would not participate in the labor force if* $\frac{w_i}{w_j}$ *is large enough, and they would not produce care themselves if* $\frac{w_j}{p}$ *is large enough.*

Proof. See Appendix A.1.2. □

Proposition 1 holds for all levels of health conditions η. When η increases, $H(\eta)$ increases, and the cutoff values of $\frac{w_i}{w_j}$ and $\frac{w_j}{p}$ change. This results in the change of optimal corner solution for some households. By Proposition 1, I can categorize households by their relative prices $\frac{w_i}{w_j}$ and $\frac{w_j}{p}$, and thus by the optimal corner solution they choose, at a given level of η. For convenience of notation, define the set of households that derives the maximum utility from scenario k when facing care requirement η as $E(k,\eta)$ and

$$E(k,\eta) = \{(w_i,w_j,p)|U_k(w_i,w_j,p) = max(U_i(w_i,w_j,p), i = 1,2,3,4)\}$$

For example, $E(1,\eta_0)$ is the set of households that derive the maximum utility from scenario 1 under care requirement η_0. These are the households in which both the primary earner and the secondary earner work, and purchase care services. These households have relatively small wage-gap (small $\frac{w_i}{w_j}$) and the secondary earner has a relatively high wage (large $\frac{w_j}{p} >$). To understand how changes in parental care responsibilities affect intra-household decisions, I derive conditions for which an increase in η would lead to a different optimal corner solution for a household.

Proposition 2. *When η increases, care-time requirement $H(\eta)$ and medical care expenditure $M(\eta)$ increase, and for high-wage earners ($\frac{w_j}{p} > 1$), if $\frac{w_i}{w_j}$ is sufficiently high, secondary earners remain outside the labor force, otherwise they increase labor supply. In other words, when η increases, on the extensive margin, $E(1)$ expands; on the intensive margin, n_j increases. More specifically:*

(1) For some $(w_i,w_j,p) \in E(3,\eta_0)$, there exists some $\eta_1 > \eta_0$, such that $(w_i,w_j,p) \bigcup E(1,\eta_0) \in E(1,\eta_1)$;

(2) For some $(w_i,w_j,p) \in E(4,\eta_0)$, there exists some $\eta_1 > \eta_0$, such that $(w_i,w_j,p) \bigcup E(1,\eta_0) \in E(1,\eta_1)$.

(3) For all $(w_i,w_j,p) \in E(4,\eta_0)$, for all $\eta_1 > \eta_0$, $n_j(\eta_1) \geq n_j(\eta_0)$.

Proof. See Appendix A.1.3 □

1.5 Graphing Household Decisions with Relative Prices

To better illustrate the implications of the model, I use graphs to demonstrate how households make labor supply and care decisions under the proposed framework. Each household has a unique pair of values that represents its relative prices, $(\frac{w_i}{w_j}, \frac{w_j}{p})$. For each pair of relative prices, there exists a unique scenario that maximizes the household's utility, as shown in Proposition 1. I map each household from its relative prices to its utility-maximizing scenario, representing the optimal decision of the household given certain level parental care responsibilities, $H(\eta)$ and $M(\eta)$. In all the following graphs, parameter values are set to $\mu = \nu = 0.3$. That is, assuming the weight of leisure in utility is the same for i and j, and the weight of joint consumption is 0.4 [1].

Figure 1.1 represents the mapping from household relative prices to the optimal scenario it chooses, given $H(\eta) = 0.3$ and $M(\eta) = 0.1$. The pattern follows Proposition 1. For households with large $\frac{w_j}{p}$, care service is relatively cheap and these households will purchase market care. At the same time, when $\frac{w_i}{w_j}$ is large, j does not work because j's leisure derives more utility than consumption from j's income. The four regions in the graph represent the four corner solutions. By changing the values of $H(\eta)$ and $M(\eta)$, the boundaries of the regions will change (Proposition 2). I consider the effects of $H(\eta)$ and $M(\eta)$ separately to distinguish their roles in intra-household decisions.

1.5.1 Care-Time Changes: $H(\eta)$ increases, $M(\eta) = 0$

Figure 1.2 shows the changes of household decisions with arrows marking the households with secondary earners j joining or dropping out of the labor force (recall

[1] Proposition 1 shows that the general pattern exists given any parameter values. Since the model will not be used for quantitative analysis, parameter values are not calibrated and are chosen for better graphic presentation

that i always work). It shows that as $H(\eta)$ increases, to meet the care-time requirement, some low-wage secondary earners who were working and producing care now have to drop out of the labor force to meet the amount of care produced at home. At the same time, some high-wage secondary earners who could afford to not work now have to join the labor force to compensate for the increased expense in market care purchases.

Note that n_i and n_j are functions of $H(\eta)$[2]. The intensive margins are not visible from this graph, but $H(\eta)$ has an effect on n_i and n_j.

1.5.2 Medical Expense Changes: $H(\eta) \approx 0$, $M(\eta)$ increases

In the model, medical expense $M(\eta)$ is equivalent to a lump-sum reduction from the household budget constraint. So when $M(\eta)$ increases, labor supply increases on the extensive margin for j, and in the intensive margin for both i and j. Since this change does not concern care-time $H(\eta)$, it only depends on relative wages within the households, $\frac{w_i}{w_j}$. As shown in Figure 1.3, labor supply increases for all households with relatively small wage gap. Meanwhile, for households with large wage gap, the primary earners increase labor supply. The added household income is enough to cover the increased $M(\eta)$ and the secondary earners can still not work and derive utility from leisure.

1.5.3 Change in both $H(\eta)$ and $M(\eta)$

When there is an increased requirement for both elderly care and medical expense, which is likely a more realistic situation when parents age, we can combine the effects we observe earlier. For households with high-wage secondary earners, increases in $H(\eta)$ and $M(\eta)$ both increase labor supply; for households with low-wage secondary earners, increase in $H(\eta)$ decreases labor supply but increase in $M(\eta)$ increases labor supply. So when aging parents require more elderly care and medical care, the implication is clear

[2]See the functional forms of all four corner solutions in Appendix A.1.1

for households with high-wage secondary earners, but ambiguous for households with low-wage secondary earners.

Consider the case where the parents need to have an expensive surgery, and medical care expense occurs, $M(\eta)$ changes from 0 to 0.3[3].

If elderly care time requirement dominates the medical expense (in Figure 1.4), some low-wage secondary earners will need to drop out of the labor force to produce elderly care. However, if the medical expense dominates (in Figure 1.5), then the opposite will happen - some secondary earners need to enter the labor force to earn extra income to pay for the medical expense. Note that both graphs are consistent with Proposition 2, that is, high-wage secondary earners work more.

Depends on the specific health conditions of the parents, households are likely to face different combinations of elderly care and medical expense requirements. The effect on the low-wage secondary earners can go either direction. In the empirical section, I will show that this is indeed what we observe in the data.

[3]Since household decisions depend on relative prices and this model is not used for quantitative purposes, the value of $M(\eta)$ is set arbitrarily.

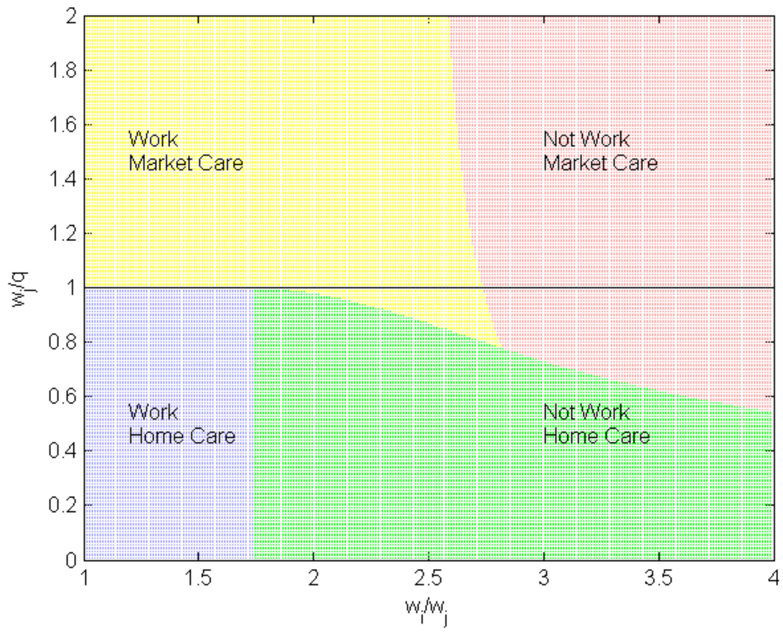

Figure 1.1. Household Labor Supply and Care Decisions

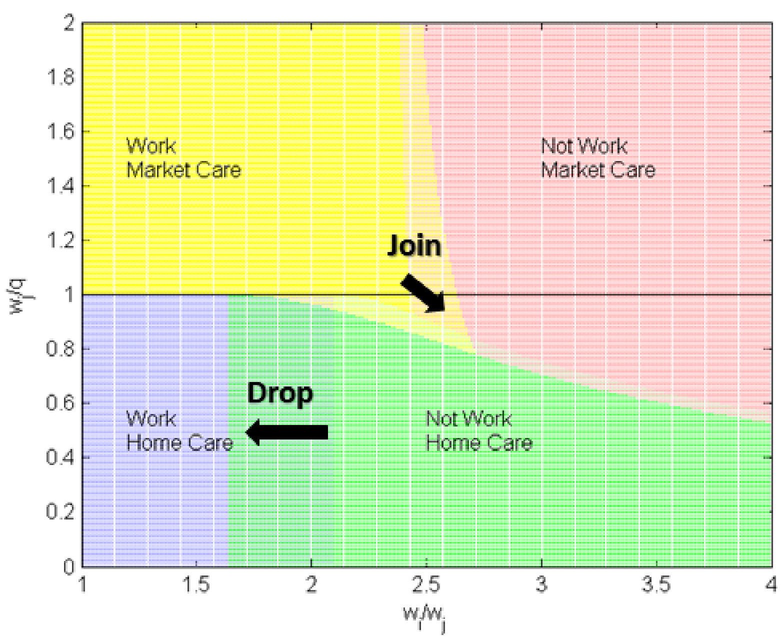

Figure 1.2. Elderly Care Increase: higher $H(\eta)$

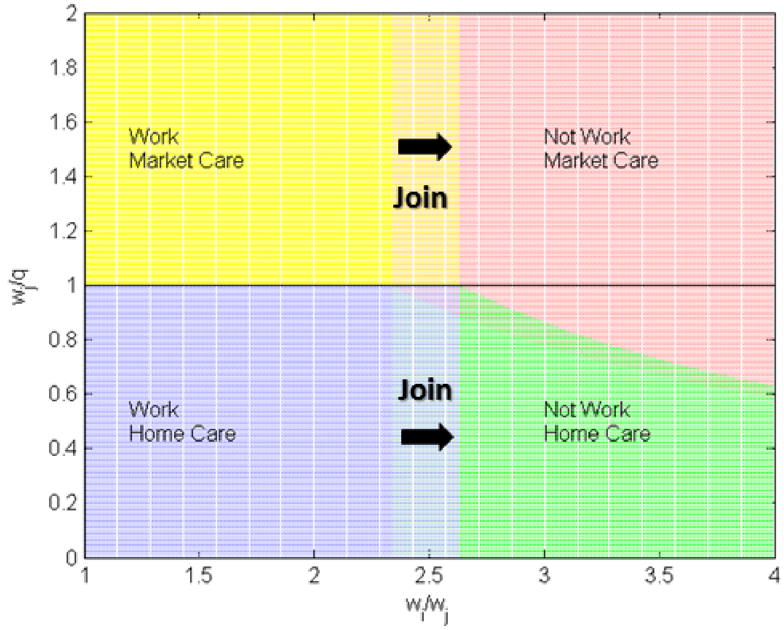

Figure 1.3. Medical Care Increase: higher in $M(H(\eta))$

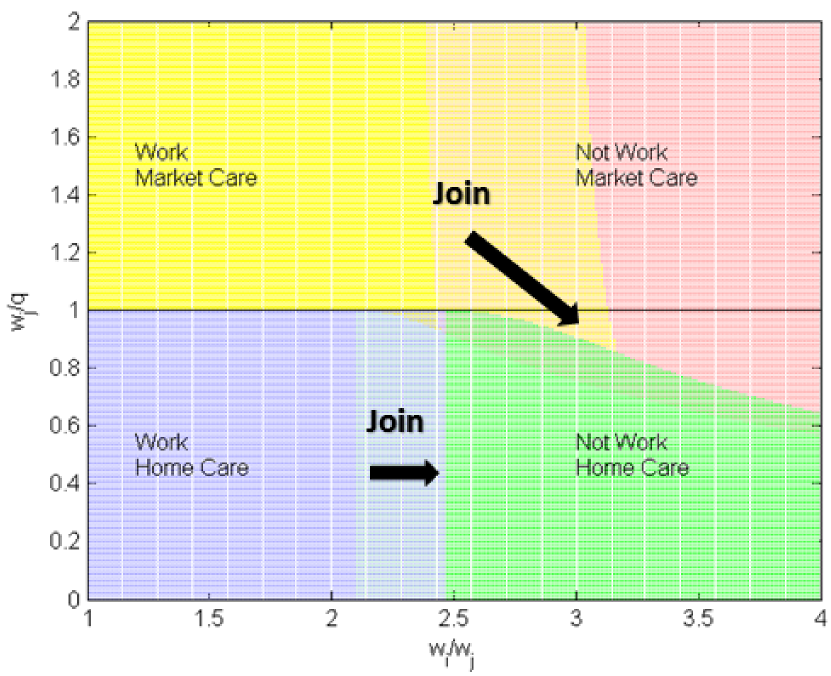

Figure 1.4. Increase in both Elderly and Medical Care

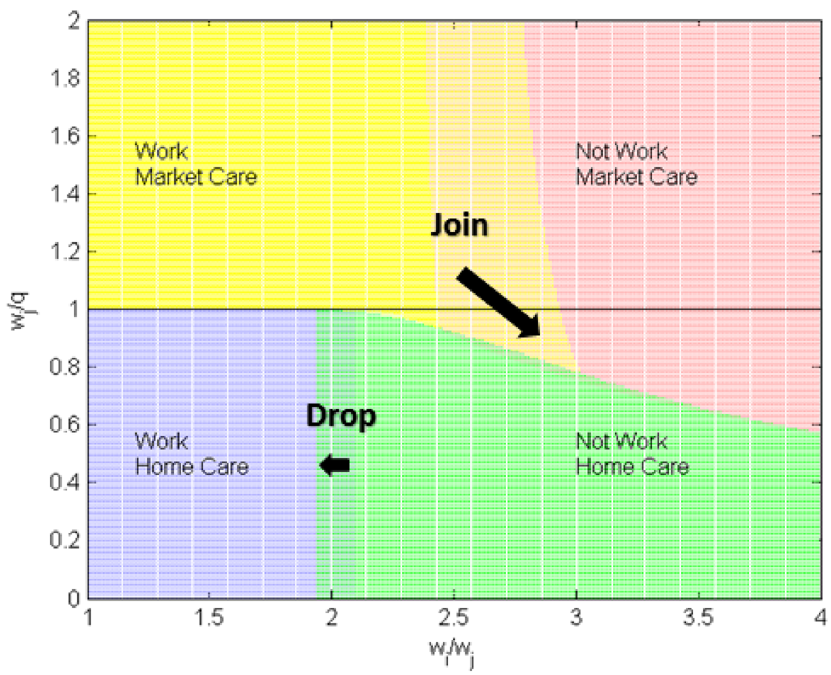

Figure 1.5. Increase in both Elderly and Medical Care

Chapter 2

Empirical Findings from HRS

2.1 Introduction

In Chapter 1, I present a static household model that describes how household decisions are made when the household needs to meet certain demand for parental care responsibilities. In this chapter, I will discuss empirical analysis guided by the implications of the model. Empirical studies on labor supply and caregiving generally focuses on the effect on caregivers, and they suggest that providing informal care can negatively affects labor supply. Lilly et al. (2007) review 35 papers that study the labor supply of caregivers using various data sets around the world, and conclude that caregivers supply fewer hours in the labor market, but labor force participation is not affected unless the caregiver is providing intensive care. Carmichael and Charles (2003) analyze data from UK and find that providing informal care negatively affects labor force participation, labor supply and wage earned, but the effects are different for men and women. Bolin et al. (2008) find that cross Europe, informal caregivers of elderly parents suffer various degree of foregone employment opportunities, though wage rates and hours worked are not as affected. Women in their pre-retirement years are more likely to need to provide care and their labor supply is shown to be negatively affected when they transfer time to help their parents(Johnson and Lo Sasso, 2006; Fahle and McGarry, 2017b).

It is crucial for us to understand decisions around caregiving, especially in an aging society. The main contribution of my empirical analysis is that it provides insight into how caregiving decisions are made, regardless of whether or not the care is provided by the household. My model does not exclude non-caregivers, which means the decision process described is applicable for all households. This helps us understand why some become caregivers and others do not. McGarry (2006) takes a first look at the transitions to caregiving. The paper compares people's market labor supply before caregiving activities take place and find surprisingly little connection between that and the later caregiving decisions, so there is no evidence that caregivers are less attached to the labor market. Fahle and McGarry (2017a) suggest that caregivers might have even stronger attachment to the labor market than non-caregivers. This suggests that we need to rethink about the common believe that the caregivers become caregivers because they are less attached to the labor market than others. While it is definitely true to some level, there is more to it that we need to explore.

I use household-level panel data from the Health and Retirement Survey (HRS, 1992-2012), which follows more than 20,000 people over time with biennial interviews. The respondents are drawn on population 51-year-old and above, so it oversamples the people that would most likely face the issue of caring for aged parents during survey time. The survey collects information such as employment status, wage, and health status of the respondents, and the health status of their parents and parents-in-law. I construct a parental health shock variable from the questionnaire, and a household is shocked when at least one parent in the household can no longer be left alone for more than an hour. I assume that a female is the secondary earner in a household. Guided by the set up and implications of the model, I use the average of BLS hourly and weekly earnings of home health care workers as a reference wage and separate the observations into high-wage and low-wage groups by female reported wages. To estimate the effect of the parental health shock, I use a linear probability model and estimate the impulse responses of female labor force participation using a dynamic panel regression with person-level fixed effect. I find that for high-wage females, their impulse response is positive, lasts for 4 periods (or 8 years), and peaks at 0.08 one period (or 2 years) after the shock. For the low-wage females, just as predicted in the model, the effect is ambiguous.

2.2 Connecting Model and Data

I first look for ways to identify critical components of the model in the data. The two most important drivers of the labor supply and caregiving decisions are the demand of parental care responsibilities and the relative prices. Neither of the two are readily observable in HRS (or most data sets), so I will discuss in detail how I identify them in my empirical strategy.

2.3 η in the data

Ideally, to measure how households respond to an increase in parental care responsibilities, I would identify the changes in required medical expense and care time and estimate the elasticity of labor supply to the two. However, they are usually not observable, especially care time, since it is a demand that may or may not be met. Though I cannot directly identify $M(\eta)$ or $H(\eta)$, they are increasing functions of parental health condition η. I can infer the direction of changes of $M(\eta)$ and $H(\eta)$ from η.

Throughout the survey, three questions are asked about alive parents' health conditions:

(1) Does she/he need any help with basic personal needs like dressing, eating or bathing?

(2) Can she/he be left alone for an hour or more?

(3) Has a doctor ever said that she/he has a memory-related disease?[1]

The health condition measure I use in my estimates is from (2). It is comparatively more objective and more robust to heterogeneity in respondents' feelings towards taking care of an elderly. At the same time, it is the most appropriate measure as to proxy the time input the parents need. The question is asked for all parents and parent-in-laws. If a parent or parent-in-law can be left alone for more than an hour, the answer takes the value zero; otherwise, it takes the value 1. If a parent or parent-in-law is no longer alive, it takes the value zero. Consider η as the sum of the values for all parents, so it represents the current elderly care situation of the household. The maximum possible value is 4, which happens when all four parents are alive and need care. I focus on a positive change in η[2], i.e. he/she/they can be left alone for an hour or more in the last survey (2 years ago) and cannot be left alone any more. When there is a positive change in η, the household is considered to have a parental health shock, where care responsibilities $M(\eta)$ and $H(\eta)$ increase.

2.3.1 Relative prices in the data

In the model, relative prices are keys to determine the optimal allocations of labor supply and care in a households. I calculate wage from the reported income and time worked, adjusted for inflation. I take the highest wage as the respondent's wage so it is closer the opportunity cost of working less. After all, it is possible that during part of the survey time, the respondent decided to take a less demanding job. Using the highest reported wage helps capture the potential wage that the respondent is capable of earning, which is w_j in the model. All respondents with highest reported real wage lower than half of real minimum wage during the surveyed year, or higher than 20 times the reference

[1] This question was added in 2002

[2] A negative change η is usually the result of the pass of a parent that needed care, which can lead to other behavioral responses. I will not focus on these in this paper

wage p, are dropped due to suspected measurement errors.

It is, however, challenging to construct intra-household wage ratios from data. Though HRS is designed to track all respondents and their spouses, the reported information from the spouses, specially employment and wage, is usually missing. This makes it impossible to identify who is the secondary earner, or to construct the relative wage, $\frac{w_i}{w_j}$. The survey respondents are older than 50, and the Heckman selection model does not yield dependable wage estimates due to the lack of information on their employment history. I assume that females are always secondary earners, and I limit my sample to females that have reported wage at least twice during their surveyed time. In this way, I cannot identify the effect along the $\frac{w_i}{w_j}$ dimension, i.e., given the same wage, which secondary earners stay home because the spouse's wage is comparatively high. Still, the heterogeneity in the responses should still be observable. That is, on average, high-wage females work more when parental care responsibilities increase. For the low-wage females, on average, their labor supply could increase or decrease, but should not be too dramatic because their responses would offset each other.

I use the average of BLS hourly and weekly earnings of home health care services and personal care services as reference[3] for p. According to the model, the heterogeneity in labor supply is determined mostly by the relative price, $\frac{w_j}{p}$ [4]. There are measurement issues with the constructed w_j and p. For example, different households might face different care service price given locations and access to such services. So in an attempt to avoid the error of misidentifying a secondary earner who is close to the $\frac{w_j}{p} = 1$ line, I define low-wage females as those earning equal or less than 80% of p, and high-wage females as those earning equal or more than 120% of p.

[3]This earnings level is comparable to other jobs related to elderly care, such as average earnings for non-supervising workers in nursing care facilities and assisted living facilities for the elderly.

[4]The cutoff values of $\frac{w_j}{p}$ is affected by the other relative price, $\frac{w_i}{w_j}$. See proof of Proposition 1 in Appendix A.1.2.

2.3.2 Descriptive Analysis

When parents' health conditions are reported to be worse than the last period (an increase in η), I consider the household experiences a parent's health shock in that period. The empirical question here is how working status changes in response to this shock. The descriptive summary statistics of high-wage and low-wage females are presented in Table 2.1. The two groups are comparable in age, number of years being surveyed, and the likelihood of experiencing the shock during survey time.

Respondents are asked to report their employment and working status every two years. The survey is designed to collect data on weeks and hours worked, but few respondents provided answers. As a result, there is no reliable information on the intensive margin of labor supply. Most respondents indicated whether they are working or not each time they were surveyed, so I use the participation in the labor market as the measure of labor supply decision. Since all respondents are aged 51 and above, the labor force participation choices naturally reflect retirement decisions. Figures 2.1 and 2.2 show the trend of decreasing labor force participation as respondents approach and go beyond their ideal retirement age. Meanwhile, low-wage workers retire earlier than high-wage workers, so labor force participation rate is higher for high-wage workers.

For respondents that experienced shock during survey time, I graph the labor force participation rates against the time to the shock period in Figures 2.3 and 2.4. Figure 2.4 limits the sample to the respondents that were working the period (2 years) before the shock happened. In both graphs, the age effect dominates: labor force participation rates decrease for both group over time. Though the labor force participation rates are higher for the high-wage group, it is unclear whether it is due to the simple wage effect or the shock. Without a control group to distinguish the wage and age effects from the treatment effect of the parent's health shock, descriptive analysis provides limited information.

2.4 Panel Analysis

I estimate the following separately for the high-wage and low-wage groups:

$$Y_{it} = \alpha + \rho Y_{i,t-1} + \gamma_1 Shock_{i,t} + \gamma_2 Shock_{i,t-1} + \gamma_3 Shock_{i,t-2} + \vec{\beta}_{i,control}\vec{X}_{i,control} + \alpha_i + u_{it} \tag{2.1}$$

where $Y_{it} = 1$ when person i is working at time t. $Shock_{i,t}$ is 1 if the female faces an increase in elderly care demand this period, and $Shock_{i,t-1}$ and $Shock_{i,t-2}$ are the lags of the shock. There are two reasons why it is important to include the lags of the shock: 1) it is possible that the shock happened relatively close to the interview time such that the respondent has not reacted to the shock yet (limited by the frequency of the survey); 2) the observed change in labor supply is on the extensive margin only, the actual adjustment can take place later.

$\vec{X}_{i,control}$ includes a dummy for the respondent's current health status and two dummies for how far the respondent is from and to normal retirement age. Current health status is a self-reported rating on how good the respondent feels about their own health; the higher the rate, the worse the respondent feels. It is a time-variant measure and affects people' retirement decision. The data set is on population 51-year-old and above, so retirement is an important part of labor supply decision. In an attempt to separate the effect of elderly care from a normal incentive to retire, I control for the distance from retirement age. Retirement age is set the normal or ideal retirement age reported by the respondent. If the respondent did not report one, retirement age is set to 65, which is the age that one can collect social security without penalty for this birth cohort. If the respondent is at least 4 years (2 survey periods) older than retirement age, she is considered to be "after" retirement. If the respondent is at least 4 years younger than the retirement age, she is considered to be "before" retirement.

With panel data, person-level fixed effect controls for all time-invariant factors. The the working status of a certain period largely depends on the working status of the last period, which means it is structurally necessary to include the lag of working status in the regression. Table 2.2 is the dynamic panel analysis for high-wage group and Table 2.3 is for the low-wage group. The results are consistent with the predictions of the model. Regressions (5) and (8) are estimations from linear probability model, described in equation (2.1). From both regressions, the respondent is more likely to work this period when she worked last period and are younger than retirement age. The respondent is less likely to work this period when she is bad health status and is older than retirement age. The effect of parents' health shock is consistent with the predictions of the theoretical model: for high-wage females, the coefficients for the shock and its lags are positive and significant, while for low-wage females, the coefficients are not significant. To better visualize the labor supply responses of the two groups, I derive the impulse response curves, shown in Figures 2.5 and 2.6.

I perform a series of robustness checks to confirm this pattern in the data. First, because the dependent variable is a dummy variable, I use logit model to check the reliability of the estimates from the linear probability model. (6) and (9) are conditional logit regressions, and (7) and (10) show the marginal effect estimated at the average. Due to the lack of changes in the value of the independent variable, logit model drops a considerable amount of observations. Estimates in (6) and (9) are comparable to those in (5) and (8). Secondly, to address the issue of limited dependent variable with fixed effect, Table 2.4 shows the Arellano-Bond estimates and IV with difference of lagged variables. The pattern that high-wage females are more likely to work is robust under these identifications. Finally, I consider different classifications of high-wage and low-wage, and the presents are presented in Appendix A.2.

In conclusion, the empirical findings from HRS is consistent with the implication of the theoretical model. Responses to changes in parental care responsibilities in the household are heterogeneous for women of different wage levels. Meanwhile, the confidence interval in the low-wage group is much larger, suggesting heterogeneity within the group. The result indicates that while actually providing care can reduce labor supply, having a heavier care burden does not have the same implication. In an aging economy, one of the major concerns is that labor supply will drop due to the increase in elderly care demand, and I show that it is not likely the case. I further discuss the implications of my finding for an aging economy in details in Chapter 3.

Table 2.1. Descriptive Statistics of High-wage and Low-wage Groups

	high-wage	low-wage
Number of respondents	1843	1425
average age at the start of survey	51.7	52.7
% of respondents shocked during survey time	11	9.5
Number of observations	10418	7648
% of obs working	72.1	63.6

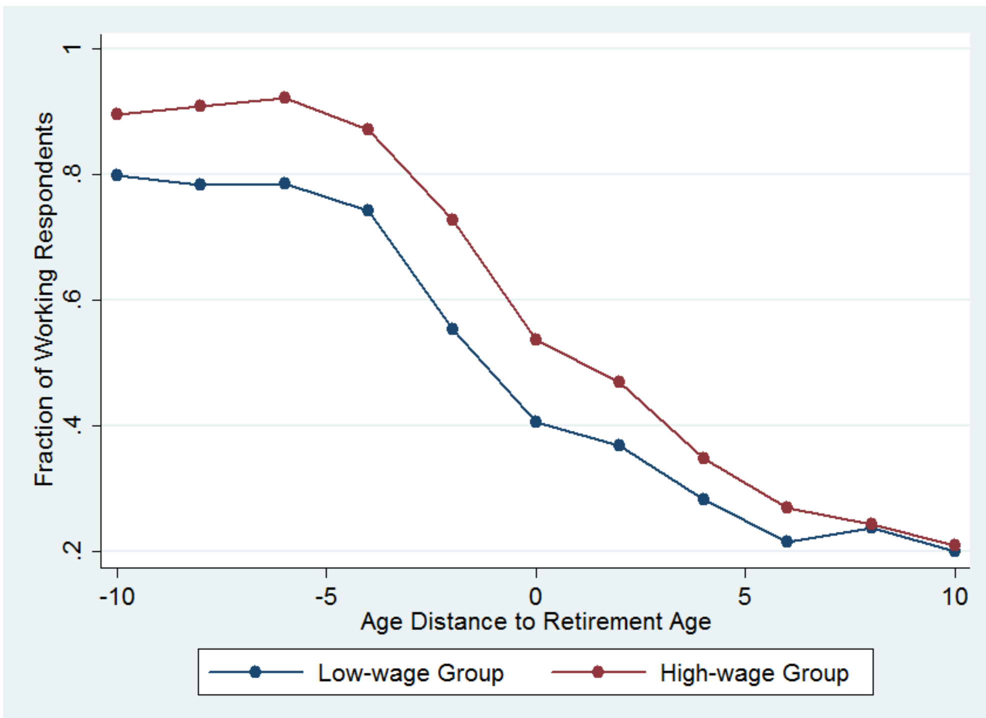

Figure 2.1. Fraction of Respondents Working: All, by wage

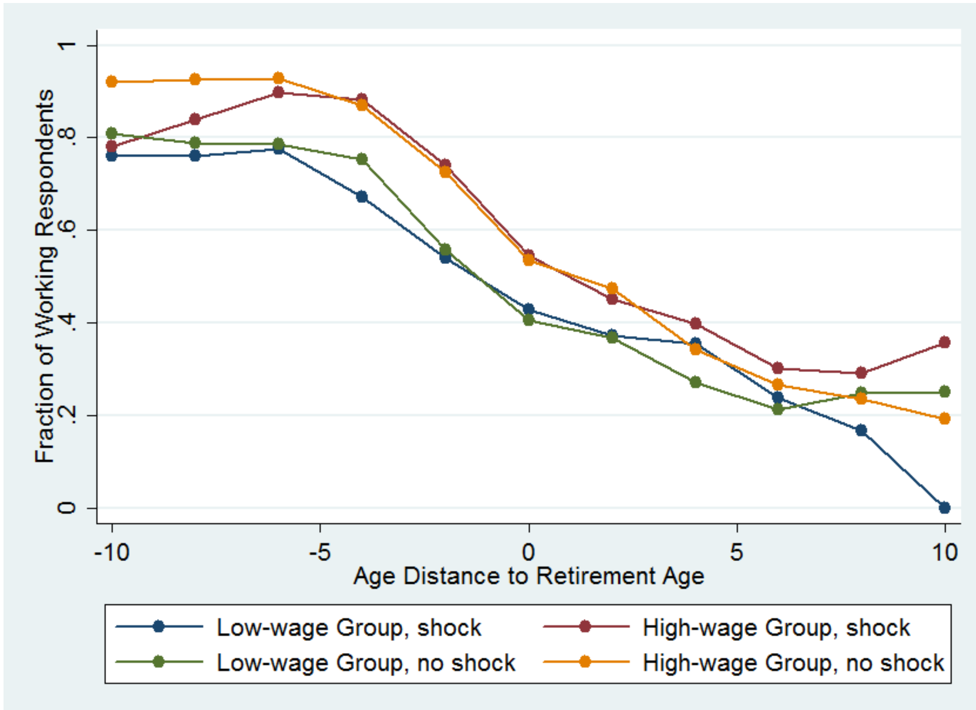

Figure 2.2. Fraction of Respondents Working: All, by wage and shock

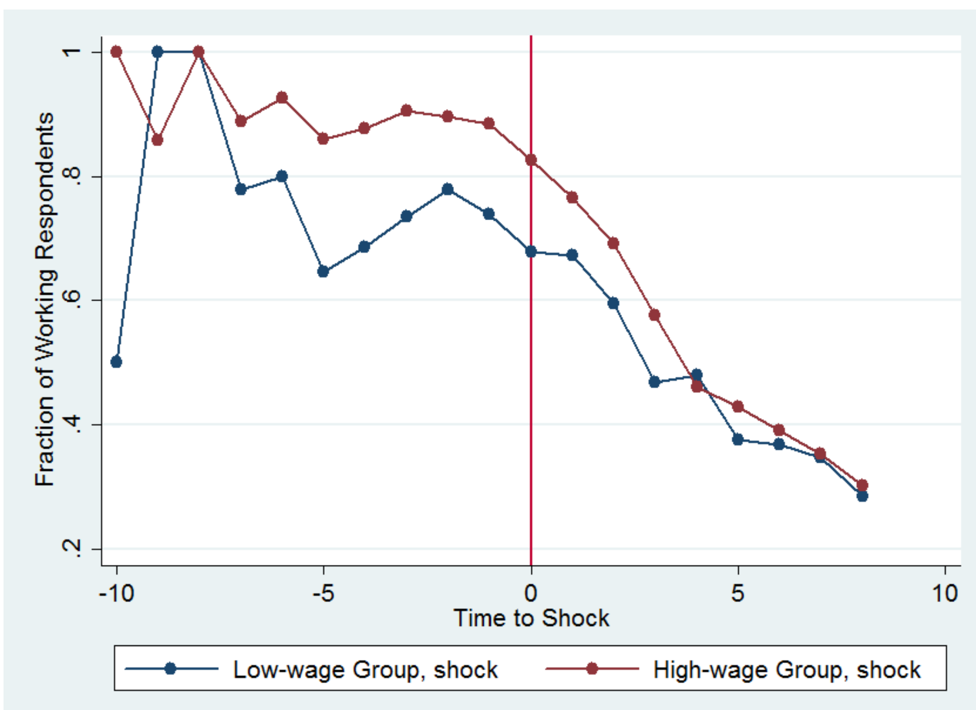

Figure 2.3. Fraction of Respondents Working: Shocked, by wage

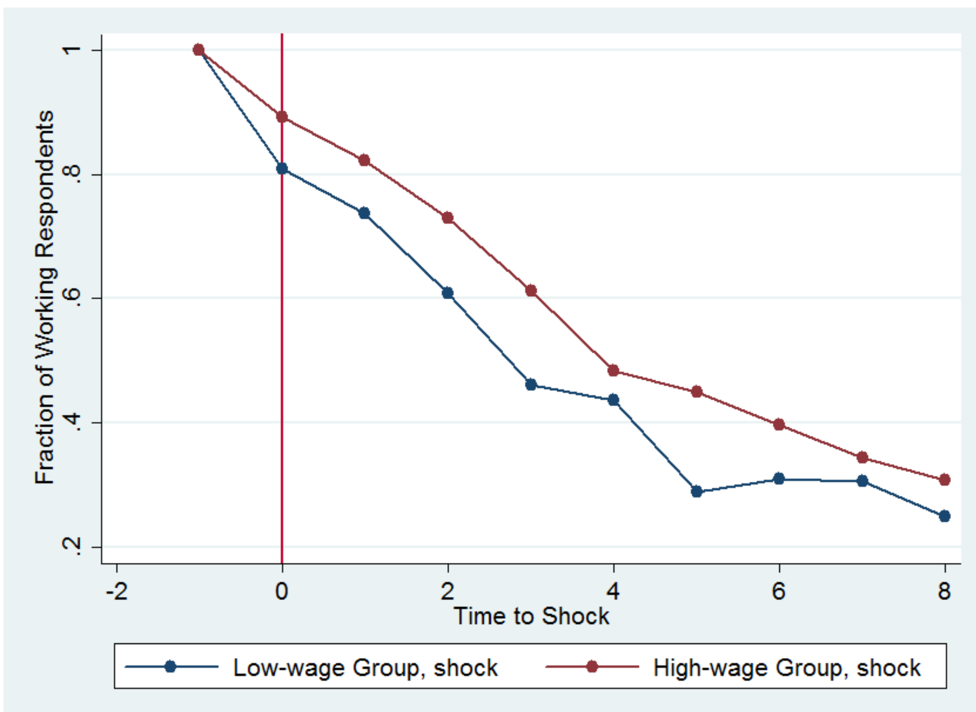

Figure 2.4. Fraction of Respondents Working: Shocked, Conditional on working

Table 2.2. Regression Results for High-wage Group

	(5)	(6)	(7)
Working	Linear Probability Model	Logit	Logit Marginal Effect
lag(working)	0.33***	1.43***	0.32***
	(0.01)	(0.07)	(0.02)
health status	-0.04***	-0.35***	-0.08***
	(0.01)	(0.06)	(0.01)
shock	0.05**	0.33	0.08
	(0.03)	(0.24)	(0.17)
lag(shock)	0.07***	0.41*	0.10*
	(0.03)	(0.22)	(0.06)
lag2(shock)	0.03	0.23	0.06
	(0.03)	(0.23)	(0.06)
before retirement	0.19***	1.81***	0.42***
	(0.01)	(0.15)	(0.03)
after retirement	-0.12***	-1.19***	-0.29***
	(0.01)	(0.12)	(0.03)
Person-level fixed effect	Yes	Yes	
Observations	10,418	6,680	6,680
Number of people	1,843	969	969

Standard errors in parentheses
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 2.3. Regression Results for Low-wage Group

Working	(8) Linear Probability Model	(9) Logit	(10) Logit Marginal Effect
lag(working)	0.28***	1.31***	0.26***
	(0.01)	(0.08)	(0.03)
health status	-0.06***	-0.46***	-0.09***
	(0.01)	(0.05)	(0.01)
shock	-0.00	0.04	0.01
	(0.03)	(0.27)	(0.06)
lag(shock)	0.04	0.41	0.09
	(0.03)	(0.26)	(0.06)
lag2(shock)	-0.00	0.19	0.04
	(0.03)	(0.27)	(0.06)
before retirement	0.18***	1.35***	0.30***
	(0.02)	(0.13)	(0.04)
after retirement	-0.13***	-1.19***	-0.25***
	(0.01)	(0.13)	(0.03)
Person-level fixed effect	Yes	Yes	
Observations	7,648	5,197	5,197
R-squared	0.19		
Number of people	1,425	829	829

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

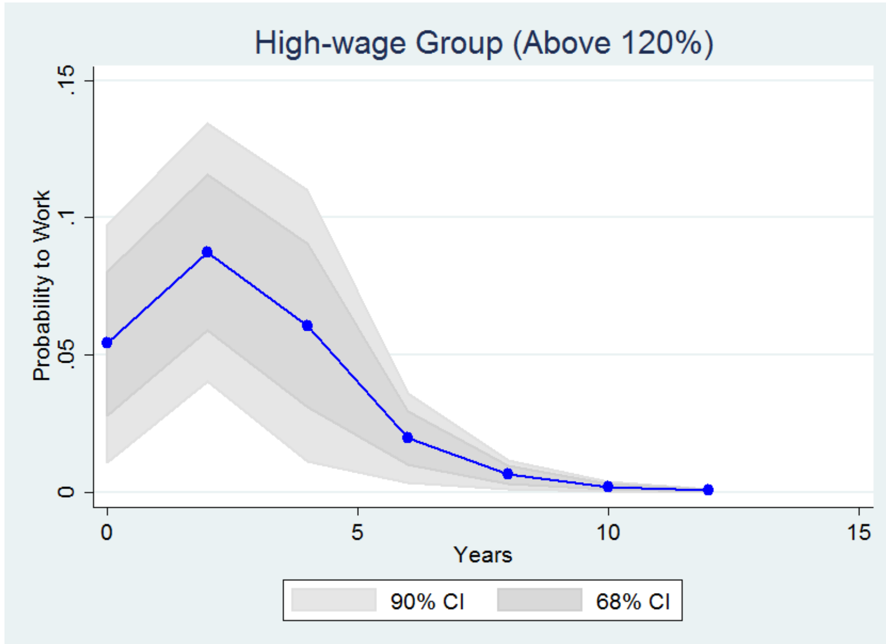

Figure 2.5. Impulse Response Curves of Current Working Status

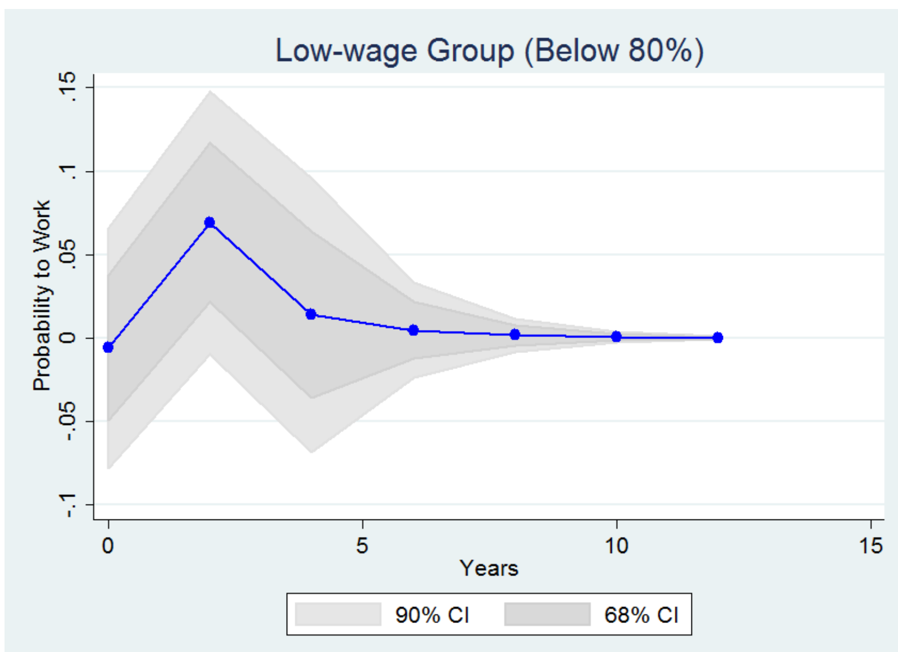

Figure 2.6. Impulse Response Curves of Current Working Status

Table 2.4. Robustness Check: Arellano-Bond and IV

	(11)	(12)	(13)	(14)	(15)	(16)
Working	Arellano-Bond		IV + FE			
lag(working)	0.59***	0.62***	0.28***	0.33***	0.15***	0.26**
	(0.02)	(0.02)	(0.01)	(0.01)	(0.06)	(0.04)
health status	-0.05***	-0.03***	-0.06***	-0.04***	-0.06***	-0.04***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
shock	0.02	0.06	-0.00	0.05**	-0.02	0.06*
	(0.05)	(0.04)	(0.03)	(0.03)	(0.04)	(0.03)
lag(shock)	0.09*	0.10***	0.04	0.07***	0.04	0.10***
	(0.05)	(0.03)	(0.03)	(0.03)	(0.04)	(0.03)
lag2(shock)	0.03	0.06*	-0.00	0.03	0.02	0.05*
	(0.05)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)
before retirement	0.07***	0.13***	0.18***	0.19***	0.18***	0.20***
	(0.02)	(0.02)	(0.02)	(0.01)	(0.02)	(0.02)
after retirement	-0.08***	-0.07***	-0.13***	-0.12***	-0.15***	-0.13***
	(0.02)	(0.02)	(0.01)	(0.01)	(0.02)	(0.02)
Constant	0.32***	0.27***	0.56***	0.53***	0.60***	0.55***
	(0.03)	(0.03)	(0.02)	(0.02)	(0.04)	(0.04)
Person-level FE	Yes	Yes	Yes	Yes	Yes	Yes
IV of lag(working)			L2-L	L2-L	L3-L2	L3-L2
Samples	Low-wage	High-wage	Low-wage	High-wage	Low-wage	High-wage
Observations	6,172	8,513	7,646	10,418	6,171	8,513
Number of people	1,317	1,739	1,425	1,843	1,317	1,739

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

Chapter 3

The General Equilibrium of Female Labor Market

3.1 Introduction

An aging population presents various challenges for the society and the households in it, and one of them is how to cope with the increasing demand for elder care. In the previous two chapters, I discuss how this affects household decisions, especially female labor supply. I now focus the analysis on an aggregate level and discuss what my finding means for an aging society.

A large literature discusses the impact of providing care on caregivers, and the aggregation of these negative effects always looks worrisome in an aging population. However, it is not the complete picture because non-caregivers are not considered. This chapter extends on the theoretical framework from Chapter 1 and further explores the connection between parental care and labor supply in household decisions. I use an overlapping generation model to show the general equilibrium effect of increasing parental care responsibilities. OLG frameworks are usually used to study the general equilibrium effects of intergenerational transfers, though the execution varies significantly.

While many papers discuss the role of goods transfer and bequest, far fewer discuss time transfer. As a result, we do not quite agree on the most effective way to model time transfer and it is incorporated into the models based on its assumed role in the context of the questions asked. In some papers, the transfer of time is modeled as the input for home production, from which the recipient of the transfer yields utility. For example, Cardia and Michel (2004) use a two-period OLG model to compare how altruism affects the transfer of goods and the transfer of time. Cardia and Ng (2003) evaluate the effectiveness of time and goods transfers to children by using a three-period (to include grandparent-generation) OLG model. Time transfer is also modeled as an input for health production in models featuring longevity uncertainty to study the aggregate effect on social welfare and economic growth (Mizushima, 2009; Tabata, 2005). Fahle (2015) aims at comparing the implications of different long-term care programs and policies, so time transfer takes effect in health production, care production and at the same time, is a part of the care constraint for the household.

In the setting of my model, to emphasize the role of the market, I purposefully downplay the role of altruism and model care responsibilities that only affect binding constraints and do not play a part in anyone's utility. To focus on the young generation and their labor supply decisions, I minimize the role of the old generation. There is a positive probability that a parental health shock is realized for the young households and it would require them to meet the care requirements. This is similar to the setting from De Donder and Leroux (2015) and Pestieau and Sato (2008), where the old generation has a positive probability of being the dependent of the young generation. The economy has two production sectors: consumption goods and care. I allow the agents to supply labor in either sector and let general equilibrium clearing conditions determine price and output levels.

To discipline the model, I draw data from the Health and Retirement Survey and American Community Surveys. I calibrate the model to match the moments in the female labor market, as well as the response to parental health shock estimated in Chapter 2.

The model is able to generate similar responses observed the empirical analysis, which suggests that it is helpful in understanding how parental care responsibilities affects the female labor market. I then conduct a quantitative experiment where I solve the model under the census projected population structure in 2060 and predict how labor supply will respond to an aging population under this framework.

3.2 The Model Economy

I now describe a model economy that allows me to analyze household decisions in an general equilibrium setting. While in general, I follow Becker (1965) to think about time allocation, however, just as the static model, I opt to model elderly care as binding constraints for the household, as opposed to an altruistic component in the utility function. In other words, instead of modeling elderly care as an intergenerational transfer of time or money, I am treating it as a tightening of the time and budget constraints. In this way, household decisions are driven more by market factors such as prices and wages. [1]

I simplify the traditional OLG framework in two major ways so that the model focuses on the general equilibrium of female labor market. First, I treat the investment and capital market as exogenous. While the young generation still saves, savings is invested into a storage technology that pays an exogenous return when the generation is old. Second, I assume that all males are homogeneous in their time use decisions. In this way, all responses and effects are directed towards females, who are associated more closely to care taking, either as daughters or daughters-in-law.

3.2.1 The Household Problem

Each generation lives for two periods: the young generation works, saves, and meets the care requirements from the old generation, and the old generation only con-

[1] Fahle (2015) also used a similar approach to study policy effects on long-term care.

sumes. The agents in the old generation have a positive probability of having a health shock, and if the shock is realized, these old agents require financial and time inputs from the young generation, as in the static model. The care requirements are modeled as binding constraints for the young generation, so the old generation's demand for care is always satisfied. The old generation takes utility in consumption only, and for generation t at time $t+1$, the old's problem is:

$$\begin{aligned} max\ u_{t+1} &= max\ ln(c_{t+1}) \\ \text{s.t.} \quad c_{t+1} &\leq (1+r)s_t \end{aligned}$$

where s_t is savings from when the household was young and r is an exogenous interest rate. Note that this is the old's utility function regardless of their health status. So when there is a parental health shock, it only affects the young. There is no channel for bequests, so:

$$c_{t+1} = (1+r)s_t \tag{3.1}$$

For the young generation, each household has two agents, a male(m) and a female(f). The male corresponds to the primary earner in the static model and the female the secondary earner. Each agent is endowed with 3 units of time that they allocate among work, producing care at home or leisure. For work, an agent can choose to either work to produce consumption goods(c) or to produce care (x).

For simplicity, I assume that in all households, males work full time and do not provide any care, $n_m = 1$ and $h_m = 0$, which implies that all males also have the same leisure, $l_m = 2$ and household utility in male leisure can be omitted. A young household takes utility in joint household consumption and female leisure. With the present value of old-age utility, for generation t at time t, the maximized lifetime utility is:

$$
\begin{aligned}
&\max \quad u_t + \beta E(u_{t+1}) \\
\text{or} \quad &\max \quad ln(c_t) + \nu ln(l_f) + \beta E(u_{t+1})
\end{aligned}
$$

where c_t is joint household consumption, and l_f is female's leisure time. The parameter ν measures the appreciation for female leisure, and $\nu > 0$. Since time allocations are fixed for males by assumption, the only relevant time constraint is for the one for females:

$$h_f + n_f + l_f = 3$$

There is no bequest from the old and the total income of a young household is the wage earnings from the two agents. Each young agent receives an exogenous ability draw, e_c, that determines his or her efficiency units of labor when working to produce consumption goods. Let w_c be the wage per efficiency unit of labor in the goods sector. Then for individual i with ability $e_{i,c}$, his or her wage when producing consumption goods is:

$$w_i = w_c e_{i,c}$$

Meanwhile, a female also receives an exogenous draw for her care ability, e_x, that reflects how effective she is as a caregiver in the market. So for a female with care ability $e_{j,x}$, her wage when producing care in the market is:

$$w_j = w_x e_{j,x}$$

where w_x is wage per efficiency unit of market care that is paid to the care workers. Note that both w_c and w_x are an exogenous price for the households and are determined in the markets by the production technologies and profit maximization conditions. A male's wage is always his wage in the consumption good sector by assumption, and a female compares her potential wages to decide which sector to work in. For a female j

with abilities $(e_{j,c}, e_{j,x})$, she has potential wages:

$$w_{j,c} = w_c e_{j,c}$$

$$w_{j,x} = w_x e_{j,x}$$

When j is deciding how much time to supply to work, she considers as wage as $w_j = max(w_{j,c}, w_{j,x})$ and she works in the care sector if and only if $w_{j,x} > w_{j,c}$. For a household with wages w_m and w_f, the household budget constraint is:

$$w_m n_m + w_f n_f = c_t + p_x h_s + M(\eta) + M_n + s_t$$

where s_t is savings. The terms for care-related expenses, $p_x h_s$ and $M(\eta)$, are the same as in the static model, where h_s is the amount of market care the household decides to purchase (a choice variable) and $M(\eta)$ is a lump-sum medical cost depending on the old's health status η. I will discuss how h_s is determined in the next section. The price of consumption goods is normalized to 1.

After choosing which sector to work, a female chooses how much to work, $0 \leq n_f \leq 1$. I assume a fixed cost M_n for the female to work and

$$M_n = \bar{M} \mathbb{1}\{n_j > 0\}$$

So as long as a female works, regardless of which sector and how much she chooses to work, a fixed cost $\bar{M}$ will occur as an expense to the household. This fixed cost raises the threshold for females to participate in the labor market, especially for ones with a low-wage.

3.2.2 Home and Market Productions

There are two formal production sectors in the model, one for consumption goods(c) and one for market care(x). A household cannot produce consumption goods at home, but can supply time to produce care. In the static model, both market care and home care are final goods and they are perfect substitutes. This leads to corner solutions where the households would use either market care or home care to meet all of the care demand. In this model, to allow a more realistic process for care production, I assume that home care and market care are intermediate goods, and the technology of care production is CES. The care constraint in a household is:

$$[h_f^{\theta} + \alpha h_s^{\theta}]^{1/\theta} \geq H(\eta),\ 0 < \theta < 1$$

where h_s is purchased care time from the market, and h_f is care time supplied by the female in the household. If the parents of the household are healthy, $H(\eta) = 0$; otherwise, $H(\eta) = \bar{H}$. The elasticity of substitution between home care and market care is $\varepsilon = 1/(1-\theta)$. The parameter α can be interpreted as the effectiveness of market care. Assume $\alpha > 1$, so market care is more effective than home care than meeting the demand for care. For example, a care worker could take care of multiple individuals simultaneously. When a care worker watches over 5 patients for an hour, each patient receives one hour of care but pays for a fifth of the care worker's hourly wage. Meanwhile, being in the formal sector, a care worker could complete certain tasks using less time compared to when providing care at home. Note that females are only heterogeneous in providing care when they work formally in the care sector. So when providing care at home, all females have the same productivity, 1.

For simplicity, I assume that labor is the only input in the production of both goods and care sectors. So the production technology for the consumption goods market is

$$Y_c = A_c N_c$$

where A_c is the total factor productivity in the goods sector, and N_c is the the labor input, measured in efficiency units of labor in goods production. Recall that the price of output in the goods sector is normalized to 1. Then the profit for a representative firm in the goods sector is

$$\pi_c = A_c N_c - w_c N_c$$

where w_c is wage per efficiency unit of labor in the goods sector. Thus

$$w_c = A_c$$

Labor is also the only input in the care sector, and the total output of the care sector is the total labor input, measured by efficiency units of labor in care:

$$Y_x = N_x$$

This output Y_x corresponds to the intermediate care h_s in the CES care production function. A representative firm in the care sector has the following profit function:

$$\pi_x = p_x N_x - w_x N_x$$

So the profit maximizing wage per efficiency unit of care is

$$w_x = p_x$$

Recall that in the static model, the supply side of market care is not present.

In this model, market care is not only more effective (reflected in α), but can be less expensive to produce: for a female with high e_x where $e_x > 1$, 1 unit of time produces 1 unit of h_s at home but e_x unit of care in the formal sector.

3.2.3 Clearing the Markets

Let $F_{t,y}$ be the set of all young households at time t. The output from the goods sector satisfies the demand for consumption and saving for the young:

$$Y_c = \sum_{F_{t,y}} (c_t^t + s_t^t)$$

Note that the sum is over all young households because although the old consumes in time t, their savings s_{t-1} gives them $(1+r)s_{t-1}$ from an exogenous storage technology. Similarly, at the end of time t, generation t takes out s_t of their goods production and put it in the storage, which will give $(1+r)s_t$ unit of consumption goods in time $t+1$ for generation t's old age consumption.

The market clearing condition of the care sector is given by:

$$Y_x = \sum_{F_{t,y}} h_s$$

Since labor is the only input in both production sectors, the labor markets in these sectors clear automatically when the goods and care markets clear. Given a set of wages and prices, young households choose the utility maximizing allocations of labor supply and care supply, and determine household consumption level and the amount of care to purchase. The wage of the goods sector ($w_c = A_c$) is exogenous. There is a market clearing price w_x such that the care sector clears. Note that household optimal labor and care allocations are driven by $\frac{w_m}{w_f}$ and $\frac{w_f}{p_x}$, the same relative prices in the static model. Let $\bar{\rho}$ be the probability that a household receives a parental health shock.

Then in aggregate, $\bar{\rho}$ fraction of the total households, and to have the shock uniformly applied to all households, $\bar{\rho}$ fraction of the households with a certain relative prices $(\frac{w_m}{w_f}, \frac{w_f}{p_x})$, maximize their utility with a set of higher medical and care time requirements. I then aggregate over all household decisions by the household weight and solve for the market-clearing price of care, p_x*.

3.2.4 The Household's Decision: To Hire or To Care?

In the static model, the hire or care decisions are a clear-cut: either hire or care. This decision is now more complicated with the CES care production. From the first order conditions of the household problem for the young generation, I derive the optimal ratio of h_f and h_s for a household:

$$r_{fs} \equiv \frac{h_f}{h_s} = \alpha^{\frac{1}{\theta-1}} (\frac{w_f}{p_x})^{\frac{1}{\theta-1}} \tag{3.2}$$

Given care constraint $H(\eta)$:

So r_{fs} depends on α, θ and the relative price ratio $\frac{w_f}{p_x}$. Take the partial derivative of r_{fs} with regard to α and w_f respectively:

$$(\alpha) \quad \frac{\partial r_{fs}}{\partial \alpha} = \frac{1}{\theta - 1} \alpha^{\frac{\theta}{\theta-1}} (\frac{w_f}{p_x})^{\frac{1}{\theta-1}} \leq 0 \tag{3.3}$$

$$(\frac{w_f}{p_x}) \quad \frac{\partial r_{fs}}{\partial w_f / p_x} = \frac{1}{\theta - 1} \alpha^{\frac{1}{\theta-1}} (\frac{w_f}{p_x})^{\frac{\theta}{\theta-1}} \leq 0 \tag{3.4}$$

Since $0 < \theta < 1$, $\frac{1}{\theta-1} < 0$, and both partials are smaller than 0. This is intuitive because as α increases (market care is more effective), or when a female has a higher wage, the household will put more weight on market care when optimizing. When θ is bigger (approaches 1), home care and market care are closer to perfect substitutes, the closer the implications of this model is to the static model. The optimal amount of h_s to purchase is given by:

$$h_s = [r_{fs}^{\theta} + \alpha]^{-1/\theta} H(\eta) \tag{3.5}$$

Recall that in the predictions of the static model, with the parental health shock, the high-wage females always work more, but the response of the low-wage females depends on which constraint is affected more. When home care and market care are perfect substitutes in producing care time, the effects of the parental health shock can be separated clearly - the medical care expense affects the budget constraint and the care time requirement affects only the time constraint, unless the household decides to purchase care instead of providing home care. Furthermore, for any household that decides to purchase care, the secondary earner (or female) has a relatively high wage. In other words, for the low-wage females in the static model, the care time requirement only affects their time constraint. In this model, however, an increase in $H(\eta)$ would increase both h_f and h_s, and while h_f affects the time constraint, purchasing more h_s affects the budget constraint. As $\frac{w_f}{p_x} \to 0$, $r_{fs} \to \infty$, so the lower the female's wage, the more predominant home care is for the household. Yet as long as $w_f > 0$ and $H(\eta) > 0$, from 3.5, $h_s > 0$ and h_s is increasing in $H(\eta)$. As a result, even a female with the lowest possible wage needs to spend more on purchasing care, in addition to providing more care.

This implication is slightly different from the static model in Chapter 1. If I ignore the general equilibrium effect of changes in prices and wages, we should observe that when there is a parental health shock, it is more likely that low-wage females will increase labor supply. The magnitudes of the responses depend on the combination of increases in $M(\eta)$ and $H(\eta)$. If the increase in $M(\eta)$ is significant, then low-wage females respond more because their wages are low and to compensate for the same amount of loss in income, they need to supply a lot more labor. If the increase in $H(\eta)$ is significant, then high-wage females respond more because they use a high ratio of market care and would spend more on purchasing care. In general, we should still observe heterogeneity in females' responses to parental health shock in the setting of this model.

I present the details of the solutions to the model in Appendix A.3.

3.3 Parameterization

I draw data from the 2007 American Community Surveys[2] and the Health and Retirement Survey(1992-2012) to calibrate the model. In the Health and Retirement Survey, 10% of households experienced a parental health shock at some point during their surveyed time, so the probability of receiving a parental health shock for the young household is set to 10 %. This shock is applied uniformly across the population in the simulated economy.

Given the theory is that the main driving force of household decisions are the relative prices ($\frac{w_m}{w_f}, \frac{w_f}{p_x}$), it is essential that in my simulated economy, full representation of households of different sets of relative prices (especially $\frac{w_m}{w_f}$), I generate the young households by a female ability distribution and an intra-household ability ratio distribution. I use female wage and intra-household wage ratios from the 2007 ACS to estimate the distribution parameters. I limit my samples to observations that reported weeks worked last year, usual hours worked per week. I calculate hourly wage from income and the estimated total hours worked in the last year (weeks worked times usual hours worked). I drop all observations working in military specific occupations and any observations with self-employment or sources of income outside salary income.

Out of all prime-aged (25-54) females surveyed, 64.42% reported to be working.

[2]After 2007, weeks worked are reported as intervals, which would seriously affect my estimation of total hours worked. The 2007 ACS is weighted and since all estimates are on population aggregates, personal weights and household weights are taken into consideration.

I define care workers as people working in the following three occupations:

(1) Nursing, Psychiatric, and Home Health Aides (ACS Occupation Code 3600),

(2) Personal and home care aides (ACS Occupation Code 4610), and

(3) Personal Care and Service Workers, All Other (ACS Occupation Code 4650).

By this definition, 3.32% of all prime-aged females are care workers in 2007 ACS, with a mean hourly wage of \$11.6. The mean hourly wage of all other working females is \$20.7, which to the care/goods wage ratio, 0.56.

The log normal distribution of female efficiency unit of labor in the consumption goods market is estimated from the hourly wage distribution of prime-aged non-care female workers. The mean and the standard deviation of the corresponding normal distribution are 1 (normalized) and 0.29. The log normal distribution of female efficiency unit in care is estimated from the hourly wage distribution of prime-aged female care workers. The mean and the standard deviation of the corresponding normal distribution are 0 (normalized[3]) and 0.2.

To estimate the intra-household male to female wage ratio, I take ratio of hourly wages for all married couples over age 22 in the 2007 ACS. The distribution is log normal and the mean and the standard deviation of the corresponding normal distribution are 0.29 and 0.85. For each household, the draws from female goods production ability and intra-household ability ratios are independent, and male goods production ability is calculated as the product of the two draws.

For the value of θ, I take the empirically estimated value from Rupert et al. (1995) that reflects the elasticity of substitution between market and home production consumption of married couples. The estimations in Rupert et al. (1995) provide a range

[3]it is normalized to 0 so that the mean of the log normal distribution is 1, so that on average, a female that works in the care sector has the same productivity as a female that provides care at home.

from 0.363 to 0.75 for the value of θ, and I use the upper bound value because in the context of my model, home and market production should be relative good substitutes.

I use the remaining five parameters to jointly match five moments in data and my empirical estimation in Chapter 2. The five parameters I use are: 1) the utility weight of female leisure time, ν, 2) the effectiveness of market care, α, 3) the fixed cost to work, $\bar{M}$, and 4 and 5) medical expense requirement and care time requirement when there is parental health shock, $M(\eta)$ and $H(\eta)$. For the five moments, the first three are calculated from the 2007 ASC: 1) female labor force participation rate, 2) wage ratio of care and non-care female workers, and 3) percentage of female working in the care sector, and the last two are from the empirical estimates in Chapter 2: 4) labor force participation response from high-wage females and 5) labor force participation response from low-wage females.

All parameter values are summarized in Table 3.1.

3.4 Results

3.4.1 Matching the Moments

Under a general equilibrium setting, the targeted moments are informative about the parameters in both direct and indirect ways. Labor force participation largely pins down values for ν and $\bar{M}$. It also has information on the size of $M(\eta)$ and $H(\eta)$. Care section size and wage ratio are informative about α and $H(\eta)$. Since $M(\eta)$ and $H(\eta)$ always go as a pair when there is a parental health shock, care sector size also indirectly sets the relative size of $M(\eta)$ and $H(\eta)$. By the wage percentile in the HRS data, high-wage females are above 59th percentile and low-wage females are below 33th percentile. This is the definition I use when calculating the responses from the model. I calculate the labor force participation rate of the females in the wage range, and the difference between females with a parental health shock and females without the shock is the magnitude of the response from the group. The high-wage and low-wage responses mostly guide the values of $M(\eta)$ and $H(\eta)$, and since household decisions are made based on all the parameters, they are informative about the other three parameters as well. The values of the moments and the corresponding values produced in the model are reported in Table 3.2. In general, the targeted moments are matched well with the set of parameters in Table 3.1. The shock responses resemble the empirical findings.

3.4.2 Discussion

One major assumption I make to simplify the model is that all males work full time in the goods sector and they do not provide care. This assumption seems to be strong but it does not interfere much with the goal of the model. Females are overwhelmingly more likely to provide informal care compared to males. Moreover, the main driving force of the decision mechanism in this model is the balancing between market care and home care, in other words, leisure and consumption. Male's wage income is an large part of the budget constraint. Meanwhile, in the quantitative exercises, I allow male wage heterogeneity through female wage heterogeneity and intra-household wage ratios, which actually gives the male in the household a significant role to play in the background in determining female labor supply. The relative wage, $\frac{w_m}{w_f}$, matters in the same way as the static model. In the extreme case where w_m is high enough, even a high-wage female might choose to not work because leisure has much higher marginal utility for the household. So though the males are not directly involved in providing care or make any endogenous decisions, they have a crucial effect on the female labor market under the framework of this model.

Home production is an important feature in models that analyze intergenerational transfers, and production and wage processes are usually designed to best represent the mechanism of the model. For example, Doepke et al. (2015) study fertility decisions, so wages are determined with a human capital accumulation process. Cardia and Ng (2003) focus on quantifying the role of time transfers over multiple generations, so the production functions are calibrated to match the household-level data in time and resource allocations of home and market goods. In my model, the general equilibrium effect is generated by the heterogeneity in households' responses to care responsibilities, so wages are relevant as opportunity costs and their distributions, especially the variances, are the fundamental drives in the model. I avoid the discussion of wage and human capital accumulation processes by limiting agent's lifespan to two periods. Meanwhile, I use the observed wage variances in the data to discipline the ability draws to make sure that generated households resemble the data in terms of wage differences. One potential issue is that there is a selection problem with the observed wage data - wage is not observable when a person does not work. In the context of my model, it would be a concern if the generated distribution has a unusually fat tail due to the unobserved lower tail. If this were true, the population would respond sharply to a small increase in the marginal wage. The responses of labor force participation in aggregate and in different wage groups are relatively modest, which suggests that the selection bias is not a serious concern in this case.

In general, the model matches the data well. In Table 3.2, I report the point estimates and the 90% confidence intervals of the peak shock responses estimated from HRS. The shock responses from the high-wage and low-wage groups are comparable to the estimate from the empirical analysis both in direction and in magnitude. The response of the high-wage females is much bigger than the low-wage females. This shows that the model and the market care channel proposed in the model have a reasonable representation of how female labor supply decisions are made.

3.4.3 Quantitative Prediction

The model is calibrated to the female labor supply and the care market in 2007. To explore the implication of this framework on an aging population, I use this model, including the preference parameters and the distributions of efficiency units of labor, to predict the changes to the labor market under an aged population structure. Consider people aged 18-64 as working population (the young generation) and above 65 as elderly (the old generation). In 2007, for each elderly, there are 5.2 working-age people. According to the census population projection, by 2060, for each elderly, there will be 2.4 working-age people. This means that elderly care burden will go up by 115%. This increase in elderly care burden can be broken down into two components in the setting of my model: an increase in the time commitment a household needs to meet when it receives the parental health shock, $H(\eta)$, and an increase in the probability of receiving the shock across the population (currently at 10%). According to the Current Population Survey (1970-2014), the mothers of baby boomers had 3 children on average whereas the baby boomers had 2 (Graph 3.1). As a result, the children of baby boomers will have on average 1 fewer sibling to share parental care responsibilities with. This can be interpreted as a 50% increase in $H(\eta)$. Then the probability of parental health shock increase by (1+115%)/(1+50%)-1 = 43%.

The calibrated model is the steady state under the current population structure. The quantitative experiment moves the model economy one generation forward, when the young generation (the baby boomers) becomes the old, and the new young generation (the children of the baby boomers) faces the increased parental care responsibilities estimated above. The solutions from the next generation in the experiment are shown in Table 3.3. The prediction shows that female labor supply increases in aggregate by nearly 2% and the responses to the shock increases for both high-wage and low-wage groups.

The responses of the households follow the same pattern as the baseline model - now as the care responsibilities increase, the magnitude of the responses also increases. The general equilibrium effect shows up mostly in the care sector. The employment share of the care sector shows that the care sector would expand by more than 50%, and care wage decreases by more than 10%. This is the result of two forces that drives the care sector. On the demand side, since more households need to purchase market care and purchase more per household, the care sector expands and the care wage goes up. On the supply side, as the low-wage females whose care wage is higher than goods wage now need to work more to pay for the required medical expanse, the care sector expands further and care wage goes down. In case case, the supply side effect dominates the demand side. The care sector expands more than the proportion increase in care responsibilities. As a result, care wage decreases.

There is some limitation to this quantitative experiment. For a two-generation OLG model, the actual number of years that one time period corresponds to is hard to gauge. By life expectancy, each time period would correspond to 35 to 40 years. By the year distance between one generation to the next, each time period would correspond to 20-25 years. So while a two-generation model is the simplest and most intuitive setting, the predictive power is limited because one period forward leap over too many years, which makes the care responsibility dramatically different from one generation to the next. While the magnitude of the changes could be exaggerated by the compression of time in the model, the results still provide us with valuable insights on the trend of parental care and female labor supply.

First, with the presence of a complete care market, the increase in care responsibilities will likely increase female labor supply on the aggregate level. This does not contradict the findings in the caregiving literature. Most studies reviewed by Lilly et al. (2007) show that the negative effect on labor supply is mostly found with informal intense care providers. From both empirical analysis and theoretical simulations, I show that the negative effect of informal caregivers is offset by the positive effect of a much larger portion of the population who work more to purchase market care or pay for medical expense associated with the parental care responsibilities. Second, it is worthwhile to consider the heterogeneity in females' responses to the care responsibilities because they have different general equilibrium implications. According to the simulation and the experiment with the model, while both high-wage and low-wage females respond to parental care responsibilities by working more, the high-wage work more in the goods sector to purchase care and the low-wage work more in the care sector to finance medical expense. Since the households struggle around different things, it is important for policy makers to identify the needs of the targeted group. For example, for low-wage females, monetary subsidies that help cover medical bills are likely to be more useful than providing them with community care options. On the other hand, a care-related tax credit would not have a significant effect as it would be only a small amount for the low-wage females. Meanwhile, for the high-wage females, the tighter constraint is the time constraint, so a better market care option, e.g. inexpensive and high-quality adult and retirement homes, would have a larger impact.

Table 3.1. Parameters

Parameters	Values
β: discount rate	0.96
Shock probability	10%
n_i: male (fixed) labor supply	1
Mean log(female goods ability)	1
Std dev log(female goods ability)	0.29
Mean log(male/female ability ratio)	0.29
Std dev log(male/female ability ratio)	0.85
Mean log(female care ability)	0
Std dev log(female care ability)	0.2
A_c: goods sector TFP	1
Calibration Parameters	
ν: female leisure utility weight	2.2
α: market care effectiveness	18
$M(\eta)$: Medical expense requirement	0.05
H_η: Care time requirement	1.5
$\bar{M}$: fixed cost to work	0.15

Table 3.2. Moments

Moments	Model	Data
Female labor force participation rate	64.17%	64.42%
Goods/Care worker wage ratio	0.563	0.56
Care sector size	3.34%	3.32%
High-wage shock response	4.07%	7.68%, CI 3.83% - 11.53%
Low-wage shock response	1.19%	6.24%, CI -2.22% - 14.73%

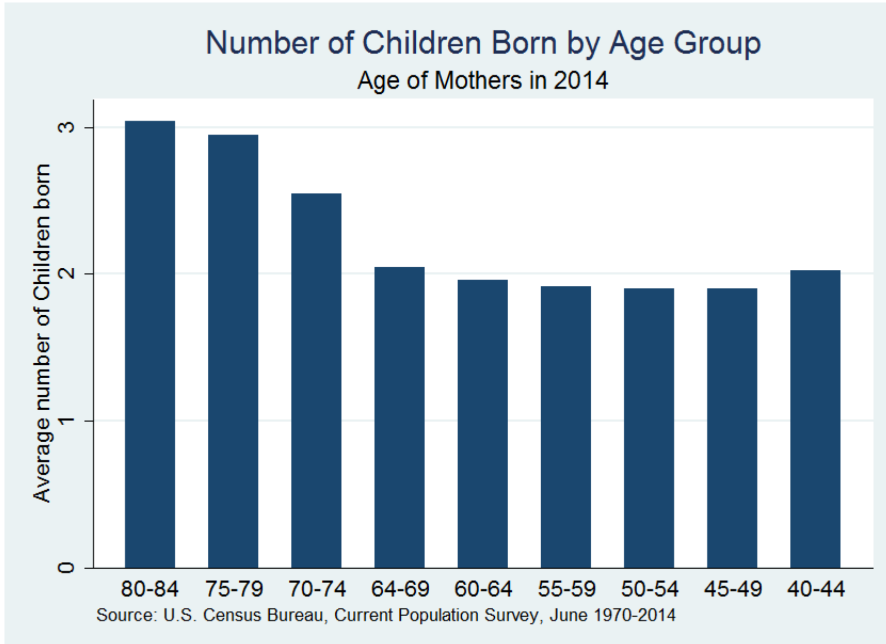

Figure 3.1. Fertility Trend

Table 3.3. Quantitative Experiment

	Current	Experiment	Changes (in %)
Parameters			
Shock Probability	0.1	0.143	+43%
$H(\eta)$: Care time requirement	1.5	2.25	+50%
$M(\eta)$: Medical expense requirement	0.05	0.075	+50%
Moments			
Female labor force participation rate	64.17%	65.28 %	+1.73%
Goods/Care worker wage ratio	0.56	0.49	-12.5%
Care sector size	3.32%	5.19%	+56.3%
High-wage shock response	4.07%	5.06%	
Low-wage shock response	1.14%	2.21%	

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Appendix A

A.1 Solving the Model

A.1.1 Four Corner Solutions

Recall the maximizing problem is:

$$\max(1-\mu-\nu)ln(c)+\mu ln(l_i)+\nu ln(l_j)$$

over time constraints:

$$l_i+n_i+h_i=1 \qquad l_f+n_j+h_i=1$$

care constraint:

$$h_i+h_j+h_s \geq H(\eta)$$

and budget constraint:

$$c+ph_s+M(\eta)=w_i n_i+w_j n_j$$

Let Lagrange multiplier of budget constraint be λ_1 and care constraint λ_2. First order conditions:

$$(c) \qquad \frac{1-\mu-\nu}{c}=\lambda_1 \tag{A.1}$$

$$(n_i) \qquad \frac{\mu}{1-n_i-h_i} = \lambda_1 w_i \tag{A.2}$$

$$(n_j) \qquad \frac{\nu}{1-n_j-h_j} = \lambda_1 w_j \tag{A.3}$$

$$(h_i) \qquad \frac{\mu}{1-n_i-h_i} = \lambda_2 \tag{A.4}$$

$$(h_j) \qquad \frac{\nu}{1-n_j-h_j} = \lambda_2 \tag{A.5}$$

$$(h_s) \qquad \lambda_1 p = \lambda_2 \tag{A.6}$$

Boundary conditions:

$$c, n_i, n_j, h_i, h_j, h_s \geq 0, \quad n_i, n_j, h_i, h_j \leq 1$$

Now we solve the optimal labor supply allocations and consumption allocation for each scenario.

Case 1: $n_i, n_j \geq 0$, $h_i = h_j = 0$ and $h_s = H(\eta)$

First order conditions A.1,A.2, A.3 and A.6 are valid. Plug them into the household budget constraint:

$$n_i = 1 - \mu[1 + \frac{w_j}{w_i} - \frac{pH(\eta)}{w_i} - \frac{M(\eta)}{w_i}]$$

$$n_j = 1 - \nu[1 + \frac{w_i}{w_j} - \frac{pH(\eta)}{w_j} - \frac{M(\eta)}{w_j}]$$

$$c = (1-\mu-\nu)[w_i + w_j - pH(\eta) - M(\eta)]$$

Let the utility derived by this allocation be U_1.

$$U_1 = (1-\mu-\nu)ln(1-\mu-\nu)[w_i + w_j - pH(\eta) - M(\eta)] + \\ \mu ln\mu[1 + \frac{w_j}{w_i} - \frac{pH(\eta)}{w_i} - \frac{M(\eta)}{w_i}] + \nu ln\nu[1 + \frac{w_i}{w_j} - \frac{pH(\eta)}{w_j} - \frac{M(\eta)}{w_j}]$$

Case 2: $n_i, n_j \geq 0$**,** $h_i = h_s = 0$ **and** $h_j = H(\eta)$

Plug first order conditions A.1,A.2, A.3 and A.5 into the budget constraint:

$$n_i = 1 - \mu[1 + \frac{w_j}{w_i} - \frac{w_j H(\eta)}{w_i} - \frac{M(\eta)}{w_i}]$$

$$n_j = 1 - H(\eta) - \nu[1 - H(\eta) + \frac{w_i}{w_j} - \frac{M(\eta)}{w_j}]$$

$$c = (1-\mu-\nu)[w_i + w_j - H(\eta)w_j - M(\eta)]$$

Let the utility derived by this allocation be U_2.

$$U_2 = (1-\mu-\nu)ln(1-\mu-\nu)[w_i + w_j - w_j H(\eta) - M(\eta)] \\ + \mu ln\mu[1 + \frac{w_j}{w_i} - \frac{w_j H(\eta)}{w_i} - \frac{M(\eta)}{w_i}] + \nu ln\nu[1 - H(\eta) + \frac{w_i}{w_j}) - \frac{M(\eta)}{w_j}]$$

Case 3: $n_i \geq 0$**,** $n_j = 0$**,** $h_i = h_j = 0$ **and** $h_s = H(\eta)$

In this case, household chooses n_i to solve the following optimization problem:

$$(1-\mu-\nu)ln(w_i n_i - H(\eta)p - M(\eta)) + \mu ln(1-n_i) + v ln(1)$$

First-order condition:

$$\frac{(1-\mu-\nu)w_i}{w_i n_i - M(\eta)} = \frac{\mu}{1-n_i}$$

So the optimal allocation is:

$$n_i = 1 - \frac{\mu}{1-\nu}[1 - \frac{pH(\eta)+M(\eta)}{w_i}]$$

Since $n_i \leq 1$, we must have

$$-\frac{\mu}{1-\nu}[1 - \frac{pH(\eta)+M(\eta)}{w_i}] \leq 1$$

$$\Rightarrow \quad \frac{pH(\eta)+M(\eta)}{w_i} < \frac{1}{\mu H(\eta)} + \frac{1}{H(\eta)}$$

This is, h_s and $M(\eta)$ must be affordable enough such that $i's$ wage can afford it without over-working.

$$c = \frac{1-\mu-\nu}{1-\nu}[w_i - pH(\eta) - M(\eta)]$$

Plug in the optimized n_i into the utility function, we have the maximized utility in this case, U_3.

$$\begin{aligned} U_3 =& (1-\mu-\nu)ln(\frac{1-\mu-\nu}{1-\nu})[w_i - pH(\eta) - M(\eta)] \\ &+ \mu ln(\frac{\mu}{1-\nu})[1 - \frac{pH(\eta)+M(\eta)}{w_i}] + \nu ln(1) \end{aligned}$$

Case 4: $n_i \geq 0$**,** $n_j = 0$**,** $h_i = h_s = 0$ **and** $h_j = H(\eta)$

In this case, household chooses n_i to maximize the following:

$$(1-\mu-\nu)ln(w_i n_i - M(\eta)) + \mu ln(1-n_i) + \nu ln(1-H(\eta))$$

First-order condition:

$$\frac{(1-\mu-\nu)w_i}{w_i n_i - M(\eta)} = \frac{\mu}{1-n_i}$$

$$\Rightarrow \quad n_i = 1 - \frac{\mu}{1-\nu}[1 - \frac{M(\eta)}{w_i}]$$

Again, $M(\eta)$ needs to be affordable such that $n_i \leq 1$.

$$c = \frac{1-\mu-\nu}{1-\nu}[w_i - M(\eta)]$$

Let the optimized utility be U_4.

$$U_4 = (1-\mu-\nu)ln\frac{1-\mu-\nu}{1-\nu}[w_i - M(\eta)] + \mu ln\frac{\mu}{1-\nu}[1 - \frac{M(\eta)}{w_i}] + \nu ln(1-H(\eta))$$

A.1.2 Proof of Proposition 1

To proof the Proposition 1, it is sufficient to show that for any set of parameter values η,p,μ and ν:

(1) there exists $\Phi_1(\eta, p, \mu, \nu)$ and $\Psi_1(\eta, p, \mu, \nu)$ such that for $1 < \frac{w_i}{w_j} < \Phi_1$ and $\frac{w_i}{p} > \Psi_1$,

$U_1 = max(U_i, i \in \{1,2,3,4\})$;

(2) there exists $\Phi_2(\eta, p, \mu, \nu)$ and $\Psi_2(\eta, p, \mu, \nu)$such that for $1 < \frac{w_i}{w_j} < \Phi_2$ and $\frac{w_i}{p} < \Psi_2$,
$U_2 = max(U_i, i \in \{1,2,3,4\})$;

(3) there exists $\Phi_3(\eta, p, \mu, \nu)$ and $\Psi_3(\eta, p, \mu, \nu)$ such that for $\frac{w_i}{w_j} > \Phi_3$ and $\frac{w_i}{p} > \Psi_3$,
$U_3 = max(U_i, i \in \{1,2,3,4\})$;

(4) there exists $\Phi_4(\eta, p, \mu, \nu)$ and $\Psi_4(\eta, p, \mu, \nu)$ such that for $\frac{w_i}{w_j} > \Phi_4$ and $\frac{w_i}{p} < \Psi_4$,
$U_4 = max(U_i, i \in \{1,2,3,4\})$.

Rewrite the utility from each scenario:

$$
\begin{aligned}
U_1 &= (1-\mu-\nu)ln(c) + \mu ln(l_i) + \nu ln(l_j) \\
&= ln[c^{(1-\mu-\nu)}(1-n_i)^{\mu}(1-n_j)^{\nu}] \\
&= ln\{(1-\mu-\nu)^{(1-\mu-\nu)}\mu^{\mu}\nu^{\nu}[w_i + w_j - pH(\eta) - M(\eta)](\frac{1}{w_i})^{\mu}(\frac{1}{w_j})^{\nu}\} \\
U_2 &= (1-\mu-\nu)ln(c) + \mu ln(l_i) + \nu ln(l_j) \\
&= ln[c^{(1-\mu-\nu)}(1-n_i)^{\mu}(1-n_j-H(\eta))^{\nu}] \\
&= ln\{(1-\mu-\nu)^{(1-\mu-\nu)}\mu^{\mu}\nu^{\nu}[w_i + w_j - w_jH(\eta) - M(\eta)](\frac{1}{w_i})^{\mu}(\frac{1}{w_j})^{\nu}\} \\
U_3 &= (1-\mu-\nu)ln(c) + \mu ln(l_i) + \nu ln(l_j) \\
&= ln[c^{(1-\mu-\nu)}(1-n_i)^{\mu}(1)^{\nu}] \\
&= ln\{(\frac{1-\mu-\nu}{1-\nu})^{(1-\mu-\nu)}(\frac{\mu}{1-\nu})^{\mu}\nu^{\nu}[w_i - pH(\eta) - M(\eta)](\frac{1}{w_i})^{\mu}\} \\
U_4 &= (1-\mu-\nu)ln(c) + \mu ln(l_i) + \nu ln(l_j) \\
&= ln[c^{(1-\mu-\nu)}(1-n_i)^{\mu}(1-H(\eta))^{\nu}] \\
&= ln\{(\frac{1-\mu-\nu}{1-\nu})^{(1-\mu-\nu)}(\frac{\mu}{1-\nu})^{\mu}(1-H(\eta))^{\nu}[w_i - M(\eta)](\frac{1}{w_i})^{\mu}\}
\end{aligned}
$$

There exists $w^*_{i,(1,1)}$, $w^*_{i,(2,2)}$,$w^*_{j,(1,1)}$,$w^*_{j,(2,2)}$ such that when $w_i < w^*_{i,(1,1)}$ and $w_j <$

$w^*_{j,(1,1)}$, $n_j > 0$ in scenario 1; when $w_i > w^*_{i,(2,2)}$ and $w_j < w^*_{j,(2,2)}$, $n_j > 0$ in scenario 2. This ensures that the boundary conditions hold. Note that for the same parameter values, n_j is always smaller in scenario 2. When the boundary condition does not hold in scenario 2 but hold in scenario, or $w^*_{j,(1,1)} > w_j > w^*_{j,(2,2)}$, $U_1 > U_2$ by default. So for $U_1 > U_2$, since natural log is monotonically increasing in its domain, a necessary condition is $w_j > min(p, w^*_{j,(2,2)})$.

The condition for $U_1 > U_3$:

$$(1+\frac{w_j}{w_i - pH(\eta) - M(\eta)})(\frac{w_j}{w_i - pH(\eta) - M(\eta)})^{-\nu} > \frac{1}{\nu^\nu(1-\nu)^{1-\nu}} \tag{A.7}$$

Since $0 < \nu < 1$, $-1 < -\nu < 0$. The LHS is increasing in w_j and decreasing in w_i. For all values of p and η, there exists $w^*_{i(1,3)}(\eta, p, \nu)$ and $w^*_{j(1,3)}(\eta, p, \nu)$ such that when $w_i < w^*_{i(1,3)}$ and $w_j > w^*_{j(1,3)}$, (A.7) holds.

The condition for $U_1 > U_4$:

$$(1+\frac{w_j}{w_i - pH(\eta) - M(\eta)})(\frac{w_j}{w_i - pH(\eta) - M(\eta)})^{-\nu} > \frac{(1-H(\eta))^\nu}{\nu^\nu(1-\nu)^{1-\nu}} \tag{A.8}$$

For all values of p and η, there exists $w^*_{i(1,4)}(\eta, p, \nu)$ and $w^*_{j(1,4)}(\eta, p, \nu)$ such that when $w_i < w^*_{i(1,4)}$ and $w_j > w^*_{j(1,4)}$, (A.8) holds.

The condition for $U_2 > U_3$:

$$(1+\frac{(1-H(\eta))w_j + pH(\eta)}{w_i - pH(\eta) - M(\eta)})(\frac{w_j}{w_i - pH(\eta) - M(\eta)})^{-\nu} > \frac{1}{\nu^\nu(1-\nu)^{1-\nu}} \tag{A.9}$$

For all values of p and η, there exists $w^*_{i(2,3)}(\eta, p, \nu)$ and $w^*_{j(2,3)}(\eta, p, \nu)$ such that when $w_i < w^*_{i(2,3)}$ and $w_j > w^*_{j(2,3)}$, (A.9) holds.

The condition for $U_2 > U4$ is

$$(1+\frac{(1-H(\eta))w_j}{w_i - M(\eta)})(\frac{w_j}{w_i - M(\eta)})^{-\nu} > \frac{(1-H(\eta))^{\nu}}{\nu^{\nu}(1-\nu)^{1-\nu}} \tag{A.10}$$

For all values of η, there exists $w^*_{i(2,4)}(\eta,\nu)$ and $w^*_{j(2,4)}(\eta,\nu)$ such that when $w_i < w^*_{i(2,4)}$ and $w_j > w^*_{j(2,4)}$, (A.10) holds.

The condition for $U_3 > U_4$ is

$$(1-\frac{pH(\eta)}{w_i - M(\eta)})^{1-\nu} > (1-H(\eta))^{\nu} \tag{A.11}$$

For all values of p and η, there exists $w^*_{i,(3,4)}(\eta,p,\nu)$ such that when $w_i > w^*_{i(3,4)}$, (A.11) holds. To prove Proposition 1(1), let $w^*_{i,1} = min(w^*_{i(1,3)}, w^*_{i(1,4)})$, and $w^*_{j,1} = max(w^*_{j(1,3)}, w^*_{j(1,4)})$. For $w_i < w^*_{i,1}$ and $w_j > w^*_{j,1}$, $U_1 > U_3$ and $U_1 > U_4$ hold. Define $\Phi_1 = \frac{w^*_{i,1}}{w^*_{j,1}}$. Then for $1 < \frac{w_i}{w_j} < \Phi_1$, $U_1 > U_3$ and $U_1 > U_4$. Let $\Psi_1 = \frac{min(p,w^*_{j,(2,2)}}{p}$. Then when $\frac{w_j}{p} > \Psi_1$, $w_j > min(p, w^*_{j,(2,2)}$, $U_1 > U_2$. So U_1 yields the highest utility, $U_1 = max(U_i, i \in \{1,2,3,4\})$. The proof of the rest of Proposition 1 follows the same logic.

Proposition 1(2): Let $w^*_{i,2} = min(w^*_{i(2,3)}, w^*_{i(2,4)})$, $w^*_{j,2} = max(w^*_{j(2,3)}, w^*_{j(2,4)})$, and define $\Phi_2 = \frac{w^*_{i,2}}{w^*_{j,2}}$. Then for $1 < \frac{w_i}{w_j} < \Phi_2$, $U_2 > U_3$ and $U_2 > U_4$. Let, $\Psi_1 = \frac{min(p,w^*_{j,(2,2)}}{p}$. When $\frac{w_j}{p} < \Psi_2$, $w_j < min(p, w^*_{j,(2,2)}$, so $U_2 > U_1$, then $U_2 = max(U_i, i \in \{1,2,3,4\})$.

Proposition 1(3): Let $w^*_{i,3} = max(w^*_{i(1,3)}, w^*_{i(2,3)})$, and $w^*_{j,3} = min(w^*_{j(1,3)}, w^*_{j(2,3)})$. For $w_i > w^*_{i,3}$ and $w_j < w^*_{j,3}$, $U_3 > U_1$ and $U_3 > U_2$ hold. Define $\Phi_3 = \frac{w^*_{i,3}}{w^*_{j,3}}$. Then for $\frac{w_i}{w_j} > \Phi_3$, $U_1 > U_3$ and $U_1 > U_4$. Let $\Psi_3 = \frac{w^*_{i(3,4)}}{p}$. Then when $\frac{w_i}{p} > \Psi_3$, $w_i > w^*_{i(3,4)}$, $U_3 > U_4$, and $U_3 = max(U_i, i \in \{1,2,3,4\})$.

Proposition 1(4): Let $w^*_{i,4} = max(w^*_{i(1,4)}, w^*_{i(2,4)})$ and $w^*_{j,4} = min(w^*_{j(1,4)}, w^*_{j(2,4)})$. For $w_i > w^*_{i,4}$ and $w_j < w^*_{j,4}$, $U_4 > U_1$ and $U_4 > U_2$ hold. Define $\Phi_4 = \frac{w^*_{i,4}}{w^*_{j,4}}$. Then for

$\frac{w_i}{w_j} > \Phi_4$, $U_4 > U_1$ and $U_4 > U_2$. Let $\Psi_4 = \frac{w^*_{i(3,4)}}{p}$. Then when $\frac{w_i}{p} < \Psi_4$, $w_i < w^*_{i(3,4)}$, $U_4 > U_3$, and $U_4 = max(U_i, i \in \{1,2,3,4\})$.

A.1.3 Proof of Proposition 2

To proof the effect on the extensive margin, (1) and (2):

Let $Q(\eta)$ be the LHS of (A.7) and V be the RHS. For all $(w_i, w_j, p) \in E(1, \eta_0)$, it must be true that $Q(\eta_0) > V$. Then $Q(\eta_1) > Q(\eta_0) > V$, $(w_i, w_j, p) \in E(1, \eta_1)$. So $E(1, \eta_0) \in E(1, \eta_1)$.

Let $(w_i, w_j, p) \in E(3, \eta_0)$ be a set of values such that $Q(\eta_0) = Q(\eta_0) - \varepsilon < V$, for some arbitrarily small ε. Since $M(\eta)$ is increasing in η, $Q(\eta)$ is increasing in η. There must exist an arbitrarily large $\eta_1 > \eta_0$ such that $Q(\eta_1) > Q(\eta_0) + \varepsilon$. Then $Q(\eta_1) > V$, so $(w_i, w_j, p) \in E(1, \eta_1)$, and $(w_i, w_j, p) \bigcup E(1, \eta_0) \in E(1, \eta_1)$.

To proof the effect on the intensive margin, (3):

Since $\frac{w_j}{p}$, $U_1 > U_2$. From Proposition 2(1) and (2), for $\eta_1 > \eta_0$, $E(1, \eta_0) \subset E(1, \eta_1)$. For all secondary earners in households in $(1, \eta_1)$ but not $E(1, \eta_0)$, they increase their labor supply by starting to participate in the labor force. That is $n_j(\eta_0) = 0$ and $n_j(\eta_1) > 0$, so $n_j(\eta_1) > n_j(\eta_0)$. For secondary earners in households in $E(1, \eta_0)$, note that for scenario 1,

$$n_j = 1 - \nu[1 + \frac{w_i}{w_j} - \frac{pH(\eta)}{w_j} - \frac{M(\eta)}{w_j}]$$

Note that n_j is increasing in η, so $n_j(\eta_1) > n_j(\eta_0)$.

A.2 Robustness Check

I perform a series of robustness check exercises to show that pattern that high-wage females delay retirement in response to parents' health shocks are robust to the classification of high-wage and low-wage.

If I consider high-wage females as those that earn more than 150% of reference wage and low-wage females as those that earn less than 70%, The result is robust. The impulse response curves are shown in Figures A.1 and A.2.

Figures A.3, A.4, A.5 and A.6 show the response of respondents at different wage percentile at time period 0, 1, 2 and 3 after the shock. Respondents that earns exactly the reference wage are at 45th percentile. 80% of reference wage is at 33th percentile and 120% of reference wage is at 59th percentile. Because the sample sizes are smaller, there are more noises and the confidence intervals are a lot larger. Still, the responses are positive for respondents at higher wage percentiles.

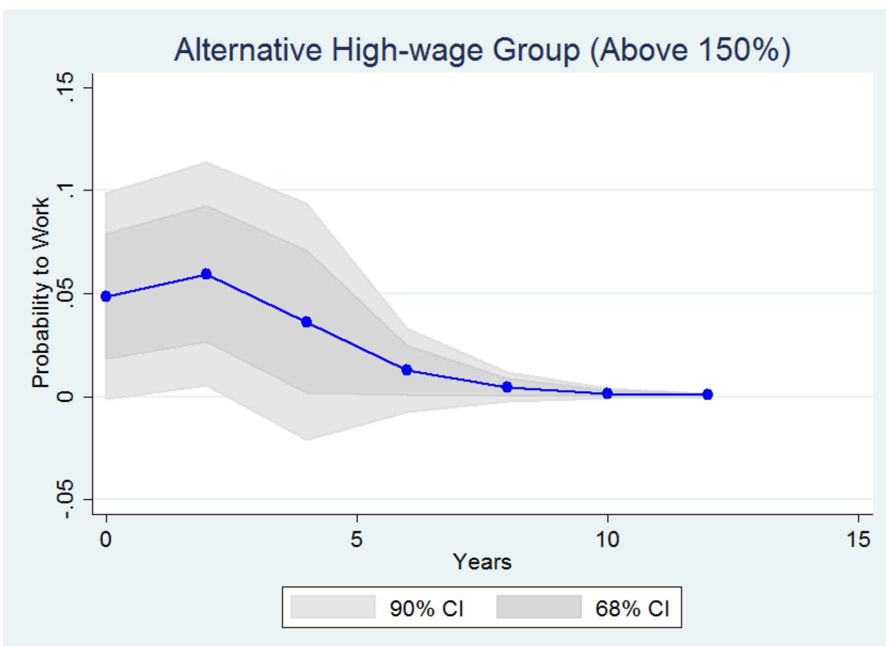

Figure A.1. Impulse Response Curves of Current Working Status

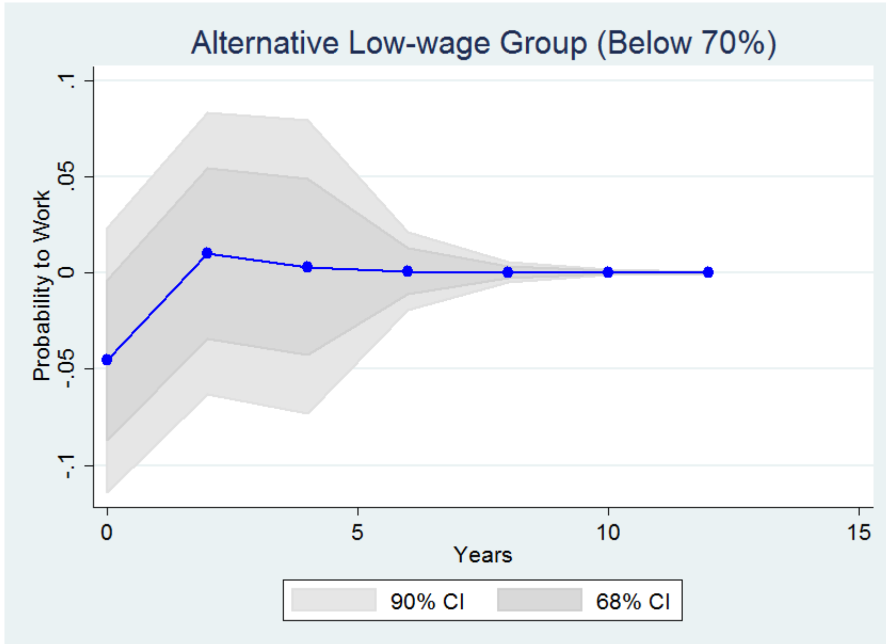

Figure A.2. Impulse Response Curves of Current Working Status

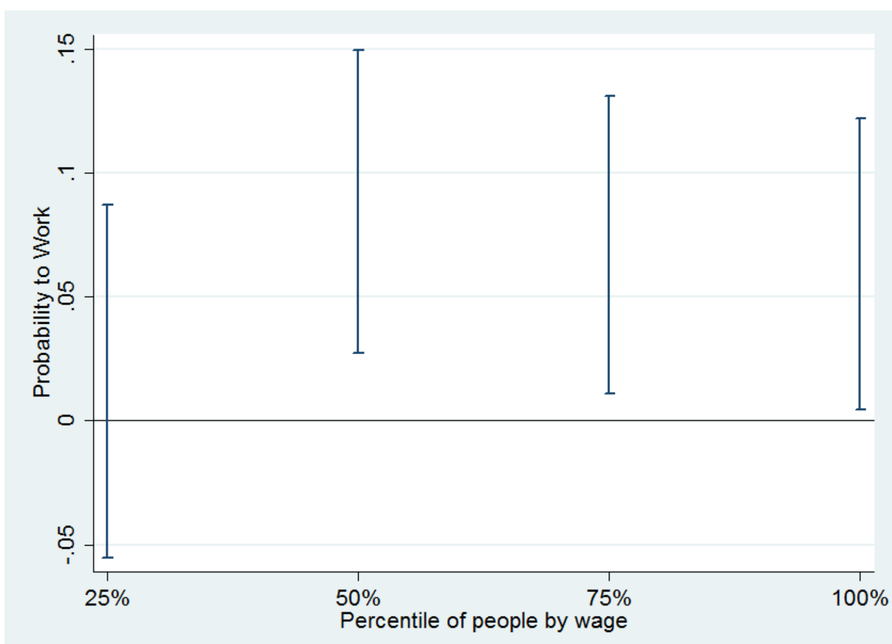

Figure A.3. Response at Period 0 (Year 0)

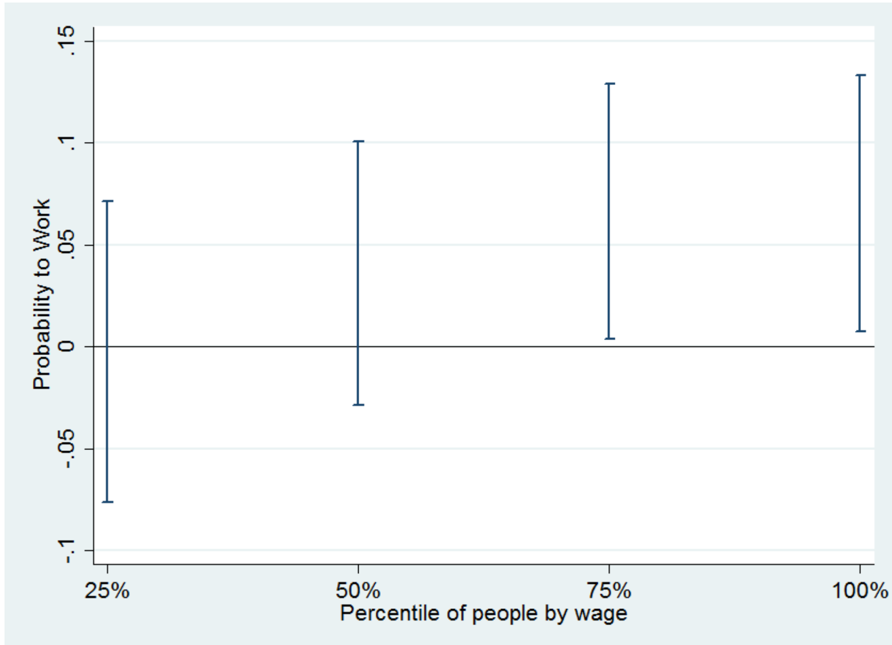

Figure A.4. Response at Period 1 (Year 2)

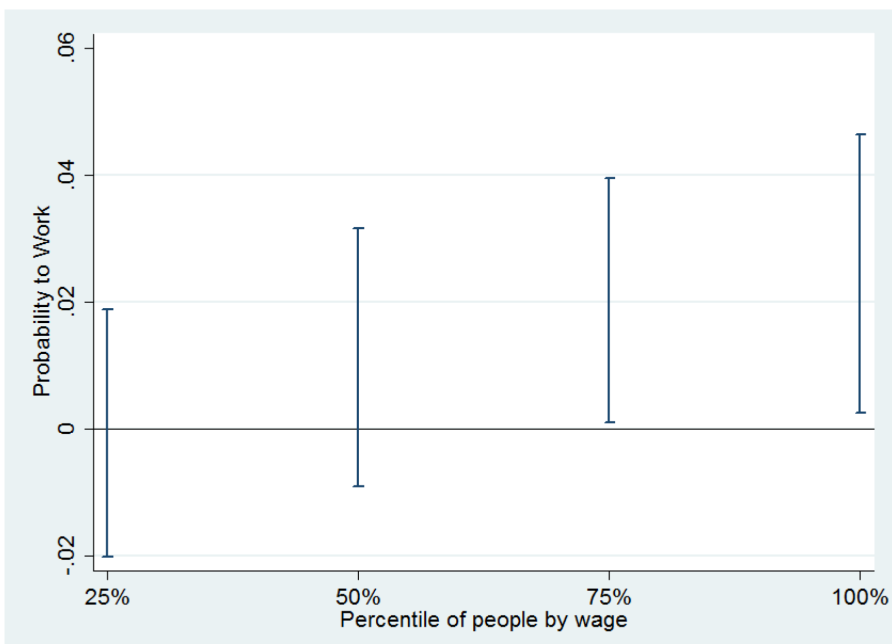

Figure A.5. Response at Period 2 (Year 4)

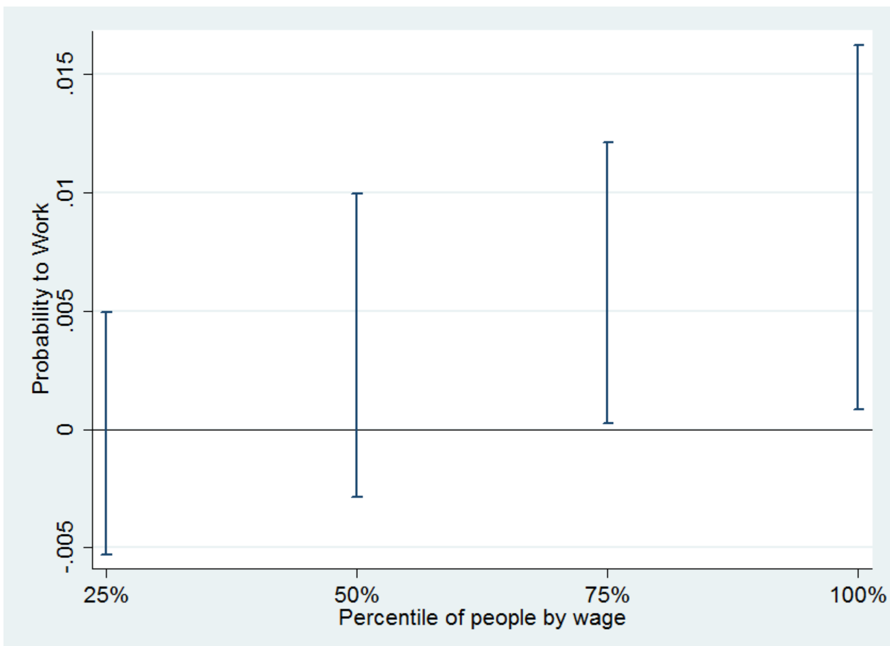

Figure A.6. Response at Period 3 (Year 6)

A.3 Solving the OLG Model

The population is generated with the three ability distributions: female goods ability, intra-household ability ratio and female care ability. Let the draws of a representative household be $(e_{c,f}, r_{mf}, e_x)$. To find the market clearing q_x*, I iterate with a vector of possible q_x values around a potential solution. For each q_x, households calculate their wages:

$$w_{c,f} = A_c e_{c,f} \tag{A.12}$$

$$w_{x,f} = q_x e_x \tag{A.13}$$

$$w_m = A_c e_{c,f} r_{mf} \tag{A.14}$$

Note that for all the wages, households use the profit-maximizing per efficiency unit wages to calculate their own wages. For A.12 and A.14, the wage per unit efficiency unit of labor is normalized to 1. For A.13, the wage q_x is in iteration. For this household, the female will choose to work in the sector that yields the higher wage:

$$w_f = max(w_{c,f}, w_{x,f}) \tag{A.15}$$

In general equilibrium, when $q_x > q_x*$, more people work in the care sector yet fewer people demand care services, so the market would not clear, and vice versa for $q_x < q_x*$. From iterating through possible values of q_x, the model finds a q_x* where the care market clears.

Suppose households with wages (w_f, w_m) has weight k in the economy, then ρk

have the parental health shock and the rest $(1-\rho)k$ have no care responsibilities. In this way, the shock is applied uniformly across households with all wages. Each household has to solve its household problem described in the main text:

$$\begin{aligned}
\max \quad & ln(c_t)+\nu ln(l_f)+\beta E(u_{t+1}) \\
\text{s.t.} \quad & h_f+n_f+l_f=3 \\
& [h_f^\theta+\alpha h_s^\theta]^{1/\theta}\geq H(\eta) \\
& w_m n_m+w_f n_f=c_t+p_x h_s+M(\eta)+M_n+s_t
\end{aligned}$$

The choice variables are c_t, n_f, h_f, h_s, and c_{t+1}. The only binding boundary is for the choice variable, n_f. First, I will solve the interior solution where $0<n_j<1$. All first-order conditions are valid:

$$(c_t) \qquad \frac{1}{c_t}=\lambda_1 \tag{A.16}$$

$$(n_f) \qquad \frac{\nu}{3-n_f-h_f}=\lambda_1 w_f \tag{A.17}$$

$$(h_f) \qquad \frac{\nu}{3-n_f-h_f}=\lambda_2 h_j^{\theta-1}[h_f^\theta+\alpha h_s^\theta]^{1/\theta-1} \tag{A.18}$$

$$(h_s) \qquad \lambda_1 p_x=\lambda_2\alpha h_s^{\theta-1}[h_f^\theta+\alpha h_s^\theta]^{1/\theta-1} \tag{A.19}$$

$$(c_{t+1}) \qquad \frac{\beta}{c_{t+1}}=\frac{\lambda_1}{1+r} \tag{A.20}$$

From (A.16) and (A.20)

$$c_{t+1}=\beta(1+r)c_t$$

from (A.17) and (A.18):

$$\lambda_1 w_f = \lambda_2 h_f^{\theta-1}[h_f^\theta + \alpha h_s^\theta]^{1/\theta-1} \tag{A.21}$$

Combine (A.21) and (A.19):

$$\frac{w_f}{p_x} = (\frac{1}{\alpha})(\frac{h_f}{h_s})^{\theta-1} \tag{A.22}$$

$$\frac{h_f}{h_s} = \alpha^{\frac{1}{\theta-1}}(\frac{w_f}{p_x})^{\frac{1}{\theta-1}} \equiv r_{js} \tag{A.23}$$

Given $H(\eta)$, the ratio in (A.23) solves h_f and h_s for each household:

$$h_s = [r_{fs}^\theta + \alpha]^{-1/\theta} H(\eta)$$

Since for a household, all prices and care responsibilities are exogenous, the above ratio and the allocations of h_s and h_f can be solved without solving for consumption or labor supply, and are part of the household's solution regardless of the solution of labor supply. From (A.16) and (A.17), I solve for the interior solution of female labor supply:

$$(n_f) \qquad \frac{\nu}{3 - n_f - h_f} = \frac{w_f}{c_t} \tag{A.24}$$

That is:

$$n_f = 3 - h_f - \nu \frac{c_t}{w_f} \tag{A.25}$$

Combine A.3 with the budget constraint to solve for c_t:

$$c_t = [w_m n_m + 3w_f - w_f h_f - p_x h_s - \bar{M}]/(1 + \beta + \nu) \tag{A.26}$$

Plug A.26 back into to solve for n_f:

$$n_f = 3 - h_f - \frac{\nu}{1+\beta+\nu}[\frac{w_m}{w_f} + 3 - h_f - \frac{p_x}{w_f}h_s - \bar{M}] \tag{A.27}$$

The above n_f and c_t are the interior solution.

When $n_f = 0$, the female does not work, and $M_n = 0$ in the budget constraint. So:

$$c_t = [w_m n_m - p_x h_s]/(1+\beta+\nu)$$

When $n_f = 1$, the female work full time, and

$$c_t = [w_m n_m + w_f - p_x h_s - \bar{M}]/(1+\beta+\nu)$$

For the final solution of a household, I calculate the utility levels of the boundary solutions(at $n_f = 0$ and $n_f = 1$) and the interior solution, and the optimal solution is the one that yields the highest utility.