# How Important Is Health Inequality for Lifetime Earnings Inequality?*

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**Abstract**

Health and earnings are positively correlated and this is for several reasons. First, individuals who are in poor health are significantly less likely to work than healthy individuals. Second, conditional on working, individuals in poor health work fewer hours on average. Third, individuals in poor health earn lower wages on average. We document these facts using an objective measure of health called a frailty index which we construct for PSID respondents. The frailty index measures the fraction of observable health deficits an individual has. In previous work, we documented that health, as measured by the frailty index, deteriorates more rapidly and has a larger increase in dispersion with age than self-reported health. It is also more persistent over the life-cycle. These facts put together suggest that health inequality over the life cycle may be an important driver of lifetime earnings inequality. To assess this claim we develop a model of the joint dynamics of health and earnings over the life cycle. Individuals in the model face health, earnings and unemployment risk, and optimally choose labor supply on both the intensive and extensive margin. Agents are partially insured against these risks through government-run unemployment and disability insurance programs. We give agents in the model a dynamic process for frailty (health) that is estimated using the PSID data. Because of selection concerns, agents' productivity processes, including the contribution of frailty to productivity, are estimated using the model and a method of moments estimation. Targeted moments are constructed off distributions of wages, hours, and participation by frailty and age. These distributions are obtained from an auxiliary simulation model that is estimated using PSID data. We find that health inequality can account for a significant share of the variation in lifetime earnings among 70 year-olds. Most of this effect is due to the fact that unhealthy individuals exit the labor force at much younger ages than healthy ones. We find that health inequality has a larger impact on earnings inequality than

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previous literature for two reason. One, our model is the first in this literature that allows health to impact earnings through all three margins: participation, hours, and wages (productivity). Two, previous literature measured health using self-reported health status and thus understated the extent to with health deteriorates with age for some individuals.

**Keywords**: earnings, health, inequality, disability, life-cycle models
**JEL Classification numbers:** D52, D91, E21, H53, I13, I18

# 1 Introduction

Recent studies have shown that health has important implications for many economic variables including asset accumulation, labor supply, and income and wealth inequality.[1] However, despite the importance of health in economic studies, there is no unified objective measure of health status. In this paper we adopt a new objective measure of health status that we introduce in Hosseini et al. (2018), and use it to study the role of health dynamics in shaping lifetime earnings inequality. Using this measure, which we call *frailty index*, we first document three facts about the joint dynamics of health and earnings over the life cycle. First, at each age individuals who are in poor health are significantly less likely to work than healthy individuals. Second, conditional on working, these individuals in poor health work fewer hours. Third, individuals in poor health earn lower wages on average. In previous work, we documented that health, as measured by the frailty index, deteriorates more rapidly and has a larger increase in dispersion with age than self-reported health. It is also more persistent over the life cycle. These facts put together suggest that health inequality over the life cycle may be an important driver of lifetime earnings inequality. Motivated by these observations, we ask how much of the earnings inequality over the life cycle can be accounted for by rise in the health inequality. More specifically, we ask to what extent rapid deterioration of health at the bottom of the health distribution contributes to individuals exit from the labor force (into retirement and or disability).

To this end we build a life cycle general equilibrium model featuring agents who experience heterogeneous and risky *frailty* dynamics over their life cycle as well as earnings and employment risk. Markets are incomplete for health and earnings risks, but there exists a government in the model that runs an unemployment insurance program and a disability insurance program similar to US SSDI. Agents jointly make consumption, savings, and labor supply decisions in each period over the life cycle.

We calibrate the model to the US data, and choose key parameter values to match the joint dynamics of health and earnings that we document here and in Hosseini et al. (2018). We find that our calibrated model is capable of generating the lifetime earnings inequality of 70 year-olds that is observed in the data. We then use the calibrated model to answer the following question: how important is health inequality for lifetime earnings inequality? In particular, how much of the variation in lifetime earnings of 70 year-olds is due the fact that individuals experience heterogeneous health dynamics over their life cycle?

To quantitatively assess the role of health inequality in shaping lifetime earnings inequality, we compute and examine a counterfactual economy in which individuals are assumed to experience the identical health profile over the life cycle. We find that health inequality is able to account for a substantial share of the variation in lifetime earnings among the 70 year-olds. Overall, relative to previous studies that use other health measures of health status, such as self-reported health status (SRHS hereafter), we find that health (frailty index) has a larger impact on labor force participation and earnings. This is largely due to the fact that frailty index is better at capturing evolution of the distribution of health status over life cycle (we discuss this below).

[1] See De Nardi et al. (2017), De Nardi et al. (2010), Kopecky and Koreshkova (2014), Capatina (2015) and Prados (2017) among others.

Frailty index, is simply the accumulated sum of all adverse health events that has occurred to an individual. Our construction is inspired and based on findings in gerontology literature.[2] The idea behind the construction of frailty index is as follows. As individuals age, they accumulate health problems. These health problems can range from symptoms to clinical signs and laboratory abnormalities to diseases and disabilities. These health problems are referred to as *deficits*. Mitnitski et al. (2001) and Mitnitski et al. (2002) have demonstrated that health status can be represented by combing deficits in an index variable, called frailty index. Mitnitski et al. (2005) and Goggins et al. (2005) find that frailty index is comparable between databases even when list of deficits used to construct the index do not coincide. They also find the frailty index to be a better predictor of mortality and institutionalization than age.

In Hosseini et al. (2018) we show that the frailty index is highly correlated with the main existing health measure, self-reported health status, and it has several advantages compared to SRHS. In particular, the frailty index gives a more accurate picture of how an individual's health evolves with age. That is, individuals' health decay at a substantially faster pace over the life cycle when measured by frailty as opposed to SRHS, and in addition health status measured by frailty is more persistent. Based on these findings, we argue that using the frailty index would also allow us to better capture the joint dynamics of health and earnings over the life cycle.

Our paper is closely related to a number of recent studies that uses quantitative life-cycle models to analyze the interactions between health and earnings over the life cycle.[3] For example, Kitao (2014) builds a life-cycle model of individuals who face employment and health risks, and use the model to study the impact of Disability Insurance (DI) policies on employment decisions. Capatina (2015) studies the life-cycle effects of health risks for different education groups, and finds that the effect of health risks is the largest among the non-college group. However, both studies (similar to many other studies in the literature) measure health status using the subjective measure, SRHS, which is known to suffer several limitations (see Hosseini et al. (2018) for a detailed explanation). Relative to SRHS, we argue that our constructed measure of frailty is better at capturing joint dynamics of health status and earnings particularly for middle aged poor and unhealthy individuals. This is an important contributing factor in our findings.

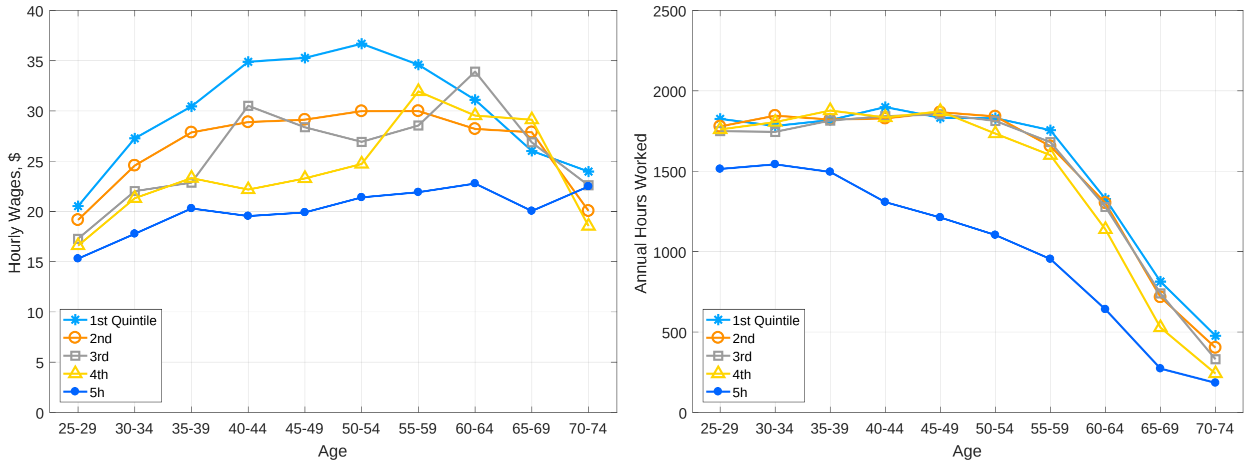
Our paper belongs to the fast-growing broadly-defined literature that studies extended life-cycle models with health and health expenditure.[4] While studies in this literature differ substantially in terms of the question of interest and modeling strategy, they share one common issue, that is, how to measure health. Therefore, we believe that our use of frailty index in this paper is relevant and can be potentially useful for other studies in this literature.

In the remainder of the section we present the key observations from the PSID data on the joint dynamics of health and earnings that motivate our modeling choices and quantitative analysis. We provide detailed description of our data in Section A.

[2]See Searle et al. (2008); Rockwood and Mitnitski (2007); Rockwood et al. (2007); Mitnitski et al. (2001, 2005); Kulminski et al. (2007a,b); Goggins et al. (2005); Woo et al. (2005), and among others.

[3]See Kitao (2014), Capatina (2015), Prados (2017), Michaud and Wiczer (2017), and among others.

[4]See De Nardi et al. (2010), Kopecky and Koreshkova (2014), Suen (2006), Zhao (2014), Ozcan (2013), and among others.




(a) Wage rates by frailty quintile among workers who work at least 260 hours annually and earn at least $3 per hour.

(b) Hours worked by frailty quintile, total sample.

Figure 1: Wage rates by frailty quintiles (left), and hours worked by frailty quintiles (right)

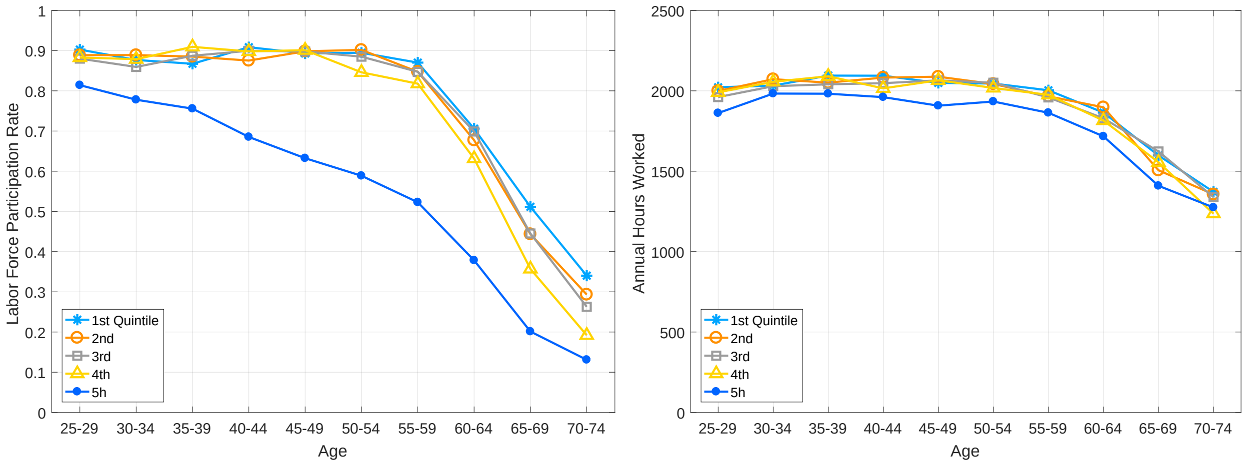
## Labor Productivity

We first examine how frailty and labor productivity jointly evolve by age for working individuals. Here labor productivity is measured by wage rates. Figure 1a presents the average wage rates by frailty quintiles for each age group from age 25-29 to age 70-74. Note that higher frailty index correspond to worse health status. Therefore the first quintile of frailty is the healthiest and the fifth quintile is the unhealthiest. As can be seen, the mean wage rates display a hump shape over the life cycle for the first four frailty quintiles, while the wage profile is relative flat for the fifth one (the most frail quintile). In addition, for any given age group, the wage rates decrease as individual become more frail. The wage gap between different frailty quintiles is relatively small in 20s and 30s, and it becomes larger in 40s. Another interesting feature of the frailty-wage relationship is that the wage gap among the first four frailty quintiles starts shrinking after age 50, while the wage rate of the most frail workers remain substantially lower than the rest of the workers.

## Hours Worked and Labor Force Participation

Frailty also has important implications for labor supply decisions. Figure 1b displays the average hours worked by individuals in each frailty quintiles for each age group over the life cycle. Among the first four quintiles, the average hours worked are similar for age groups until 60. After that, the hours worked start to differ significantly with the more frail individuals work fewer hours. However, for the fifth frailty quintile, the average hours worked are always substantially below those of other four quintiles for the entire life cycle.

Note that the average hours worked per person can be simply decomposed into two components: the average hours worked per worker (intensive margin) and the labor force participation rate (the extensive margin). In Figures 2a and 2b, we examine the relationship between frailty and each of the two components. As can be seen, the relationship between




(a) Participation rate by frailty quintile

(b) Hours worked by frailty quintile for workers

Figure 2: Labor force participation (left) and hours worked for workers (right). We only consider workers who work at least 260 hours annually and earn at least \$3 per hour.

frailty and hours worked is largely driven by the extensive margin. Individuals in the most frail quintile are much less likely to participate into the labor force than the other four quintiles. For instance, for age group 45-49, the labor participation rate is around 90% among the first four frailty quintiles while this rate is only around 60% in the fifth quintile. On the other hand, conditional on working, the impact of frailty on hours worked is much smaller, though still significant.

The remainder of the paper is organized as follows. Section 2 presents the benchmark model. The calibration of the model and the main quantitative findings are presented in Section 3 and 4. Section 5 provides the concluding remarks.

# 2 The Model

## 2.1 Demographics, preferences and technology

Time is desecrate and the economy is populated by continuum of individuals in $J$ overlapping generations. Individuals go through $J$ age groups stochastically, indexed by $j = 1, 2, ..., J$ .The probability of transiting from age $j$ to $j + 1$ is denoted by $\phi_j$. Individuals experience shock to their health status, measured by frailty index $f$. They also face uncertain labor productivity, medical expenditure shock (out of pocket) and mortality risk, all of which depend on their frailty. At each age group the probability of surviving to the next period is denoted by $P(j, f)$. Individuals are ex ante heterogeneous with respect to their education level $s$. There is an age $R < J$, after which individuals can choose to retire. Each period a new cohort is born at rate $n$ and enters the economy.

Individuals derive utility from consumption $c$ and suffer disutility from working hours $l$. The disutility from work depends on age and frailty and is denoted by $\nu(l, j, f)$ with $\nu(0, j, f) = 0$. Everyone has access to a risk-free asset $a$ that pays return $r$. There are no other assets. Before retirement, each individual can be either employed, unemployed or Disability Insurance (DI) beneficiary. Employed workers earn wage $w(j, s, f, \epsilon)$ that depends on age $j$, education $s$, frailty $f$, and a stochastic shock $\epsilon$. The stochastic component $\epsilon$ evolves according to transition probability $\pi^e(\epsilon'|\epsilon, j)$. Employed workers may choose to quit and become unemployed. They may also separate from their job exogenously with probability $\theta_s$.

Unemployed individuals can search for job or apply for DI. If applied, they are awarded DI with probability $\theta_d(j, s, f, I_d)$, where $I_d$ indicates whether they have previously applied. An individual who is awarded DI benefit remains DI beneficiary until he retires. Those who search for job receive a job offer with probability $\theta_e$.

All retires receive social security security benefit which is a function of their past earning histories, $\bar{e}$.

## 2.2 Health status and medical expenditure

Individuals' health status is measured by their frailty index, $f$, which evolves stochastically. An individual at age $j$ who has frailty $f$ will have frailty $f'$ next period with probability $\pi^f(f'|f, j)$. As mentioned before frailty affects wage process, disutility from work, chance of successful DI award, and mortality. Moreover, frailty affects the medical expenditure. An individual of age $j$ and education $s$ who has frailty $f$ experience medical expenditure $m^i(j, s, f)$ for $i = e, u, d, r$ depending on whether he is employed $(e)$, unemployed $(u)$, DI beneficiary $(d)$ or retired $(r)$.

## 2.3 Government

Government makes three distinct transfers to different type of individuals:

- Disability insurance (DI): a DI beneficiary with earning history $\bar{e}$ receives DI benefit $B_d(\bar{e})$.
- Unemployment insurance (UI): an unemployed worker with earning history $\bar{e}$ receives unemployment benefit $B_u(\bar{e})$.
- Social Security (SS): a retired person with earning history $\bar{e}$ receives social security benefit benefit $SS(\bar{e})$.

In addition, government collects the asset of deceased and make lump-sum transfer $tr$ to all individuals who are alive. To finance these transfers government levies a nonlinear tax on labor and capital income $T(wl, ra)$.

## 2.4 Individual decision problems

We now describe the individual decision problem. Let $V^e(j, a, f, s, \epsilon, \bar{e})$ be the value function for employed, $V^u(j, a, f, s, \epsilon, \bar{e}, I_d)$ be value function for unemployed, $V^d(j, a, f, s, \bar{e})$ be value function for DI beneficiary, and $V^r(j, a, f, s, \bar{e})$ be value function for retiree. We start by describing problems facing individuals before they are eligible for retirement, i.e. $j < R$.

**Employed worker with $j < R$:** employed worker who does not have option to retire has two choices; quit or work at current wage. Those who choose to work, face the risk of exogenous separation at the beginning of next period.

$$V^e(j,a,f,s,\epsilon,\bar{e}) = \max\Bigg\{V^u(j,a,f,s,\epsilon,\bar{e},0), \quad \max_{c,l,a'}\{u(c) - \nu(l,j,f) + \tag{1}$$

$$\beta P(j,f) E\left[(1-\theta_s) V^e(j',a',f',s,\epsilon',\bar{e}') + \theta_s V^u(j',a',f',s,\epsilon',\bar{e}',0)\right]\}\Bigg\}$$

subject to

$$\frac{a'}{1+r} + c + m^e(j,f,s) = a + w(j,s,f,\epsilon)\,l - T(w(j,s,f,\epsilon)\,l, ra) + tr, \tag{2}$$

$$\bar{e}' = \frac{(j-1)\,\bar{e} + w(j,s,f,\epsilon)\,l}{j},$$

$$c, a' \geq 0.$$

**Unemployed worker with $j < R$:** unemployed worker receives unemployment benefit and can choose to apply DI or search for job. Those who apply for DI, become DI beneficiary with probability $\theta_d(j,f,s,I_d)$, otherwise they remain unemployed next period. The chance of approval depends on whether they have applied for DI during the current unemployment spell, $I_d$. When a worker becomes unemployed $I_d$ is set to 0. Upon first DI application $I_d$ is set to 1 until the DI is awarded or individual finds a job. Those who search for job, receive an offer with probability $\theta_e$, otherwise they remain unemployed.

$$V^u(j,a,f,s,\epsilon,\bar{e},I_d) = \max\Bigg\{\max_{c,a'} u(c) + \beta P(j,f) E\Big[\theta_d(j,f,s,I_d) V^d(j',a',f',s,\bar{e}) \tag{3}$$

$$+ (1-\theta_d(j,f,s,I_d)) V^u(j',a',f',s,\epsilon',\bar{e},1)\Big], \quad \max_{c,a'} u(c) + \beta P(j,f) E\Big[\theta_e V^e(j',a',f',s,\epsilon',\bar{e}) \tag{4}$$

$$+ (1-\theta_e) V^u(j',a',f',s,\epsilon',\bar{e},I_d)\Big]\Bigg\} \tag{5}$$

subject to

$$\frac{a'}{1+r} + c + m^u(j,f,s) = a + B_u(\bar{e}) + tr - T(0,ra), \tag{6}$$

$$c, a' \geq 0.$$

**DI beneficiary:** DI recipients only make consumption and saving decision.

$$V^d(j,a,f,s,\bar{e}) = \max_{c,a'} u(c) + \beta P(j,f) E\left[V^d(j',a',f',s,\bar{e}')\right] \tag{7}$$

subject to

$$\frac{a'}{1+r} + c + m^d(j,f,s) = a + B_d(\bar{e}) + tr - T(0,ra), \tag{8}$$

$$c, a' \geq 0.$$

When DI enrollees reach retirement age $R$ they automatically move from disability insurance to social security. Thus

$$V^d(R, a, f, s, \bar{e}) = V^r(R, a, f, s, \bar{e}).$$

We define $V^r(j, a, f, s, \bar{e})$ below.

**Employed worker with $j \geq R$:** employed workers who are age-eligible for retirement choose between continuing work or going to retirement. If they choose to work they face the risk of exogenous separation next period (there is no quit option, except for retirement).

$$V^e(j, a, f, s, \epsilon, \bar{e}) = \max \Big\{ V^r(j, a, f, s, \bar{e}), \quad \max_{c,l,a'} u(c) - \nu(l, j, f) + \tag{9}$$

$$\beta P(j, f) E[(1 - \theta_s) V^e(j', a', f', s, \epsilon', \bar{e}') + \theta_s V^u(j', a', f', s, \epsilon', \bar{e}', 0)] \Big\} \tag{10}$$

subject to

$$\frac{a'}{1+r} + c + m^e(j, f, s) = a + w(j, s, f, \epsilon) l - T(w(j, s, f, \epsilon) l, ra) + tr,$$

$$\bar{e}' = \frac{(j-1)\bar{e} + w(j, s, f, \epsilon) l}{j},$$

$$c, a' \geq 0.$$

**Unemployed worker with $j \geq R$:** unemployed workers who are age-eligible for retirement choose between searching for job or retirement (there is no disability option).

$$V^u(j, a, f, s, \epsilon, \bar{e}, 0) = \max \Big\{ V^r(j, a, f, s, \bar{e}), \quad \max_{c,a'} u(c) + \tag{11}$$

$$\beta P(j, f) E[\theta_e V^e(j', a', f', s, \epsilon', \bar{e}) + (1 - \theta_e) V^u(j', a', f', s, \epsilon', \bar{e}, 0)] \Big\} \tag{12}$$

subject to

$$\frac{a'}{1+r} + c + m^u(j, f, s) = a + B_u(\bar{e}) + tr - T(0, ra), \tag{13}$$

$$c, a' \geq 0.$$

**Retired worker:** retired workers only make consumption and saving decision.

$$V^r(j, a, f, s, \bar{e}) = \max_c u(c) + \beta P(j, f) E[V^r(j', a', f', s, \bar{e}')] \tag{14}$$

subject to

$$\frac{a'}{1+r} + c + m^r(j, f, s) = a + SS(\bar{e}) + tr - T(SS(\bar{e}), ra) \tag{15}$$

## 2.5 Recursive competitive equilibrium

Definition of equilibrium goes here.

# 3 Calibration

This section describes our calibration procedure. We calibrate the benchmark model to the U.S. data. In particular, we determine the key parameter values to match the joint dynamic of health and earnings over the life cycle that we documented in Section 1 using the frailty index as the health measure. The rest of our calibration is similar to Kitao (2014) and Michaud and Wiczer (2017).

## 3.1 Demographics

We assume five year age groups with $j = 1$ corresponding to 25 to 30 year olds and $j = 15$ corresponding to 95 to 100 year olds. Retirement period is $j = 9$ (60 to 65 year olds). Aging is stochastic and period is one month. Therefore, individuals move to the next age group with probability $\phi_j = 1/(5 \times 12)$. We estimate 5 year mortality probability at each age group controlling for frailty. We then scale these mortality so that population mortality is consistent with life-table in Bell and Miller (2005). Annual birth rate is $n = 0.01$.

## 3.2 Preference , labor productivity and job search

Individuals have CRRA utility over consumption and constant Frisch elasticity disutility over hours. Moreover, a period at age $j$ who has frailty $f$ suffer an extra disutility from working. Therefore period utility is

$$\frac{c^{1-\sigma}-1}{1-\sigma} - \psi \frac{l^{1+\frac{1}{\varepsilon}}}{1+\frac{1}{\varepsilon}} - \nu(f, j)$$

for workers and

$$\frac{c^{1-\sigma}-1}{1-\sigma}$$

For everyone else.

We set $\sigma = 2$ and $\varepsilon = 0.5$, and choose $\psi$ to match average hours worked by workers. We choose the function $\nu(f, j)$ to match labor force participation by age and frailty. We will estimate the wage process, and will estimate job finding rate and job separation rate from JOLTS and report here.

## 3.3 DI application

We need to specify functional form for $\theta_d(j, f, s, I_d)$, estimate it and report here.

### 3.4 Frailty and medical expenditure

Briefly discuss frailty profile estimation from our other paper and report estimation results.

Describe process for medical expenditure, estimate it and report here.

### 3.5 Policy parameters

For social security and disability insurance benefits we use social security benefit formula for primary insurance amount (PIA) - (we need need to figure out unemployment insurance). The tax function $T(\cdot, \cdot)$ have two component. One is the nonlinear HSV tax function. The other is the FICA payroll tax function (subject to maximum taxable earning cap).

### 3.6 Rental rate and wages

We have two options:

1. Assume general equilibrium by introducing a Cobb-Douglas production function, depreciation rate and corporate tax (drop asset tax in individual problem). Then we can choose TFP parameter to normalize wage (marginal product of labor) to 1. We also choose depreciate rate to match investment rate of 0.2. Finally, we choose $\beta$ to match capital-output ratio.

2. Assume partial equilibrium. In this case we set $r = 0.04$ as after tax return on asset and drop asset taxes. Normalize aggregate wages to 1. Choose $\beta$ to match wealth-income ratio.

## 4 Quantitative Results

## 5 Conclusion

## A Appendix

### A.1 Data

We use 2003–2015 PSID data. The PSID is biennial over this period. We do not use years prior to 2003 because the PSID expanded its disability and health-related questions in 2003 to include questions on specific medical conditions, activities of daily living (ADL's) and instrumental activities of daily living (IADL's) which we rely on to construct individuals' frailty indices. For the base sample, the only restriction is that a person is a household head or the spouse of a household head and at least 25 years of age. A good description of the PSID household head definition is in Heathcote et al. (2010). The base sample consists of 18,548 individuals (8,765 men, 9,784 women; 13,224 household heads, 7,128 spouses).

Table 1 lists the variables we used to construct the frailty index for PSID respondents. The index is constructed by summing the variables in the first column of the table using their values which are assigned according to the rules in the second column. Then dividing this sum by the total number of variables observed for the individual in the year. The construction of this frailty index mostly follows the guidelines laid out in Searle et al. (2008), and uses a set of PSID variables similar to the index created in Yang and Lee (2009).

Table 1: Health Variables used to construct frailty index for PSID respondents

| Variable | Value |
|---|---|
| Some difficulty with ADL/IADLs: | |
| Eating | Yes=1, No=0 |
| Dressing | Yes=1, No=0 |
| Getting in/out of bed or chair | Yes=1, No=0 |
| Using the toilet | Yes=1, No=0 |
| Bathing/showering | Yes=1, No=0 |
| Walking | Yes=1, No=0 |
| Using the telephone | Yes=1, No=0 |
| Managing money | Yes=1, No=0 |
| Shopping for personal items | Yes=1, No=0 |
| Preparing meals | Yes=1, No=0 |
| Heavy housework | Yes=1, No=0 |
| Light housework | Yes=1, No=0 |
| Getting outside | Yes=1, No=0 |
| Ever had one of following conditions: | |
| High Blood Pressure | Yes=1, No=0 |
| Diabetes | Yes=1, No=0 |
| Cancer | Yes=1, No=0 |
| Lung disease | Yes=1, No=0 |
| Heart disease | Yes=1, No=0 |
| Heart attack | Yes=1, No=0 |
| Stroke | Yes=1, No=0 |
| Arthritis | Yes=1, No=0 |
| Asthma | Yes=1, No=0 |
| Loss of memory or mental ability | Yes=1, No=0 |
| Psychological problems | Yes=1, No=0 |
| Other serious, chronic condition | Yes=1, No=0 |
| BMI $\geq 30$ | Yes=1, No=0 |
| Has smoked ever | Yes=1, No=0 |

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