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Delay the Pension Age or Adjust the Pension Benefit? Implications for Labor Supply and Individual Welfare in China*

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Abstract

We develop and calibrate a life-cycle model of labor supply and consumption to quantify the implications of alternative pension reforms on labor supply, individual welfare, and government budget for China's basic old-age insurance program. We focus on urban males and distinguish low-skilled and high-skilled individuals, who differ in their preferences, health and labor income dynamics, and medical expense processes. We use the calibrated model to evaluate three potential pension reforms: (i) increasing the pension eligibility age from 60 to 65, but keeping the current pension benefit rule unchanged; (ii) keeping the pension eligibility age at 60, but proportionally lowering pension benefits so that the pension program's budget is the same as under Reform (i); and (iii) increasing the pension eligibility age to 65 *and* simultaneously increasing the pension benefits so that individuals of both skill types attain the same individual welfare levels as in the status quo. We find that relative to the baseline, both Reforms (i) and (ii) can substantially improve the budgets of the pension system, but at the cost of substantial individual welfare loss for both skill types. In contrast, we find that Reform (iii) can modestly improve the budget of the pension system while ensuring that both skill types are as well off as in the status quo. We find that Reforms (i) and (ii) slightly increases, but Reform (iii) slightly decreases, the overall labor supply.

Keywords: pension reform; labor force participation; welfare; life-cycle behavior; China.

JEL Classification: D14, D15, H55, J22

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1 Introduction

Populations in both developed and developing countries are aging (United Nations, 2019a). This demographic shift places financial pressure on public pension systems that rely on redistribution of incomes from the working-age population to retirees. Therefore, many countries have increased their statutory pension age or are in the process of doing so. For example, the Chinese government has announced plans to gradually increase the pension eligibility age for both men and women who are covered by the basic old-age insurance (BOAI) pension program. However, despite the significance of such planned reforms for millions of individuals, there is only limited formal analysis of the implications of increasing the pension age on the labor supply and individual welfare of the impacted Chinese population.

In this paper we develop and calibrate a life-cycle model of labor supply and consumption to quantify the implications of alternative pension reforms on labor supply, individual welfare, and government budget for the BOAI pension program in China. We focus on the urban males and differentiate between low-skilled and high-skilled individuals as there are large differences in their health dynamics and wages for different skill types in China (Qiu and Zhao, 2019). In our model, low-skilled and high-skilled individuals differ in their preferences, health transition probabilities, labor income processes, and out-of-pocket medical expenses. We calibrate the model parameters using data from the China Health and Retirement Longitudinal Study (CHARLS) and the Chinese Longitudinal Healthy Longevity Survey (CLHLS). We also closely approximate the current pension rules of the BOAI pension program. We use the calibrated model to evaluate the effect of three reform proposals: (i) increasing the pension eligibility age from 60 to 65, but keeping the current pension benefit rule unchanged; (ii) keeping the pension eligibility age at 60, but proportionally lowering pension benefits so that the pension program's budget is the same as under Reform (i); and (iii) increasing the pension eligibility age to 65 and simultaneously increasing pension benefits so that individuals of both skill types attain the same individual welfare levels as in the status quo.

We focus on China because population aging in China is especially rapid, and the country is still expanding its pension system. China's old-age dependency ratio (i.e., the ratio of the population aged 65+ per 100 persons of working age 20–64) is forecasted to be 47.5% in 2050, up from 17.7% in 2019 (United Nations, 2019a). The recently released statistics from China's 2020 Population Census confirmed these projected trends. The average life expectancy at birth in China is projected to be 81.5 years in 2045–2050 (United Nations, 2019b), up from 77 years in 2015–2020, while the average pension age is currently lower than 55. China has a multi-layer pension system that is comprised of different programs for different population groups. The public pension system has been extended and reformed over the last three decades and there is an ongoing debate about whether to increase the pension eligibility age.

Our results show that the effects of different pension reforms will differ substantially by skill type. High-skilled individuals increase their labor supply more than low-skilled individuals in response to alternative pension reforms. We find that under Reform (i), individuals of both skill types substantially increase their labor supply between ages 60 and 64; however, the average working years relative to the baseline only increase for the high-skilled individuals; however, Reform (ii) results in longer working years for both skill types. Both Reforms (i) and (ii) substantially improve the pension system's budgets relative to the status quo, but at the cost of substantial individual welfare loss for both skill types. Interestingly, we find that Reform (iii), which simultaneously increases the pension age to 65 and proportionally increases pension benefits to ensure that individuals of both skill types are as well of as the baseline, could result in a modest (about 5.5%) improvement of the pension system's net deficit (payout minus the contributions from age 45 onward).

The objective of the planned pension reform in China is currently unclear, given that the implementation and details are still under discussion. Our results suggest that the preferred pension reform critically depends on policymakers' objectives. For instance, if the policymaker wants to increase labor supply and improve the financial sustainability of the BOAI pension program, our results suggest that reducing the pension benefits instead of delaying the pension eligibility age might be a preferred policy; but such a reform will cause welfare losses for both low-skilled and high-skilled individuals. If the policymaker wants to improve the budget of the pension program while ensuring that both skill types are not made worse off relative to the status quo, then our results suggest that a combined reform that *simultaneously* increases the pension eligibility age and proportionally raise the pension benefits may be an option to pursue, though it will likely have an negative overall impact on labor supply.

Our research is informed by the vast literature exploring the impact of changes to pension benefit levels and pension eligibility ages on labor supply in the U.S. and Europe. This literature has found that labor supply is strongly associated with pension eligibility age (Rust and Phelan, 1997), that changes in pension benefits have a strong effect on labor supply (French and Jones, 2011; Laun et al., 2019; Malkova, 2020; Gustman and Steinmeier, 2009), and that increasing the pension age generates large labor supply responses (Haan and Prowse, 2014; Gustman and Steinmeier, 2005). Our result that reducing pension benefits yields the largest overall labor supply effects is in line with Laun et al. (2019)'s Norwegian study, which finds that proportionally reducing retirement and disability benefits yields the largest labor supply responses, compared with increasing retirement age, raising income taxes, or lowering retirement benefits.

A growing number of studies analyze the impact of pension reforms in China. Giles et al. (2012, 2015) document a strong association between pension eligibility and labor force in China. In line with the data and the empirical analysis by Giles et al. (2012, 2015), our model generates a sharp drop in participation rates around pension age. Feng et al. (2019) apply a cohort-component method to investigate the impact of increasing the statutory pension age on health and education, and find that China's workforce could increase by up to 92 million per year. Song et al. (2015) show in an overlapping generations (OLG) model that China's current pension system is not financially sustainable but that delaying reforms could result in significant welfare gains for current (poorer) generations at relatively small welfare costs to future (richer) generations. He et al. (2019) develop an OLG model to quantify the effects of Chinese pension reforms in the 1995–2009 period, which reduced pension benefits, on household saving rates and labor supply. Jin (2016) adopts a life-cycle model to investigate the effects of increasing the pension age on urban female labor supply in China; however, it does not explicitly model the pension benefit and does not focus on the effects of adjusting the pension benefit.

Our paper contributes to the ongoing policy debate in China about pension reforms by quantifying the implications of different plausible reforms of the pension eligibility age and the pension benefit in a single framework. Our model also approximates the current pension rules of the BOAI pension program more closely than previous studies (e.g., Song et al., 2015; He et al., 2019). In addition, we quantify how the labor supply and welfare effects of the different reforms differ by skill types.

The remainder of the paper is organized as follows. In Section 2, we briefly describe China's pension system. In Section 3, we present our model. In Section 4, we describe the data and the stylized facts that emerge from the data. In Section 5, we describe the model calibration. In Section 6, we present our baseline results and the performance of our calibrated model. In Section 7, we discuss the implications of three pension reform proposals on labor force participation, individual welfare, and the budget of the pension system. In Section 8, we conclude.

2 China's Pension System

China's public pension system is currently comprised of two parallel programs: the BOAI and the Unified Basic Pension program. The BOAI was initially established in 1997 to cover urban workers in for-profit enterprises. In 2015, the Public Employee Pension for civil servants and employees in non-profit government institutions was merged into the BOAI, which now covers all workers. The Unified Basic Pension program, which covers rural and urban non-employed residents, resulted from a merger of the Urban Resident Pension and the New Rural Resident Pension in 2014 (Fang and Feng, 2020). Our analysis focuses on the BOAI, which covered 435 million people at the end of 2019, among whom 312 million were working while the remaining 123 million were retirees (Ministry of Human Resources and Social Security, 2019).

The BOAI pension program has two components. The first component is a compulsory social pooling program, where employers are required to contribute 20% of the wages of currently employed individuals. This contribution is used to pay the pension benefits of current retirees. The second component is a notional individual account financed by an 8% employee contribution. The pension benefit is available for individuals who reach the statutory pension age and have contributed to the BOAI for 15 years. We describe the computation of the benefits from these two components in more detail in Appendix A.

The pension eligibility age for the BOAI is 50 for blue-collar women, 55 for white-collar women, and 60 for men. Individuals are not allowed to delay claiming pension benefits beyond the statutory pension age, and early pension claiming is rare in China.[1] Once individuals reach the statutory pension age, they start to receive monthly pension benefits, which are not taxable in China. Claiming pension benefits does not require individuals to stop working, but it does stop employer and employee contributions to the pension system. Also, labor income beyond the statutory pension age does not affect the calculation of monthly pension benefits.

The BOAI pension program has maintained an annual surplus for many years. In 2019, the BOAI's revenue was *RMB* 5.29 trillion, and its expenditure was *RMB* 4.92 trillion (Ministry of Human Resources and Social Security, 2019).[2] The BOAI surplus is attributable to the increase in the number of participants and substantial direct fiscal subsidies from the central and local governments.[3] Government subsidies amounted to *RMB* 0.8 trillion in 2017, which accounted for 18.4% of the total revenue of the BOAI in 2017 (Ministry of Human Resources and Social Security, 2017). The proportion of fiscal subsidies to the BOAI has increased in recent years. Without government subsidies, the BOAI would have reported a deficit every year since 2015. A recent report from the Chinese Academy of Social Sciences reported that the BOAI pension program is likely to run out of money in 2035 (Chinese Academy of Social Sciences, 2019). Reforms are therefore needed to improve the financial sustainability of the BOAI pension program and reduce its financial burden on the central and local governments.

In response to these challenges, the Chinese government is planning to gradually increase the pension eligibility age for both women and men covered by the BOAI pension program. The government first proposed an increase in the pension eligibility age in June 2012, when the State Council approved the "Twelfth Five-Year Plan for Social Security," which proposed "research on the policy of flexible delay in statutory pension age" (State Council, 2012). More recently, the idea of increasing the pension eligibility age has been further debated (see, for example, Wang et al., 2019, for a discussion). Since the details of the pension reform are still under discussion, we proceed by constructing and estimating a life-cycle model to structurally

[1]Under the following special circumstances, individuals can retire early and start to claim pension benefits before the statutory pension age: (1) Individuals who have contributed for at least ten years and who have been employed in arduous or unhealthy work can claim pension benefits at ages 45 (women) and 55 (men). (2) Individuals who have contributed for at least 10 years and who have been assessed to have a total disability can claim pension benefits at ages 45 (women) and 55 (men).

[2]The exchange rate between *USD* and *RMB* on May 27, 2021, was $1 USD = 6.38 RMB$.

[3]"Local" could be a province, city or county, depending on the administrative region of the public pension fund.

evaluate different potential reform proposals. We also study the effects of allowing individuals to choose when to retire with different benefits.

3 The Model

We model the decisions of 45-year-old Chinese urban males who have a maximum lifespan of 100 years. We use $t = Age - 45$ to denote the time period in the model, with $t \in \{0, 1, 2, ..., T = 55\}$. In each period t, individuals maximize their expected lifetime utility by making consumption and labor supply decisions. We solve the model separately for high-skilled ($s = h$) and low-skilled ($s = l$) individuals. We assume that an individual's skill type is permanent.

3.1 Health Dynamics and Medical Expenses

Health dynamics play an important role in our analysis as a potential channel through which pension reforms can have heterogeneous impacts on the labor supply and individual welfare of individuals with different skill types. We model individual health transitions using a three-state Markov chain similar to the models developed by Fong et al. (2015) using U.S. data and Hanewald et al. (2019) using Chinese data. The model has two transient states, good health (g) and bad health (b), and one absorbing state, death (d).

For $s \in \{h, l\}$, let $\pi_t^s(i, j)$ denote the probability of being in state j in period $t+1$ conditional on being in health state i in period t, where $\pi_t^s(i, j) = \Pr(H_{t+1} = j|H_t = i), i \in \{g, b\}$, and $j \in \{g, b, d\}$.

We parameterize $\pi_t^s(i, j)$ as

$$\pi_t^s(i, j) = 1 - \exp\{-r_{ij}^s(t)\}, \;\; i \in \{g, b\}, \;\; j \in \{g, b, d\}, \tag{1}$$

where $r_{ij}^s(t)$ are the instantaneous health transition rates. Following Fong et al. (2015) and Hanewald et al. (2019), we model $r_{ij}^s(t)$ using the generalized linear modeling approach with a log link function. We extend the models used in these previous papers by including the skill type s in the linear predictor of the model. Our model assumes that each log transition rate is a quadratic function of age (denoted by t) and an interaction effect between age and skill type.[4]

Following Ameriks et al. (2011), but allowing for the possibility of zero medical costs, we model the out-of-pocket medical expenses for an individual with health status $H_t \in \{g, b, d\}$,

[4]We also tested a model with an interaction between age squared and skill type. We found that including this interaction does not improve the goodness-of-fit of the model and has little impact on the estimation results.

denoted by $\tilde{M}_t^s(H_t)$, as follows:

$$\tilde{M}_t^s(H_t) = \begin{cases} 0, & \text{with probability } p_0^s(H_t) \, , \\ m_{H_t}^s, & \text{with probability } 1 - p_0^s(H_t) \, . \end{cases} \tag{2}$$

where, for individuals of skill type s in health state H_t, the medical expense will be zero with probability $p_0^s(H_t)$, and $m_{H_t}^s$ with the complementary probability. Note that we allow for the medical expenses to be positive in the year in which the individual dies.

3.2 Preferences

Individuals derive utility from consumption and leisure when they are alive. Following French and Jones (2011) and Capatina (2015), the within-period utility for a skill-type-s individual with health status $H_t \in \{g, b\}$ is assumed to take the following functional form:[5]

$$u^s(C_t, H_t, \tau_t) = \frac{1}{1-\gamma}\left[C_t^{\alpha^s}\left(1 - \omega_{H_t}^s \tau_t\right)^{(1-\alpha^s)}\right]^{1-\gamma}, \tag{3}$$

where C_t denotes the consumption of non-medical goods; $\tau_t \in \{0, 1\}$ denotes the binary labor force participation choice, where $\tau_t = 1$ indicates full-time work in period t, and $\tau_t = 0$ indicates otherwise; and $\omega_{H_t}^s \in \{0, 1\}$ controls the size of the disutility of work, which varies across skill types and is health-dependent. With the total amount of time for each period normalized to 1, $1 - \omega_{H_t}^s \tau_t$ can be interpreted as the effective quantity of leisure enjoyed in t. The parameter γ represents the relative risk aversion for total utility from both consumption and leisure.[6] The parameter α^s governs the relative importance of consumption and leisure, and varies across skill types.

We impose compulsory retirement at age 75 to reduce the computational burden.[7] Thus we have:

$$\tau_t = 0, \text{ for } t + 45 \geq 75. \tag{4}$$

Following De Nardi et al. (2010) and French and Jones (2011), we assume that individuals with skill type s who leave a bequest of wealth W_t obtain utility in the period of death according

[5]Such utility functions are known as Constant Elasticity of Substitution (CES) utility functions, which are widely used in the life-cycle model literature (Heckman, 1974; French, 2005; Capatina, 2015). French (2005) finds that non-separable preferences fit the data better than separable preferences.

[6]The parameter γ also determines the non-separability in CES preferences over consumption and leisure. Consumption and leisure are substitutes when $\gamma > 1$.

[7]Less than 1% of urban males were still working after reaching age 75 in CHARLS waves 2011–2015.

to the function

$$v^s(W_t) = \theta \frac{(W_t + \kappa)^{\alpha^s(1-\gamma)}}{1-\gamma}, \tag{5}$$

where the parameter θ measures the strength of the bequest motive, and the parameter κ controls the extent to which bequests are luxury goods. A higher value of κ indicates that bequests are more of a luxury, and negative κ suggests bequests are a necessity.

3.3 Budget Constraints

At age 45 ($t = 0$), a male in our model starts with an initial liquid wealth of W_0 and an initial health state H_0. From this point onward, he enters each period $t = 1, 2, ..., T-1$ with a level of liquid wealth W_t and health state H_t. In each period, conditional on survival he decides whether to work or not. Total income Y_t^s is the sum of labor income L_t^s and pension benefits P, where $Y_t^s = L_t^s + P$. The individual incurs out-of-pocket medical expenses $\tilde{M}_t^s$. After paying $\tilde{M}_t^s$, this individual chooses a level of consumption C_t such that

$$C_t \geq C^f, \tag{6}$$

where C^f is the consumption floor. If the individual incurs out-of-pocket medical expenses that exceed their financial resources and thus cannot afford a consumption level $C_t \geq C^f$, the individual receives government transfers G_t, whose value is given by (see Hubbard et al. (1995) and French and Jones (2011)):

$$G_t = \max\left\{0, C^f - (W_t + Y_t^s - \tilde{M}_t^s)\right\}. \tag{7}$$

We do not allow for borrowing in our model. Thus, the after-consumption wealth at the end of period t, which we denote by $\overline{W}_t$, must satisfy:

$$\overline{W}_t = W_t + Y_t^s - \tilde{M}_t^s + G_t - C_t \geq 0. \tag{8}$$

We assume that individuals invest their after-consumption wealth $\overline{W}_t$ in a portfolio with a rate of return r, hence his wealth evolves according to:

$$W_{t+1} = \begin{cases} \overline{W}_t(1+r), & \text{if } G_t = 0, \\ 0, & \text{if } G_t > 0. \end{cases} \tag{9}$$

3.4 Labor Income

Individuals working in period t receive a positive labor income L_t^s. Following Yu and Zhu (2013) and Capatina (2015), we model individual labor income L_t^s as follows: for $H_t \in \{g, b\}$,

$$\ln(L_t^s) = l_t^s(H_t) + \bar{\mu}^s + \lambda_t^s + \mu_t^s, \tag{10}$$

$$l_t^s(H_t) = \beta_0^s + \beta_1^s t + \beta_2^s t^2 + \beta_3^s t^3 + (\beta_4^s + \beta_5^s t + \beta_6^s t^2) I_{H_t=b}, \tag{11}$$

where $l_t^s(H_t)$ denotes the deterministic component of labor income and is assumed to be a function of age, age squared, age cubed, health, and health interacted with age (see Equation (11)). $I_{H_t=b}$ is an indicator equal to one for individuals in bad health. $\bar{\mu}^s$ is the individual's fixed effect determined at birth with the distribution $\bar{\mu}^s \sim N(0, \sigma^2_{\bar{\mu}^s})$. We also assume that the income process contains two types of shock: an idiosyncratic transitory shock λ_t^s with the distribution $\lambda_t^s \sim N(0, \sigma^2_{\lambda^s})$, and a persistent shock μ_t^s, which follows an AR(1) process with a correlation coefficient ρ^s, and i.i.d innovation η_t^s:

$$\mu_t^s = \rho^s \mu_{t-1}^s + \eta_t^s, \quad \text{where } \rho^s \in [0, 1], \quad \eta_t^s \sim N(0, \sigma^2_{\eta^s}). \tag{12}$$

3.5 Pension Benefit

An innovative feature of our paper is how we model and calibrate the pension benefit. In practice, the statutory pension benefit P^* in China depends on: (1) the individual's wage history before retirement; (2) the local average wage of all individuals in a given year; (3) the ratio of (1) and (2) during all working years; and (4) an individual's year of retirement. To calculate P^*, we must have a full record of each individual's wage history, employment history, and year of retirement in each local area, which is impractical and computationally intensive. Instead, we approximate the statutory pension benefit P^* using P, which is a linear function of the individual's career average wage $\bar{w}_t$ and the number of years worked y_t before the pension eligibility age. We assume that each individual has worked 20 years before age 45, i.e. $y_0 = 20$. This regression-based approximation explains over 96% of the variations in the statutory pension benefit P^* and is described in more detail in Appendix A.

As mentioned in Section 2, individuals in China are not allowed to delay claiming pension benefits beyond the statutory pension age, and labor income beyond the statutory retirement age no longer affects the calculation of pension benefits. Early pension claiming is rare in China and is not allowed in our model.[8] To reflect those settings, in our model, the pension benefit P is determined at the statutory pension age (currently 60 for males) and remains constant after

[8] In three waves of CHARLS (2011, 2013 and 2015), only 1.7% of urban males under 60 received pension benefits.

that:

$$P = \begin{cases} 0, & \text{if } t + 45 < 60, \\ P(\bar{w}_t, y_t), & \text{if } t + 45 \geq 60, \end{cases} \tag{13}$$

where

$$P(\bar{w}_t, y_t) = \beta_{p0} + \beta_{p1}\bar{w}_t + \beta_{p2}y_t + \beta_{p3}\bar{w}_t^2 + \beta_{p4}\bar{w}_t^3 + \beta_{p5}\bar{w}_t^4 + \beta_{p6}\bar{w}_t y_t. \tag{14}$$

Moreover, y_t, the number of years worked, evolves according to:

$$y_t = \begin{cases} y_{t-1} + 1, & \text{if } t + 45 < 60 \;\; \& \;\; \tau_t = 1, \\ y_{t-1}, & \text{if } t + 45 \geq 60 \text{ or } (t + 45 < 60 \;\; \& \;\; \tau_t = 0), \end{cases} \tag{15}$$

and $\bar{w}_t$, the career average wage, evolves according to:

$$\bar{w}_t = \begin{cases} \frac{\bar{w}_{t-1}y_{t-1} + L_t^s}{y_t}, & \text{if } t + 45 < 60 \;\; \& \;\; \tau_t = 1, \\ \bar{w}_{t-1}, & \text{if } t + 45 \geq 60 \text{ or } (t + 45 < 60 \;\; \& \;\; \tau_t = 0). \end{cases} \tag{16}$$

3.6 Recursive Formulation

The individual's problem is to maximize the expected lifetime utility by making labor supply and consumption decisions, starting from age 45. The individual's state variables in period t are denoted by the vector $\mathbf{X}_t \equiv \{W_t, H_t, \bar{w}_t, y_t, \bar{\mu}^s, \lambda_t^s, \mu_t^s\}$, where W_t is liquid wealth, H_t is health status, $\bar{w}_t$ is the average wage over the individual's career, y_t is the number of years they have worked before the pension eligibility age, $\bar{\mu}^s$ is the individual fixed effect, and λ_t^s and μ_t^s are the two labor income shocks. In recursive form, the problem for an individual with skill type s can be written as:

$$\mathrm{V}_t^s(\mathbf{X}_t) = \max_{\{\tau_t, C_t\}} \left\{ u^s(C_t, H_t, \tau_t) + \delta \mathbb{E}_t \left[\textstyle\sum_{H_{t+1} \in \{g,b\}} \pi_t^s(H_t, H_{t+1}) V_{t+1}^s(\mathbf{X}_{t+1} | \mathbf{X}_t, \tau_t, C_t) + \pi_t^s(H_t, d) v^s(W_{t+1}) \right] \right\}, \tag{17}$$

subject to constraints (4), (6), (7), (8), and (9), and state evolutions (11)-(16), where δ is the discount factor. This optimization problem is solved numerically by backward induction. We use the discrete-continuous endogenous gridpoint method (DC-EGM), developed by Iskhakov et al. (2017), to smooth out the kinks in the value functions and the discontinuities in the optimal consumption rules which arise from a dynamic programming model with both discrete labor supply choice and continuous consumption choice. More details on the numerical solution method are provided in Appendix B.

4 Data

4.1 China Health and Retirement Longitudinal Study (CHARLS)

Our main data source for model calibration is CHARLS. CHARLS aims to collect a nationally representative sample of Chinese residents aged 45 and older. It surveys individuals every two years and provides detailed information on individual-level out-of-pocket medical expenses, assets, self-reported health status, labor income, and employment status. We use three waves of CHARLS covering the period 2011–2015.

We limit our sample to urban males who are eligible for the BOAI pension program. A person is defined as eligible for the BOAI if (1) he has urban residence status (*"Hu Kou"* in Chinese); or (2) he does not have urban *hukou* but his occupation is not farming.[9] Our sample contains 7,079 person-year observations. We define the skill types of individuals based on their education: those who have completed high school and above are classified as high-skilled individuals, and all others are classified as low-skilled individuals. Roughly 26% of our sample is high-skilled.

In CHARLS, respondents report whether they have worked for at least one hour in the previous week for a salary, for their own business, or for a family business, and whether they engaged in agricultural work for more than 10 days in the previous year. Respondents also report the number of hours worked per day, the number of days worked per week, and the annual wage received in the previous year. We define respondents as currently working ($\tau_t = 1$) if they (1) worked for a salary for their own business or a family business for 20 hours or more per week, or (2) engaged in agricultural work for 20 hours or more per week and received an annual salary in the previous year.[10]

We measure an individual's wealth as the sum of cash, deposits, the value of government bonds, stocks, mutual funds, public housing provident fund ("*Gong Ji Jin*" in Chinese), housing fund of the working unit ("*Ji Zi Kuan*" in Chinese), and unpaid salaries, excluding credit card debt and unpaid loans. The initial wealth level at age 45 for both skill types is calibrated using the wealth data of males who are aged 45-49 in the 2011 wave of CHARLS. The average initial wealth level at age 45 is *RMB* 27,360 for the high-skilled and *RMB* 10,757 for the low-skilled.

Consumption includes expenditures for the following items: (1) spending on food (including both food purchased and the market value of consumed home-grown food), eating out, alcohol, cigarettes, cigars, and tobacco; (2) fees for communication, utilities, fuels, matrons, housekeep-

[9] We also exclude the following individuals: (1) respondents who have missing information regarding age, wave, consumption, assets, working status, health status, labor income, individual ID, and whether they have worked for at least three months during their lifetime; (2) respondents who have never worked in their lifetime as they are not eligible for the BOAI; and (3) respondents who claimed a pension benefit before age 60 because our model does not capture this feature.

[10] In China, the employment rate and the labor force participation rate are almost equivalent, as the official urban unemployment rate stayed almost constant between 4.0-4.3% throughout the decade under study. We will use these two concepts interchangeably below.

ers, servants, local transportation, entertainment, household items, and personal toiletries that are used daily plus beauty treatments; and (3) spending on clothing and bedding, long-distance traveling, heating, durable goods, education and training, fitness, automobiles, purchase, maintenance, repair, property management, taxes, and donations. In CHARLS, consumption is measured at the household level. Following Keane and Wasi (2016), we apply a household equivalence scale to adjust to the individual consumption level using the square root scale.

4.2 Chinese Longitudinal Healthy Longevity Survey (CLHLS)

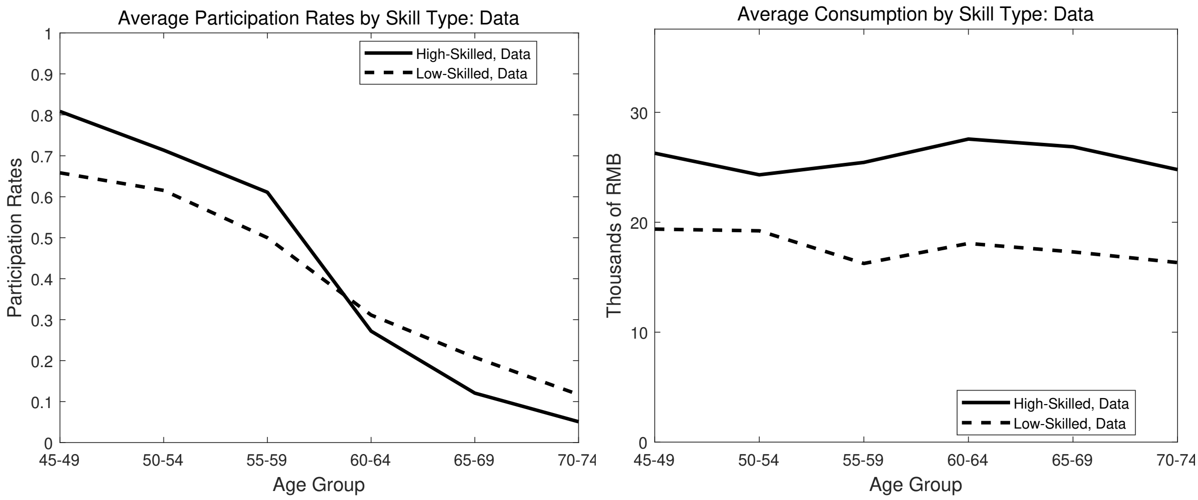
To compensate for the limited number of very old age observations in CHARLS, we supplement CHARLS with data from CLHLS to calculate the health transitions and mortality rates used in our model calibration. CLHLS provides information on the health status and quality of life, including limitations on the activity of daily living (ADL), for elderly Chinese aged 65 and older, with a special focus on the healthy longevity, the health risk factors, and the mortality of those aged 80 and older. Combining CHARLS and CLHLS data produces a sample that covers all ages from 45 and is large enough for estimation. We use six waves of the CLHLS, covering the period 1998–2012.

4.3 Stylized Facts

Health and skill type are important for understanding labor force participation rates and the consumption of Chinese urban males. In this section, we document some key facts about the heterogeneity in health and skill type among Chinese urban males based on data from CHARLS.

Labor Force Participation, Consumption, and Skill Type. Figure 1 shows the average labor force participation rates and average consumption levels by skill type and age group. We note three main observations for participation rates. First, labor force participation differs by skill type: high-skilled individuals have higher average participation rates than low-skilled individuals before age 60, and have lower average participation rates than low-skilled individuals after age 60. Second, labor force participation declines with age for both skill types. The decline is largest from ages 55–59 to ages 60–64 when individuals become eligible for the BOAI. Participation drops by 34 percentage points for high-skilled individuals and 19 percentage points for low-skilled individuals. Third, a substantial share of both high-skilled and low-skilled individuals stopped working before reaching their statutory pension age, while some individuals in both groups continued working after age 60. Figure 1 also shows that, on average, high-skilled individuals consume more than low-skilled individuals in all age groups. We will see later in Section 6.2 that our model replicates these data patterns well.

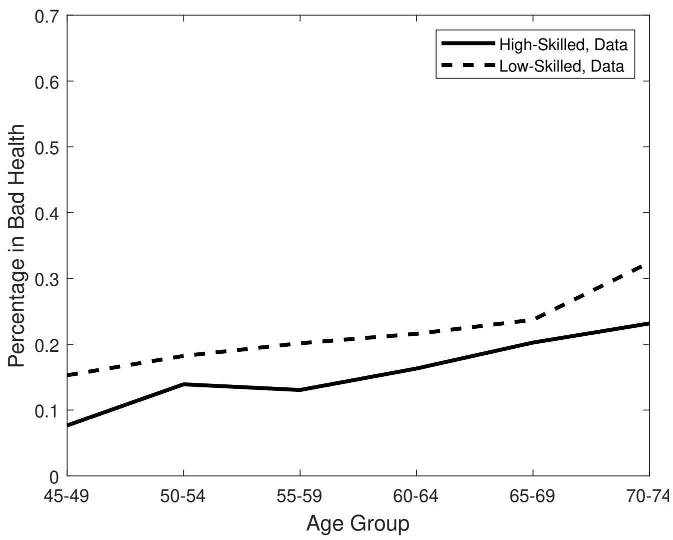
Figure 1: Average Participation Rates and Consumption by Skill Type: Data



Data source: CHARLS.

Health and Skill Type. Figure 2 shows that health differs by skill type. High-skilled individuals are less likely to be in bad health than low-skilled individuals. For example, at ages 55–59, 13% of high-skilled individuals are in bad health compared with 20% of low-skilled individuals.

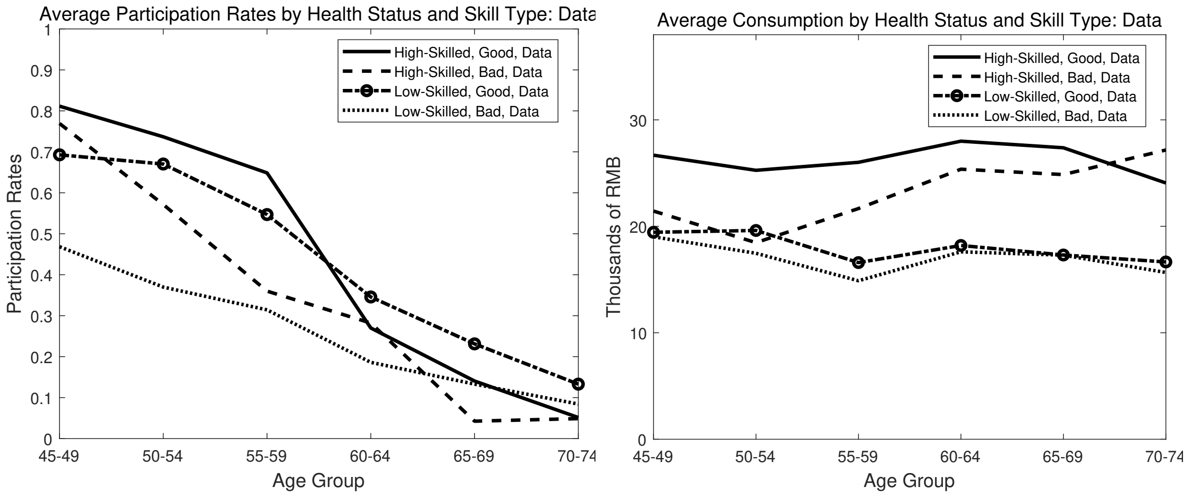
Figure 2: Percentage of Individuals in Bad Health by Skill Type: Data



Data source: CHARLS.

Figure 3 presents average participation rates and average consumption levels by skill type and health status. Average participation rates and average consumption are lower for individuals in bad health for both skill types. Low-skilled individuals who are in good health have higher participation rates but lower consumption compared with high-skilled individuals who are in bad health. Low-skilled individuals who are in bad health have the lowest average participation rate and average consumption.

Figure 3: Average Participation Rates and Consumption by Skill Type and Health Status: Data



Data source: CHARLS.

Summary. Labor force participation rates and consumption levels differ by skill type and health status. Health status also differs by skill type. Our model takes this heterogeneity into account and calibrates health transitions and mortality rates separately for high-skilled and low-skilled individuals.

5 Calibration

We use a two-step strategy to calibrate our model. In the first step, we calibrate several parameters outside the model, including health transitions, mortality rates, out-of-pocket medical expenses, and parameters to approximate pension benefits. In the second step, we calibrate the remaining parameters within the model.

We fit our model to the following moments:

(i) average participation rates in five-year age groups from age 45 to 74 (45–49, 50–54, ..., 70–74) by skill type and health status;

(ii) average consumption levels in five-year age groups from age 45 to 74 (45–49, 50–54, ..., 70–74) by skill type and health status;

(iii) variance of average log incomes in five-year age groups from age 45 to 74 (45–49, 50–54, ..., 70–74) by skill type;

(iv) average labor income of the 45–49 age group by skill type and health status;

(v) average wealth of the 45–49 age group by skill type and health status; and

(vi) average wealth to average labor income ratio of the 45–74 age group by skill type.

In summary, we have selected moments that capture the distribution of the key variables in our model (participation rates, consumption, labor income, and wealth). The model is fitted to 70 data moments using the 2011, 2013, and 2015 waves of CHARLS data. Table 1 lists the fixed parameters that are taken as given in the model. We assume that those fixed parameters are common to both skill types. The discount factor δ is set to 0.96, as in Chen et al. (2020). The interest rate r satisfies $r = 1/\delta - 1$, thus $r = 0.04$. The consumption floor C^f is set at *RMB* 1,774, which is the average minimum livelihood guarantee (*"Di Bao"* in Chinese) income in our sample. The relative risk-aversion parameter γ is set at two, as in Gomes and Michaelides (2005). The bequest shift parameter κ is set at 215 (in thousands), and the bequest intensity θ is set at 2.36 (in thousands), as in De Nardi et al. (2010).

Table 1: Model Parameters

Parameter	Description	Values
δ	Time discount factor	0.96
r	Risk-free interest rate	0.04
C^f	Consumption floor in *RMB*	1,774
γ	Coefficient of relative risk aversion, utility	2
κ	Bequest shifter, in thousands	215
θ	Bequest intensity, in thousands	2.36

5.1 Health Status Transition

We calibrate health transitions and mortality rates separately for high-skilled and low-skilled individuals using three waves of CHARLS data (2011, 2013, and 2015) and six waves of CLHLS data (1998–2012). Both surveys use a five-point scale for self-reported health measures and assess similar ADL questions.[11] We classify individuals as in good health if they do not have limitations in performing any ADL and if their self-reported health is better than "Poor" or "Bad." We classify all other living individuals as having bad health.[12] Roughly 80% of our sample is in good health.

Table 2 shows the implications of our estimated health dynamics. The implied life expectancy at age 45 is 38.8 years for high-skilled and 35.9 for low-skilled, a difference of 2.9 years; while the healthy life expectancy at age 45 is 28.8 years for low-skilled individuals and 32.3 years for high-skilled individuals, a difference of 3.5 years. The life expectancy at age 65 is 17.2 years for low-skilled individuals and 19.5 years for high-skilled individuals, a difference of

[11]CLHLS uses "Very good," "Good," "So so," "Bad," and "Very bad." CHARLS has two types of self-reported health questions. The first uses "Very good," "Good," "Fair," "Poor," and "Very poor." The second uses "Excellent," "Very good," "Good," "Fair," and "Poor." For our analysis, we use the first version in CHARLS. ADL is assessed using questions related to the following: dressing; bathing or showering; eating, such as cutting up your food; getting into or out of bed; and using the toilet, including getting up and down from the toilet.

[12]We classify a person as being in bad health if their self-reported health is "Bad" or "Very bad" in CLHLS and if it is "Poor" or "Very poor" in CHARLS.

Table 2: Health Dynamics: Implications

Measure	High-Skilled	Low-Skilled	Difference
Life expectancy at age 45	38.8	35.9	2.9
Life expectancy at age 60	24.1	21.5	2.6
Life expectancy at age 65	19.5	17.2	2.3
Healthy life expectancy at age 45	32.3	28.8	3.5

Data Sources: CHARLS and CLHLS.

2.3 years.[13] We also note that low-skilled individuals are more likely to be in bad health than high-skilled individuals, as shown in Figure 2.

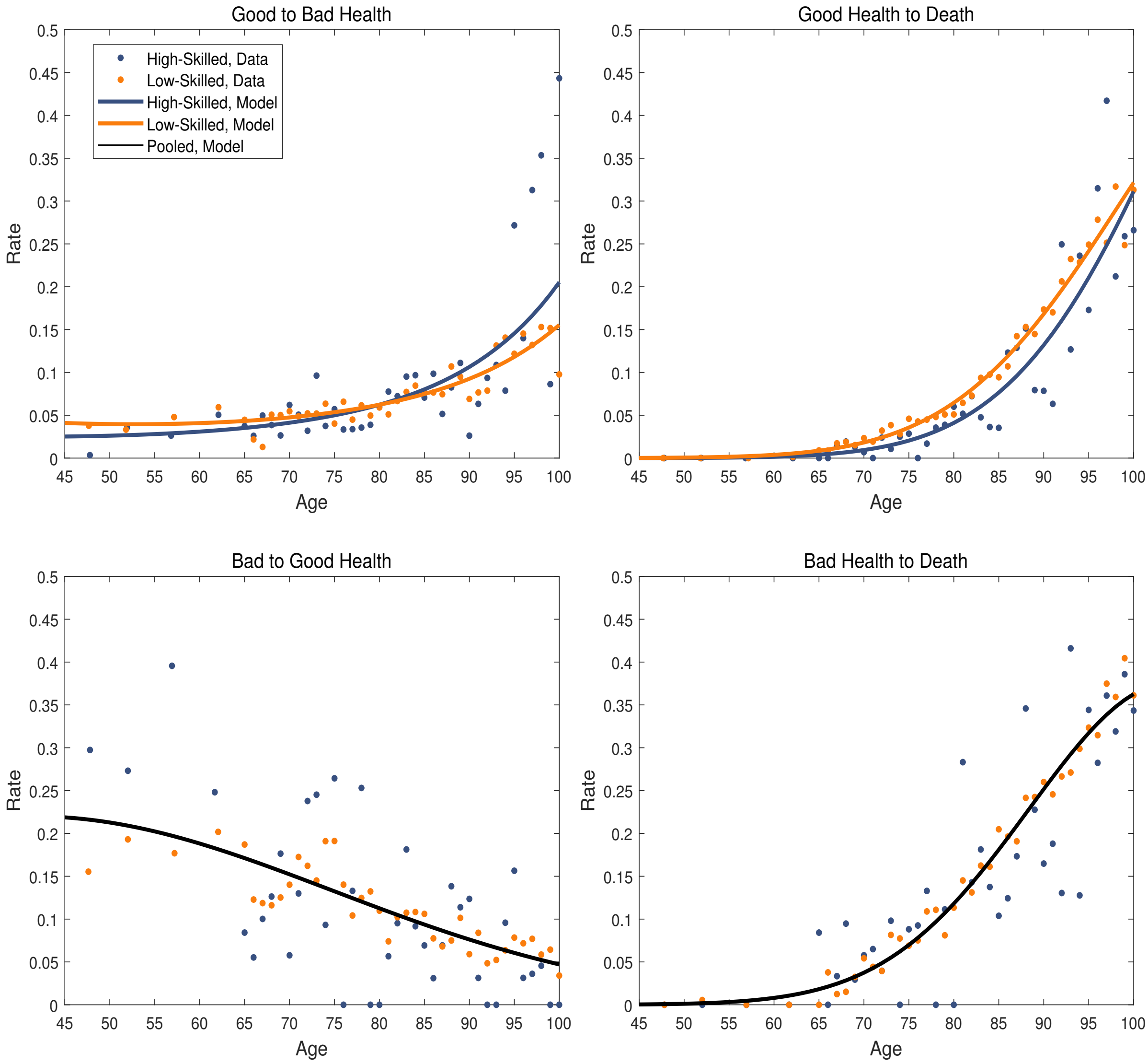
Figure 4 compares the raw and fitted health transition rates for the two skill types. We find that skill type is a significant covariate for the transitions from good health to bad health, and from good health to death. Specifically, the transition probability from good health to bad health is lower for high-skilled individuals at middle and older ages. The pattern is reversed among those aged 80 and above, likely because of the selection (survivorship) effect. In terms of the transition from good health to death, low-skilled individuals have a higher transition rate than high-skilled individuals at all ages. We do not find significant differences between the two skill types for the "recovery transition" from bad health to good health, or for the mortality rates from bad health. For these two rates, we pool the data and estimate the same model for both skill types. Overall, Figure 4 indicates that the health transition model provides a good fit for the data. The observed age patterns are also plausible: the transition rates from good health to bad health and to death, as well as the mortality rates from bad health, increase with age, while the recovery rates from bad health to good health decrease with age. We will see in Sections 6 and 7 that the differences in health dynamics and health transitions play an important role in our baseline results and policy experiments.

5.2 Out-of-Pocket Medical Expenses

We calibrate the different levels of out-of-pocket medical expenses, m_g^s, m_b^s, and m_d^s, using CHARLS data. Table 3 presents the summary statistics, conditional on health status and skill type. Table 3 shows that for individuals aged 45+ who are in good health, the average annual out-of-pocket costs are *RMB* 6,119 for high-skilled individuals, and *RMB* 4,095 for low-skilled individuals. The higher average out-of-pocket costs among high-skilled individuals in good health might be due to a stronger willingness and ability to pay for health care as high-skilled

[13]There is limited research on life expectancy by skill type in China. Using data from the CLHLS, Jiao (2019) estimates that life expectancy at age 65 is 14.1 years for uneducated Chinese males, 14.7 years for Chinese males with 1–5 years of education, and 15.7 years for Chinese males with 6+ years of education. Jiao (2019) also reports that elderly urban Chinese males have a longer life expectancy than elderly rural Chinese males at different ages. We focus on urban Chinese males and classify those who have completed high school and above (12+ years of education) as high-skilled. These differences explain why we estimate longer life expectancies and larger differences in life expectancy between skill types than Jiao (2019).

Figure 4: Estimation Results for Selected Health Transition Rates



Data sources: CHARLS and CLHLS.

individuals have a much higher wealth and wage level compared with low-skilled individuals.

In terms of zero out-of-pocket expense probabilities, $p_0^s(H_t)$, we find that, among those who are in good health, $p_0^h(g) = 45.8\%$ for high-skilled individuals and $p_0^l(g) = 45.4\%$ for low-skilled individuals. The proportion of zero out-of-pocket medical costs decreases as health deteriorates, to $p_0^h(b) = 17.6\%$ and $p_0^l(b) = 19.5\%$ for for high-skilled and low-skilled individuals, respectively. We estimate that at death, there is a small probability of zero out-of-pocket medical expenditure.

5.3 Pension Benefit

To estimate $\boldsymbol{\beta} \equiv \{\beta_{p0}, ..., \beta_{p6}\}$ in Equation (14), we first simulate for a sample of individuals aged 45-60 their wage history, labor supply history, and health transitions. We then calculate the statutory pension benefit P^* for each of these individuals using the regulatory pension

Table 3: Out-of-Pocket (OOP) Medical Expenses Distribution

	High-Skilled	Low-Skilled
Good Health		
Mean (*RMB*) (m_g^s)	6,119	4,095
Prob. zero OOP costs ($p_0^s(g)$)	45.8%	45.4%
Bad Health		
Mean (*RMB*) (m_b^s)	12,641	12,962
Prob. zero OOP costs ($p_0^s(b)$)	17.6%	19.5%
Death		
Mean (*RMB*) (m_d^s)	69,475	36,701
Prob. zero OOP costs ($p_0^s(d)$)	4.9%	2.1%

Note: The out-of-pocket costs for death are estimated based on data from the CHARLS 2013 exit survey.

benefit formulas. We then estimate $\boldsymbol{\beta}$ in Equation (14) using P^* as the dependent variable of the regression. We conduct this process in the first step of our two-step calibration strategy as described at the beginning of Section 5. In the second step of our two-step calibration, the estimated parameters $\hat{\boldsymbol{\beta}}$ are used to calculate the pension benefit P using Equation (14). Details of the statutory pension formulas and our regression-based approximation method are presented in Appendix A. We find that the approximation formula explains over 96% of the variation in P^*.

6 Baseline Results

6.1 Calibrated Parameters

The calibrated parameters are reported in Table 4. Our model contains 14 free parameters, and we calibrate them separately for high-skilled and low-skilled individuals. Disutility of work ω_g^s and ω_b^s are mainly identified by targeting the average participation rates by skill type and health status. The calibrated disutility parameter is higher for low-skilled individuals, implying that high-skilled individuals are more willing to work than low-skilled individuals. Moreover, the disutility parameter is higher for those in bad health than for those in good health for both skill types. The consumption weight α^s is identified by the average participation rates and average consumption profiles. The variance of individual fixed effect $\sigma^2_{\bar{\mu}^s}$, variance of innovation $\sigma^2_{\eta^s}$, variance of transitory shocks $\sigma^2_{\lambda^s}$, and autoregressive coefficient ρ^s are identified largely from the variance of average log labor income and the ratio of average wealth to average labor income by skill type. The labor income parameters $(\beta_0^s, \beta_1^s, ..., \beta_6^s)$ are identified by the combination of the average participation rates, average consumption levels, average wealth, and labor income profiles.

Table 4: Calibrated Parameters

Parameters	Description	Parameter Values	
		High-Skilled	Low-Skilled
	Panel A: Parameters in the Utility Function [Equation (3)]:		
ω_g^s	Disutility of work, good health	0.326	0.37
ω_b^s	Disutility of work, bad health	0.348	0.396
α^s	Consumption weight	0.31	0.31
	Panel B: Parameters for the Labor Income Process [Equations (10)-(12)]:		
$\sigma^2_{\eta^s}$	Variance of innovation	0.2116	0.1354
$\sigma^2_{\lambda^s}$	Variance of transitory shocks	0.1024	0.1681
$\sigma^2_{\bar{\mu}^s}$	Variance of individual fixed effect	0.0004	0.1318
ρ^s	Autoregressive coefficient	0.86	0.905
β_0^s	Constant	2.38	2.28
β_1^s	Age coefficient	0.119	0.071
β_2^s	Age squared coefficient	-0.0024	-0.0017
β_3^s	Age cubed coefficient	0.000007	0.0000079
β_4^s	Bad health coefficient	0.393	0.042
β_5^s	Bad health $*$ age coefficient	-0.028	-0.005
β_6^s	Bad health $*$ age squared coefficient	0.00015	-0.00016

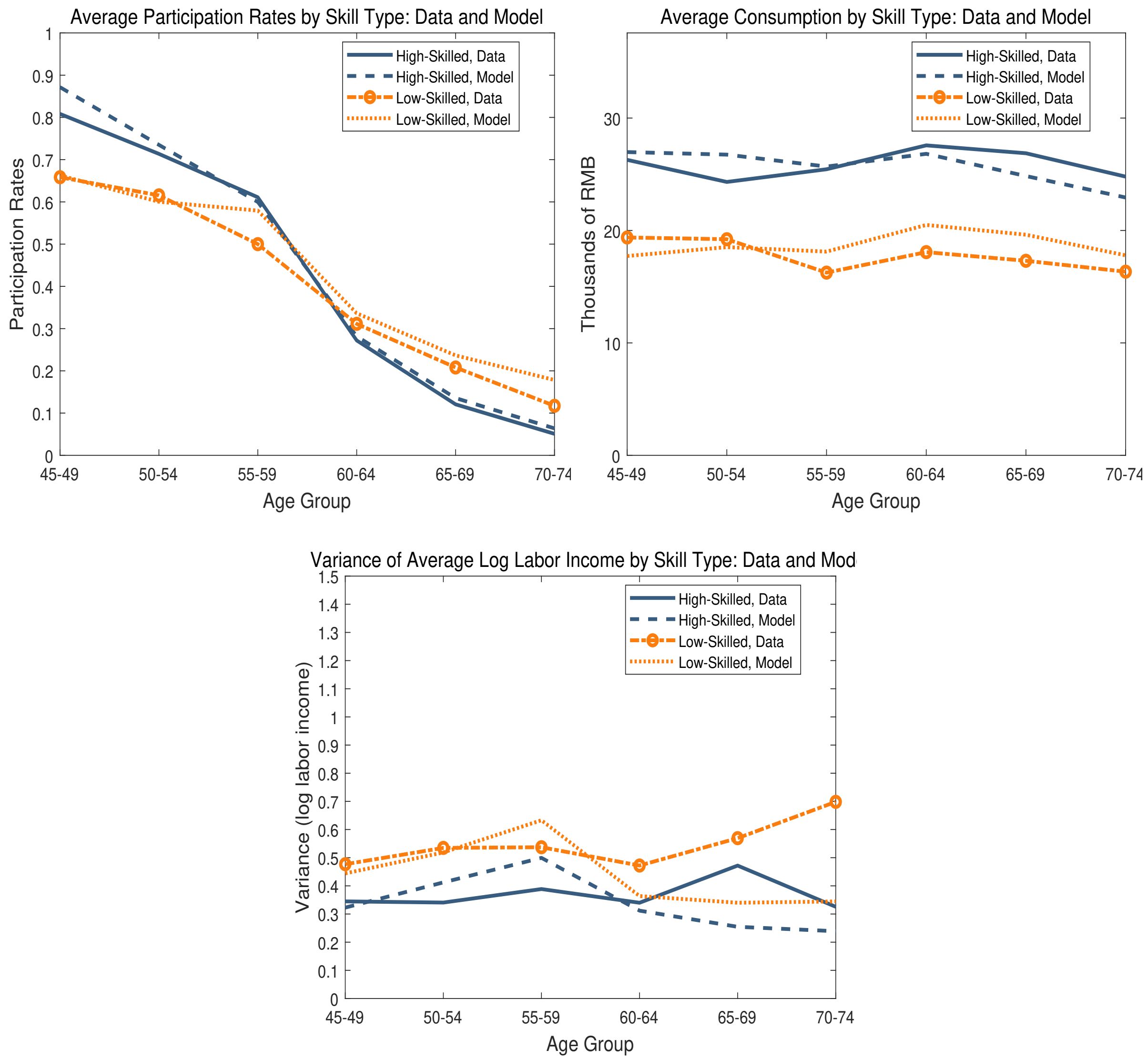
6.2 Data Patterns and Model Fit

In our baseline case, all individuals in our model start to receive pension benefits at age 60 (the current pension eligibility age). Figure 5 reports how the model fits average labor force participation rates, average consumption levels, and the variance of average log labor income by skill type. The model matches those key moments very well, especially for the high-skilled. It replicates the key features of how participation rates vary with age and skill type as emphasized in Section 4.3.

The first key feature is that participation rates decline with age, and the declines are especially sharp between ages 60 and 64. The model matches the decline in average participation rates at ages 60–64 for the high-skilled (a 34-percentage-point drop in the data versus a 32-percentage-point decline predicted by the model), but overpredicts the decline in average participation rates at ages 60–64 for low-skilled individuals (a 19-percentage-point drop in the data versus a 24-percentage-point decline predicted by the model).

The second key feature is that there are large differences in participation rates across skill types. The model does a good job of replicating observed differences in participation rates. For example, the model matches the feature that participation rates for the two skill types cross over just before the pension eligibility age observed in the data. High-skilled individuals have higher participation rates before the pension eligibility age, but lower participation rates after age 60. The model also performs well in matching the average consumption levels and the variance of average log labor income by skill type. For example, low-skilled individuals have a lower average consumption but a higher variance of average log labor income compared with high-skilled individuals. The model produces a hump-shaped average consumption age profile for both skill types. Consumption peaks at ages 60–64 and then falls, which matches the pattern observed in the data.

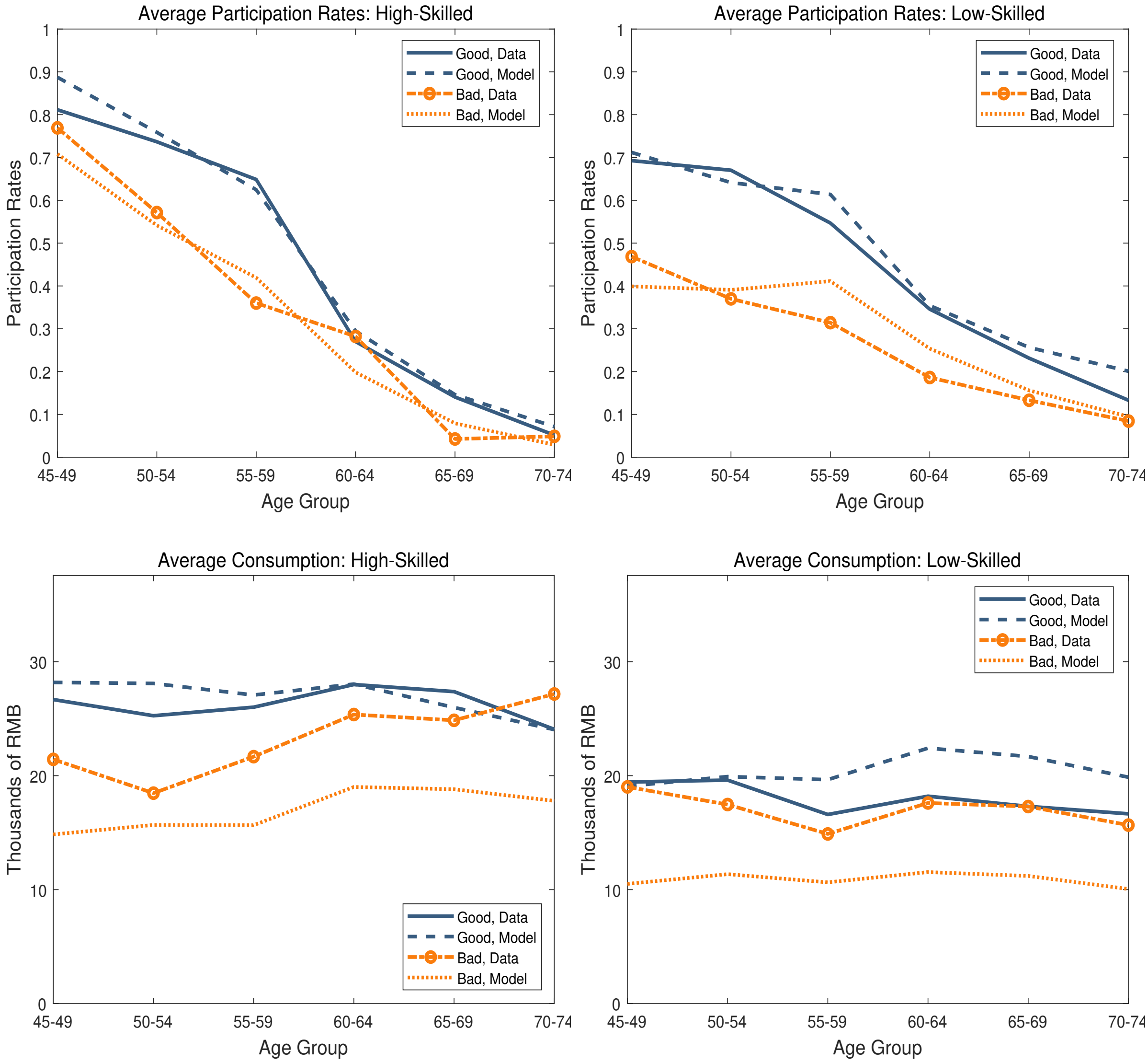
Figure 5: Participation Rates, Consumption and Variance of Average Log Labor Income: Data and Model



Data source: CHARLS.

Figure 6 shows how the model fits the average participation rates and average consumption levels by skill type and health status. For individuals in good health, the fit is quite good.

Figure 6: Participation Rates and Consumption by Skill Type and Health Status: Data and Model



Data source: CHARLS.

However, the model underpredicts the average consumption for those in bad health for both skill types. The model shows that participation rates and consumption levels vary by skill type and health status. High-skilled individuals in good health have the highest drop in average participation rates at ages 60–64, which is a 37-percentage-point decline in the data versus a 33-percentage-point decline predicted by the model. The data show that individuals in bad health have lower average participation rates and average consumption levels than those of all ages in good health. The model replicates this fact. In addition, the model matches the additional calibration moments (described at the beginning of Section 5 and listed in Table 5) well. Those moments target average labor income and average wealth by skill type and health status as well as the ratio of average wealth to average labor income by skill type.

Table 5: Calibration Targets and Model Results

Moments to Match	High-Skilled				Low-Skilled			
	Good Health		Bad Health		Good Health		Bad Health	
	Data	Model	Data	Model	Data	Model	Data	Model
Average labor income, ages 45–49	34.0	35.8	25.7	27.6	25.6	27.5	20.1	27.9
Average wealth, ages 45–49	52.4	47.7	23.1	26.7	18.1	20.6	12.9	9.0

	High-Skilled		Low-Skilled	
	Data	Model	Data	Model
Ratio of average wealth to average labor income, ages 45–74	1.5	1.8	0.7	0.9

Data Source: CHARLS.
Notes: The average labor income and average wealth are measured in thousands of *RMB*.

7 Policy Experiments

In our model, the pension system is characterized by the pension eligibility age and the pension benefits formula given by Equation (14). In the preceding sections, we showed that, under the calibrated parameter value, the model fits the data well. In this section, we use the model to evaluate the labor supply and individual welfare implications of the following three hypothetical reforms to the Chinese pension system.

Reform (i): Raising the Pension Eligibility Age. In the first counterfactual experiment, we raise the pension eligibility age from 60 to 65. This reform has two opposite effects on individual pension benefits. First, the individual loses five years of pension benefits between age 60 to 65. Second, the individual's annual pension benefits increase due to the increased career average wage $\bar{w}_t$, and the increased number of years worked y_t, before reaching the new pension eligibility age of 65 (recall from Equation (14) that the pension benefit is a function of $\bar{w}_t$ and y_t). Under Reform (i), the labor income up to the new pension eligibility age of 65 is subject to pension contribution requirements. Because the second effect is relatively small, most individuals face a substantial loss in lifetime pension benefits and will suffer welfare losses. However, both the lower pension payouts resulting from the delay in the pension eligibility age and the higher pension contributions will strengthen the pension program's finances.

Reform (ii): Reducing Pension Benefits. In the second counterfactual experiment, we keep the pension eligibility age at 60, but we reduce the annual pension benefits by a proportional factor such that the impact of Reform (ii) on the budget of the pension program's budget is the same as Reform (i).

Reform (iii): Simultaneously Raising the Pension Eligibility Age and Increasing Pension Benefits. In the third counterfactual experiment, we simultaneously raise the pension eligibility age to 65 and increase the annual pension benefits proportionally. The proportional factor is such that individual welfare for each skill type is the same as that in the status quo. Such a reform, by design, is more likely to garner public support because individuals' welfare is unchanged from the status quo. We are interested in whether it can at the same time improve the budget of the pension program.

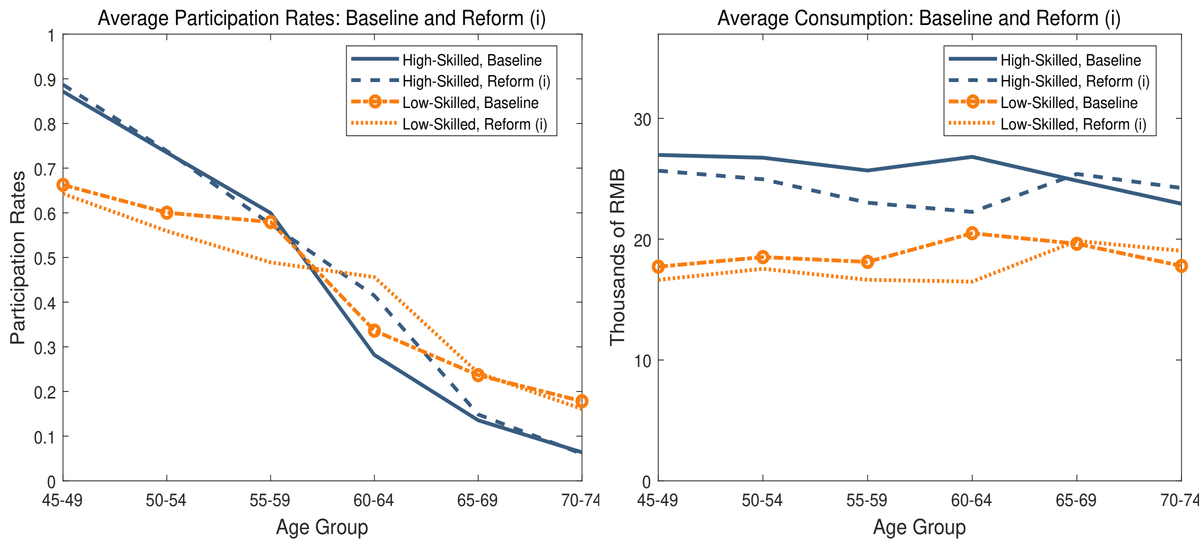
In the following, we will compare the effects of these hypothetical reforms on the labor supply, consumption, and welfare of low-skilled and high-skilled individuals. We will also assess the effects on the pension program's budget. We will measure labor supply as the average number of years an individual has worked between age 45 and the compulsory retirement age of 75. To calculate the aggregate labor supply effect, we assume that the proportion of high-skilled individuals is the same as in our estimation sample, that is, 26%. We will compare the average level of consumption by age. To assess the effects on individual welfare, we use the *compensating variation in wealth*, which is defined as the percentage change in the initial wealth level at age 45 that is required in order for the reform to achieve the same average individual-level lifetime utility, by skill type, as in the status quo. We will compare the effect on the pension program's budget based on the net present value of pension contributions and payouts, assuming that the proportion of high-skilled individuals is 26%.

7.1 Reform (i): Raising the Pension Eligibility Age from 60 to 65

In Figure 7, we present the effects of Reform (i), i.e., raising the pension eligibility age from 60 to 65, on individuals' labor supply and consumption levels by age. The left plot shows that both skill types increase their labor supply and delay retirement between age 60 and 65 in response to the higher pension eligibility age. The effect is larger for high-skilled individuals.

Table 6 reports that the model predicts an increase of 0.52 years in the average retirement age for high-skilled individuals versus an increase of 0.21 years for low-skilled individuals. More importantly, the model predicts that high-skilled individuals would work 0.67 additional years from age 45 onward, which is a 5.0% increase in high-skilled labor supply. In comparison, low-skilled individuals would decrease their average number of year worked by 0.22 years, which is an decrease of 1.8% in low-skilled labor supply from age 45 onward. The aggregate labor supply effect of Reform (i) is a 0.01-year increase in the average number of working years. The model also predicts that participation rates for those aged 60–64 would increase by 13.27 percentage points for high-skilled individuals and 11.99 percentage points for low-skilled individuals.

Figure 7: Participation Rates and Consumption by Skill Type: Baseline vs. Reform (i)



Notes: Baseline: all individuals receive pension benefits at age 60; Reform (i): raising the pension eligibility age from 60 to 65.

Table 6: Effects of Reform (i) on Labor Supply

	High-Skilled			Low-Skilled		
	Baseline	Reform (i)	Diff	Baseline	Reform (i)	Diff
Ave. retirement age	64.20	64.72	0.52	66.27	66.48	0.21
Ave. working years	13.33	14.00	0.67	12.63	12.41	-0.22
LFPR during 60–64 (%)	28.18	41.45	13.27	33.62	45.61	11.99

Notes: Baseline: all individuals receive pension benefits at age 60. Reform (i): increasing the pension eligibility age from 60 to 65. Ave. retirement age refers to the average age at which an individual exits the labor market completely. Ave. working years are the number of years an individual has worked between age 45 and the compulsory retirement age of 75.

Furthermore, the model predicts that both skill types experience a decrease in average consumption levels before the new pension age of 65 and a small increase in average consumption levels after, as shown in the right panel of Figure 7. The consumption peak shifts from the previous pension eligibility age of 60 to the new pension age of 65.

Our calculation indicates that both skill types experience welfare losses under Reform (i) compared with the baseline results, with low-skilled individuals facing larger welfare losses than high-skilled individuals. Specifically, we find that, to achieve the same lifetime utility in the baseline under Reform (i), the initial wealth level at age 45 needs to increase by 114% for high-skilled individuals and 165% for low-skilled individuals, respectively. In terms of levels, the initial wealth for the high-skilled at age 45 averages *RMB* 27,360 in the baseline; thus it needs to increase by *RMB* 31,190 in order for their welfare under Reform (i) to be the same as that in the baseline; whereas the average initial wealth at age 45 for the low-skilled is *RMB* 10,757, and it needs to increase by *RMB* 17,749 in order for their welfare in Reform (i) to be the same as that in the baseline.

Table 7: Impact of the Reforms on the Budget of the Pension System (in RMB)

	High-Skilled			Low-Skilled			Overall
	Cont45+	Payout	Net	Cont45+	Payout	Net	
Baseline	155,397.2	313,795.1	-158,397.9	104,433.8	200,665.2	-96,231.3	-112,394.6
Reform (i)	169,552.4	261,159.5	-91,607.1	115,928.2	168,769.1	-52,840.8	-62,920.0
Reform (ii)	155,295.1	242,507.2	-87,212.1	103,929.9	158,323.4	-54,393.6	-62,926.4
Reform (iii)	169,344.5	329,701.2	-160,356.7	114,989.1	202,252.5	-87,263.4	-106,267.6

Notes: All values are properly discounted or compounded to age 60 for fair comparison. The column labeled "Net" is Payout minus the contribution from 45 onward ("Cont45+"). The column labeled "Overall" is the weighted net values of high-skilled and low-skilled with the weight of high-skilled being 26%.

In Table 7, we present the impact of Reform (i) on the budget of the pension program. We sum the 28% pension contributions of earned income from age 45 to the pension eligibility age of 65. For fair comparison, we compound the contributions from 45 to 59 using the implied interest $1 + r = 1/\delta$, and discount the contributions from 60 to 65 using discount factor δ.[14] We also report the discounted present value of pension payouts (discounted to age 60) using discount factor δ. We separately calculate the contributions and payouts for the high-skilled and the low-skilled. The column labeled "Net" is simply the payout minus the pension contributions from age 45 onward ("Cont45+"). Thus a negative net value indicates that the total payout exceeds the contributions made from age 45 onward.[15] Finally, the column labeled "Overall" is the weighted average of the "Net" values for the high-skilled and the low-skilled, assuming a 26% fraction of high-skilled as in our sample.

The first row in Table 7 indicates that in the baseline, high-skilled individuals can expect to receive about 313,795 RMB (evaluated at age 60) as a payout from the pension system, while their contribution from 45 onward to the pension system is about 155,397 RMB (also evaluated at age 60). In comparison, low-skilled individuals can expect to receive about 200,665 RMB from their pension payout, and contribute about 104,434 RMB to the system.

[14] Recall that in China, income earned after the pension eligibility age is not subject to pension contributions.

[15] Note that we are only measuring the contributions to the pension system after age 45, thus a negative net value does not necessarily mean that an individual's *lifetime* contribution to the pension system is lower than his pension payout.

The second row in Table 7 indicates that Reform (i) significantly improves the pension system's budget. For high-skilled individuals, their contributions from age 45 onward increase to 169,553 RMB, representing a 9.1% increase from the baseline contributions of 155,397 RMB; at the same time, their payout decreases to 261,160 RMB, representing a 16.8% decrease from the baseline payout of 313,795 RMB. For low-skilled individuals, their contributions from age 45 onward increase to 115,929 RMB, which represents a 11.0% increase from their baseline contributions of 104,434 RMB, while at the same time, their payout decreases to 168,770 RMB, which represents a 15.9% decrease from the baseline payout of 200,665 RMB. The differential impacts of the reform on the workers of different skill-types are quite striking, and they reflect the differences between the skill types in their wages and thus pension levels, their life expectancy, and labor supply responses. Comparing Reform (i) and the baseline, we find that delaying the pension eligibility age to 65 can significantly improve the system's budgetary outlook. Of course, we should emphasize that the calculations we presented are relevant only for a fully-funded system; for China's BOAI which is mostly a Pay-As-You-Go system, despite its relatively small and notional individual account, the budgetary concerns mainly arise from the expected worsening of the old-age dependency ratio.

7.2 Reform (ii): Reducing Pension Benefits

Under Reform (ii), we leave the pension eligibility age unchanged at 60, but proportionally reduce annual pension benefits such that the pension program's budget is the same as for Reform (i). That is, we reduce annual pension benefits by a proportional factor such that the net present value of the pension budget, accounting for both the discounted stream of pension payouts and compounded stream of pension contributions, is the same under Reform (ii) as under Reform (i).

Specifically, let $\rho_2 \in (0,1)$ denote the proportional factor associated with Reform (ii). We determine the value of ρ_2 as follows. Let P_{60} and P_{65} denote the annual pension benefits calculated under the current pension rule (using Equation (14)) when the pension eligibility age is 60 and 65, respectively. Let B_i denote the pension program's budget under Reform (i), and let $B_{ii}(\rho_2)$ denote the pension program's budget under Reform (ii) when the pension eligibility age stays at 60, but the pension payout level is changed from P_{60} to $P_{60} * \rho_2$. Then, the level of ρ_2^* is chosen to satisfy

$$B_{ii}(\rho_2^*) = B_i. \tag{18}$$

We note that in B_i and $B_{ii}(\rho_2)$, we properly compound the pension contributions using the implied risk-free interest rate $1 + r = 1/\delta$, and discount the pension payouts using the discount factor δ (listed in Table 1), to age 60 for fair comparison, and we assume that the labor income before the respective pension eligibility age is subject to the 28% pension contributions, weighted by the percentage of high- and low-skill types in CHARLS. Equation (18) is solved by iteration, where in each iteration for a given ρ_2, we solve the model and then simulate individuals' labor supply decisions, wage profiles, health transitions, and pension benefits in order to calculate $B_{ii}(\rho_2)$. We find that

$$\rho_2^* = 0.6685$$

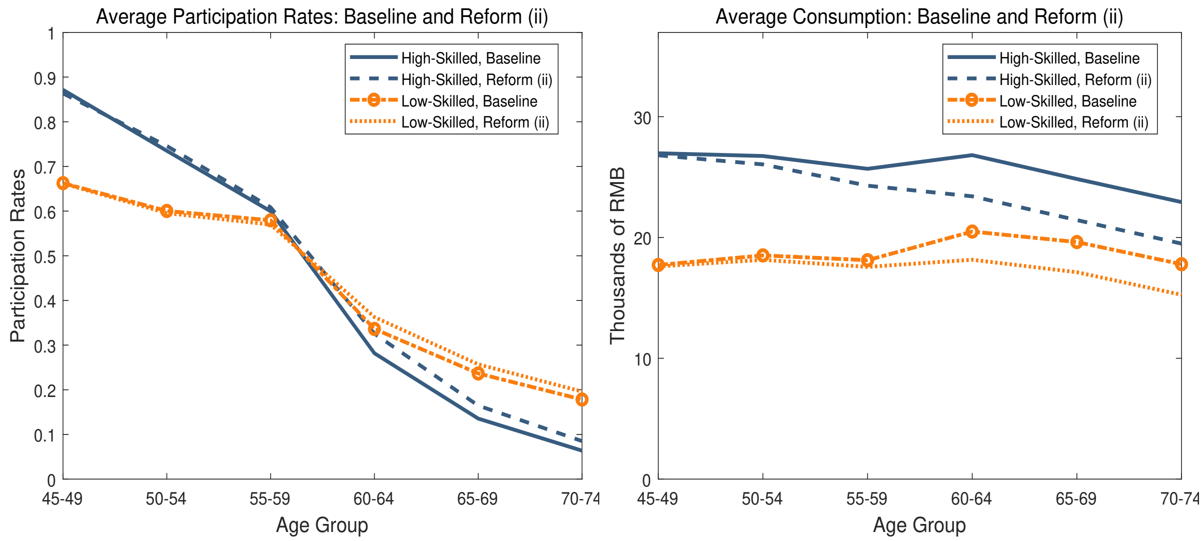
solves Equation (18).

Now we describe the key findings from Reform (ii) under $\rho_2^* = 0.6685$. Figure 8 shows the effects of Reform (ii) on labor supply and consumption, by skill type. Compared with the baseline results, both skill types increase their labor supply, delay retirement, and experience lower average consumption levels across all ages under Reform (ii). In Table 8, we show that under Reform (ii) the model predicts that the average retirement age for high-skilled individuals will increase by 0.86 years relative to the baseline; and they will work 0.51 additional years from age 45 until the compulsory retirement age of 75, which represents a 3.8% increase in labor supply relative to the baseline. In comparison, the model predicts that the average retirement age for low-skilled individuals will increase by 0.63 years, and their overall working years between 45 and 75 will increase by 0.22 years, which represents a 1.8% increase relative to the baseline. Averaging over the two skill types, the aggregate labor supply effect of Reform (ii) is a 0.3-year increase in the average number of working years.

In terms of lifetime welfare, the compensating variation in wealth for Reform (ii) indicates that, in order for high-skilled (low-skilled, respectively) individuals to achieve the same lifetime utility as their respective baseline level, their initial wealth level at age 45 needs to increase by 229% (298%, respectively). In terms of levels, recall that the high-skilled initial wealth level at age 45 is *RMB* 27,360 and needs to increase by *RMB* 62,654; whereas the low-skilled initial wealth at age 45 is *RMB* 10,757 and needs to increase by *RMB* 32,056.

In terms of the budgetary implications for the pension system, we note that, by the choice of ρ_2^* according to Equation (18), Reform (ii) achieves the same overall improvement of the budget of the pension program relative to that of the baseline; i.e., the "Overall" number for Reform (i) and (ii) are almost identical as shown in Table 7. However, row 3 of Table 7 also shows that Reform (ii) achieves this same overall budgetary improvement by reducing payouts much more than Reform (i), for both the high-skilled and the low-skilled individuals, while only slightly changing the contributions after age 45. Row 3 shows that under Reform (ii) the payouts of the high-skilled is 242,507 RMB, which is 22.7% lower than the baseline; while for the low-skilled, the payout is 158,324 RMB, representing a 21.1% reduction from the baseline of 200,665 RMB.

Figure 8: Participation Rates and Consumption by Skill Type: Baseline vs. Reform (ii)



Notes: Baseline: all individuals receive pension benefits at age 60; Reform (ii): proportionally reducing pension benefits per annum so that the impact on the pension system's budget remains the same as in Reform (i).

Table 8: Effects of Reform (ii) on Labor Supply

	High-Skilled			Low-Skilled		
	Baseline	Reform (ii)	Diff	Baseline	Reform (ii)	Diff
Ave. retirement age	64.20	65.06	0.86	66.27	66.91	0.63
Ave. working years	13.33	13.84	0.51	12.63	12.86	0.22
LFPR during 60-64 (%)	28.18	32.57	4.39	33.62	36.28	2.66

Notes: Baseline: all individuals receive pension benefits at age 60. Reform (ii): proportionally reducing pension benefits per annum so that the pension program's budget is the same as in Reform (i). Ave. retirement age refers to the average age at which an individual exits the labor market completely. Ave. working years are the number of years an individual has worked between age 45 and the compulsory retirement age of 75.

7.3 Reform (iii): Simultaneously Raising the Pension Eligibility Age and Increasing Pension Benefits

Reforms (i) and (ii) result in substantial savings for the pension program, but they also lead to large reductions in individual welfare relative to the status quo. Here, we consider an alternative reform proposal that, on the one hand, ensures that all individuals achieve the same expected lifetime welfare as that under the baseline, and on the other hand, generates budgetary savings for the pension program. Under Reform (iii), we simultaneously increase the pension eligibility age from 60 to 65 (as in Reform (i)), but to compensate individuals for the delay in pension age we proportionally increase the annual pension benefit levels, using proportional factors that differ by skill type.

Specifically, let $\rho_3^s > 1$ denote the proportional factor for individuals of skill type $s \in \{h, l\}$ under Reform (iii). As in the previous subsection, let P_{65} denote the annual pension benefits calculated under the current pension rule (using Equation (14)) when the pension eligibility age is 65 (as in Reform (i)). Under Reform (iii), individuals of skill type s receive $P_{65} * \rho_3^s$ where ρ_3^s is calculated to ensure that they achieve the same welfare as the baseline as follows: let W_0^s denote the discounted expected lifetime welfare of individuals of skill type s at age 45 under the baseline, and let $W_{iii}^s(\rho_3^s)$ denote the discounted expected lifetime welfare of individuals of skill type s at age 45 under Reform (iii), when the proportional adjustment factor of pension benefits after 65 is ρ_3^s; then, the level of $\rho_3^{s^*}$ is chosen to satisfy

$$W_{iii}^s(\rho_3^{s^*}) = W_0^s. \tag{19}$$

We solve Equation (19) iteratively, and during each iteration, we solve the model and then simulate individuals' labor supply decisions, wage profiles, health transitions, and pension benefits in order to calculate $W_{iii}^s(\rho_3^s)$). We find that

$$\rho_3^{l^*} = 1.204, \quad \text{and} \quad \rho_3^{h^*} = 1.263$$

solves Equation (19) for low-skilled ($s = l$) and high-skilled ($s = h$) individuals, respectively.[16]

Now we describe the results under Reform (iii) with $\rho_3^{l^*} = 1.204$ and $\rho_3^{h^*} = 1.263$. Figure 9 shows the effects of Reform (iii) on labor supply and consumption by skill type. High-skilled individuals increase their average labor supply and retire late. Low-skilled individuals will retire early and decrease their labor supply. Table 9 reports that the model predicts a 0.47-year increase in the average number of working years for the high-skilled versus a 0.63-year decrease for the low-skilled. This implies that the overall labor supply increases by 3.5% for high-skilled

[16]Recall from Figure 1 in Section 4.3 that high-skilled individuals have lower average labor force participation rates than low-skilled individuals after age 60, which indicates that we need to compensate the high-skilled more if we increase the pension eligibility age to 65.

individuals and decreases by 5% for low-skilled individuals from age 45 onward; the aggregate labor supply effect of Reform (iii) is a 0.35-year decrease in the average number of working years. The effects of this combined reform on individuals' consumption levels are mixed. Both skill types experience a decrease in average consumption before age 65 but enjoy higher average consumption levels from age 65 onward. Reform (iii) ensures that both skill types achieve the same expected lifetime welfare as in the baseline.

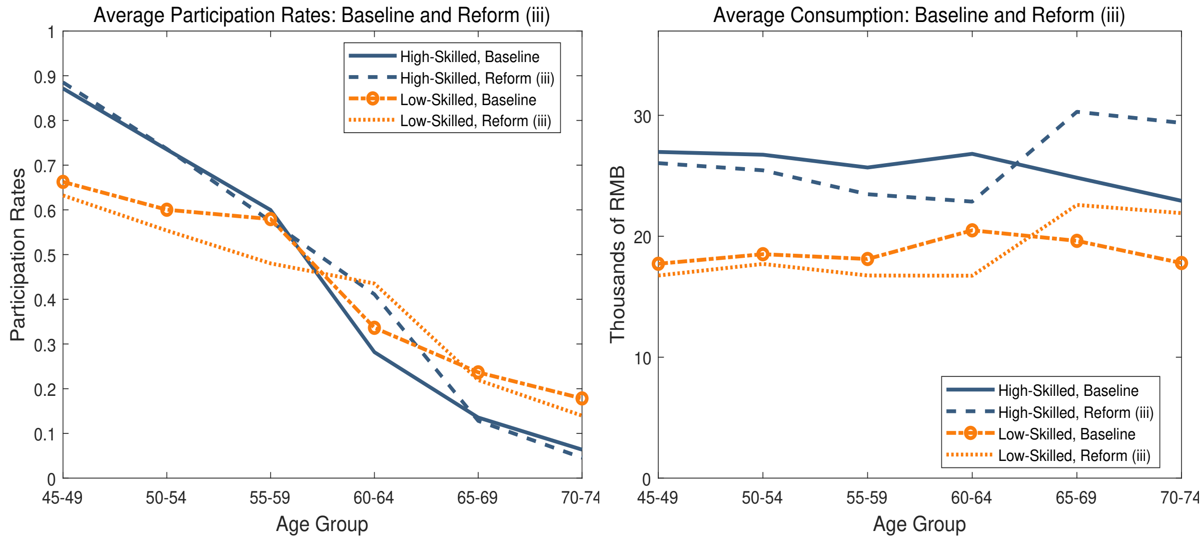
In terms of the budgetary implications, we see from Table 7 that overall Reform (iii) cuts the shortfall of the pension system by about 5.5% ([(112,394-106,267)/112,394]. Notice, however, Reform (iii) achieves the improvement in the pension system's budget by both increasing the contributions to *and* the payouts from the pension system for both the high- and the low-skilled individuals. Specifically, the contributions from age 45 onward to the pension system by the high-skilled increase by 9% relative to the baseline, from 155,397 RMB in the baseline to 169,345 RMB under Reform (iii); at the same time, their payouts from the pension system increase by 5.1%. For the low-skilled individuals, their contributions to the pension system from age 45 onward increase by 10% from the baseline, while their payouts from the pension system increase slightly by less than 1%. Note that the payouts for both types of individuals increase much less than the $\rho_3^{l*} = 1.204$ and $\rho_3^{h*} = 1.263$ we calculated earlier; the reason is that they are receiving the pension payouts for fewer years and later in their lives because of the increase of the pension eligibility age from 60 to 65; this is the case despite the fact that their annual pension levels are significantly increased relative to the baseline, both because of the proportionality factors $\rho_3^{l*} = 1.204$ and $\rho_3^{h*} = 1.263$, and because the workers have higher average pre-retirement earnings under Reform (iii) which raises their statutory pension benefit levels. Also, we note that Reform (iii) slightly reduces the overall labor supply after age 45, nonetheless, there are substantial increases in the contributions to the pension program relative to the baseline for both skill types; this is largely because the earnings between 60 and 64 are taxed under Reform (iii) but not in the baseline.

Table 9: Effects of Reform (iii) on Labor Supply

	High-Skilled			Low-Skilled		
	Baseline	Reform (iii)	Effect	Baseline	Reform (iii)	Effect
Ave. retirement age	64.20	64.21	0.01	66.27	65.77	-0.51
Ave. working years	13.33	13.8	0.47	12.63	12.00	-0.63
LFPR during 60–64 (%)	28.18	41.12	12.94	33.62	43.52	9.9

Notes: Baseline: all individuals receive pension benefits at age 60. Reform (iii): simultaneously increasing the pension eligibility age to 65 and proportionally increasing annual pension benefits so that both skill types maintain the same welfare level as the baseline level. Ave. retirement age refers to the average age at which an individual exits the labor market completely. Ave. working years are the number of years an individual has worked between age 45 and the compulsory retirement age of 75.

Figure 9: Participation Rates and Consumption by Skill Type: Baseline and Reform (iii)



Notes: Baseline: all individuals receive pension benefits at age 60. Reform (iii): simultaneously increasing the pension eligibility age to 65 and proportionally increasing annual pension benefits so that both skill types maintain the same welfare level as the baseline level.

8 Conclusion

The especially rapid population aging in China places financial pressure on its basic old age pension system, and the Chinese government is considering plans to gradually increase the pension age as one of the policy responses. In this paper, we evaluate the implications of plausible alternative reforms to the BOAI pension program on the labor supply and individual welfare of Chinese urban males aged 45 and older.

To this end, we developed a heterogeneous-agent life-cycle model featuring health, mortality, and income risk components. In our model, individuals make decisions regarding labor supply and consumption. We particularly emphasize the heterogeneous effects of the pension reforms on low-skilled and high-skilled individuals who face large differences in health and wage dynamics. We calibrate our model parameters using data from CHARLS and CLHLS, and approximate the statutory pension benefit formula of the BOAI pension program in China using a regression-based method. Our calibrated model successfully replicates the labor supply and consumption behavior of individuals with heterogeneous skill types.

We use the calibrated model to evaluate three pension reforms: (i) increasing the pension eligibility age from 60 to 65, but keeping the current pension benefit rule unchanged; (ii) keeping the pension eligibility age at 60, but proportionally lowering pension benefits so that the pension program's budget is the same as under Reform (i); and (iii) increasing the pension age to 65 and increasing pension benefits so that both high- and low-skilled individuals attain the same individual welfare level as that in the status quo.

We find that, both Reforms (i) and (ii) substantially improve the budget of the pension system relative to the status quo, but at the cost of large individual welfare losses for both skill types. In contrast, we find that Reform (iii) could cut the shortfalls of the pension system in the status quo by about 5.5%, while at the same time keep the individuals of both skill type as well off as they are in the status quo. Reforms (i) and (ii) yield a small increase in the overall labor supply, but Reform (iii) leads to a slight decrease. Our analysis is focused on China's pension system, but we believe that the insights from our analysis may have broader applicability to other countries that are experiencing similar financial pressures to their pension systems due to population aging.

Our analysis has several limitations. First, we have assumed a fixed distribution of high-skilled and low-skilled individuals throughout our analysis. That is, we have assumed that the share of high-skilled individuals (those who have completed high school or further education) is 26% as in our sample. This share is growing in China (Ministry of Education of the People's Republic of China, 2019). Our results show that high-skilled individuals increase their labor force participation more than low-skilled individuals in response to the three pension reforms. Therefore, we expect that the aggregate effects for each of the three proposed pension reforms will be larger with a higher proportion of high-skilled individuals. Second, our analysis does not account for implications of the demographic change, particularly the worsening of the dependency ratio, on the budget of the BOAI system, which is largely a Pay-As-You-Go system; instead we focused on the impact on the individuals' labor supply and welfare, and only discussed the within-cohort budget implications of the alternative reforms. Third, our analysis is a partial equilibrium analysis in the sense that we do not consider the potential effect of the pension reform on wages. A general equilibrium model in which the labor market responds to the pension reforms and the changing demographics is an important area for future research. Fourth, our analysis does not consider the potential effects of retirement on health and mortality. Using data from the China Health and Nutrition Survey, Che and Li (2018) find that the probability of "fair" or "poor" self-reported health among white-collar individuals decreases by 34 percentage points after retirement, but the authors find no significant effect for blue-collar individuals. Using data from CHARLS, Feng et al. (2020) find that retirement is positively correlated with the body mass index (BMI) and the weight of men, especially men with low education levels. Health dynamics and mortality play an important role in our analysis as channels through which pension reforms have heterogeneous effects on the labor supply and individual welfare of high-skilled and low-skilled individuals. The effects of the reforms we considered in this paper are likely to differ in magnitude if we consider the potential effects of retirement on health and mortality. We intend to study the links between retirement and health and mortality in future research. Finally, it would also be important to study the retirement decisions of women, as well as the joint decision of couples.

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Appendix A A Regression-Based Method to Approximate the Statutory Pension Benefit P^*

The statutory pension benefit for China's BOAI program consists of two components: the social pooling account and the individual account (State Council, 2005). Specifically, the social pooling account is calculated based on the previous year's local monthly average wage of all employed individuals, the individual's average monthly wage from all the years before the statutory pension age, and the number of contribution years. Each full contribution year qualifies for an increment that is equal to 1% of the accumulated social pooling benefit balance. The balance of the individual account equals the total accumulation of the 8% individual contribution divided by the projected number of payment months, which is determined by the average life expectancy at retirement, the individual's retirement age, interest rates, and other factors. Under the current statutory pension age, the projected number of payment months is 139 for urban males retiring at age 60 (State Council, 2005).

As mentioned in Section 3.5, modeling the above pension rules would require us to keep track of an individual's entire earnings history, work history, and year of retirement, which is computationally unfeasible. Instead, we use a regression-based method to approximate the two components of the statutory pension benefit. The regression-based method only requires two state variables, which are the average wage in an individual's career and the number of years the individual has worked before the statutory pension age. We find that this regression-based method provides the approximated pension benefit P and explains over 96% of the variations in the statutory pension benefit P^*.

We calculate the approximated pension benefit P as follows:

1. We simulate a sample of individuals with a wage history from age 25 to age 59. The individuals' health transitions, which are required for the calculation of the wage offer, are also simulated. We perform out of sample simulation for wage history between ages 25 and 44 to properly calculate the 28% pension contribution before age 45 and the pension benefit upon pension eligibility age because wages are not observed before age 45 in CHARLS.

2. We then simulate the labor supply history from age 45 to age 59. Recall that we assume everyone worked 20 years before age 45. The labor supply decision between ages 45 and 59 is simulated using a binomial distribution with the probability of working $\bar{p}$ calibrated using the average participation rate among males, aged 45–49 in CHARLS wave 2011.[1]

3. We now have the full wage information history for all employed individuals. We then

[1] One could use the age-specific probability of working but this leads to little improvement in the accuracy of the regression-based approximation method.

calculate the statutory *monthly* pension benefit P^* for individual i at retirement year T^*, which we denote by P_{i,T^*}, as follows:

$$P^*_{i,T^*} = SP_{i,T^*} + ID_{i,T^*}, \tag{A1}$$

where SP_{i,T^*} is the social pooling account benefit and ID_{i,T^*} is the individual account benefit, and they are given by their respective regulatory formulae as:

$$SP_{i,T^*} = \frac{(LS\_Wage_{T^*-1}) * (1 + AW\_Index_{i,T^*})}{2} * Years_{i,T^*} * 1\%, \tag{A2}$$

$$ID_{i,T^*} = \sum_{t=1}^{T^*} (8\% * CW_{i,t})/139, \tag{A3}$$

To explain (A2), first note that $LS\_Wage_{T^*-1}$ is the local average social wage in year $t = T^* - 1$, and $Years_{i,T^*}$ is the number of working years for individual i up to year $t = T^*$. To understand AW_Index_{i,T^*}, we first need to define $W\_index_{i,t}$, which is defined as the ratio of individual i's wage $Wage_{i,t}$ relative to the local average social wage LS_Wage_t in year t prior to his retirement, subject to a contribution bound of 60% and 300%:[2]

$$W\_index_{i,t} = \min\left\{\max\left\{0.6, \frac{Wage_{i,t}}{LS\_Wage\_t}\right\}, 3\right\} \tag{A4}$$

AW_Index_{i,T^*} in Equation (A2) is the average of the wage index calculated according to (A4) for individual i's working years up to year $t = T^*$. In Equation (A3), $CW_{i,t}$ is the contributory wage for individual i in year t, where:

$$CW_{i,t} = W\_index_{i,t} * LS\_Wage_t. \tag{A5}$$

4. Once we calculate the statutory pension benefit P^*_{i,T^*} for each individual i at retirement $t = T^*$ using Equations (A1), (A2), and (A3), we can then estimate $\boldsymbol{\beta} \equiv \{\beta_{p0}, ..., \beta_{p6}\}$ in Equation (14) using P^*_{i,T^*} as the dependent variable of the regression.

5. The estimated parameters $\hat{\boldsymbol{\beta}}$ are then used to calculate the approximated pension benefit P using Equation (14).

[2] According to the statutory pension rule, if an individual's wage is below 60% of the local social average wage, the contribution to the pension system, including both the social pooling account and the individual account, is 20% of 60% of the local social average wage; if an individual's wage is higher than 300% of the local average social wage, then the individual is only required to contribute 20% of 300% of the local social average wage.

Appendix B The Numerical Solution Method

The numerical solution method starts with discretizing the state variables $\{W_t, \bar{w}_t, y_t, \bar{\mu}^s, \lambda_t^s, \mu_t^s\}$. Following Iskhakov et al. (2017), we use the DC-EGM to construct grids for after-consumption wealth $\overline{W}_t$. Because changes in wealth are likely to cause larger behavioral responses at low levels of wealth, the grid is more finely discretized in this region. There are 50 endogenous grid points for $\overline{W}_t$, two grid points for the individual's fixed effect $\bar{\mu}^s$, five grid points for the idiosyncratic transitory shock λ_t^s and the persistent shock μ_t^s, six grid points for the average number of working years y_t, and nine grid points for the average labor income $\bar{w}_t$. Linear interpolation is used for points that are not on the grid and expectations are evaluated numerically using the Gauss-Hermite quadrature method (Judd, 1998).

We first define some partial derivatives:

$$\frac{\partial u^s(C_t, H_t, \tau_t)}{\partial C_t} = \alpha^s C_t^{\alpha^s - \alpha^s\gamma - 1}(1 - \omega^s(H_t)\tau_t)^{(1-\alpha^s)(1-\gamma)}, \tag{B1}$$

$$\frac{\partial v^s(W_t)}{\partial W_t} = \alpha^s\theta(W_t + \kappa)^{\alpha^s - \alpha^s\gamma - 1}, \tag{B2}$$

$$\frac{\partial W_{t+1}}{\partial W_t} = (1 + r), \tag{B3}$$

$$\frac{\partial W_{t+1}}{\partial C_t} = -(1 + r). \tag{B4}$$

The terminal value function is set equal to bequest utility: $V_T^s = v^s(W_T)$. At time $t = T - 1$ (age 99), the first-order condition for the optimal consumption is given by:[3]

$$\begin{aligned} 0 &= \frac{\partial u^s(C_{T-1}, H_{T-1}, \tau_{T-1})}{\partial C_{T-1}} + \delta\left\{[v^s(W_T)]'\frac{\partial W_T}{\partial C_{T-1}}\right\}, \\ C_{T-1}^* &= \left\{\frac{\delta(1+r)\,[v^s(W_T)]'}{\alpha^s(1 - \omega^s(H_{T-1})\tau_{T-1})^{(1-\alpha^s)(1-\gamma)}}\right\}^{\frac{1}{\alpha^s - \alpha^s\gamma - 1}}, \end{aligned} \tag{B5}$$

where $W_T = \overline{W}_{T-1}(1 + r)$ and $\tau_{T-1} = 0$. As we have the after-consumption wealth grid, the FOC can be solved.

At time $t = T - 2, ..., 0$ (age 98–45), the FOC for optimal consumption is given by:

$$0 = \frac{\partial u^s(C_t, H_t, \tau_t)}{\partial C_t} + \delta\mathbb{E}_t\left\{\sum_{H_{t+1}\in\{g,b\}} \pi_t^s(H_t, H_{t+1})\frac{\partial V_{t+1}^s}{\partial W_{t+1}}\frac{\partial W_{t+1}}{\partial C_t} + \pi_t^s(H_t, d)[v^s(W_{t+1})]'\frac{\partial W_{t+1}}{\partial C_t}\right\},$$

Using the envelope condition

$$\frac{\partial V_t^s}{\partial W_t} = \frac{\partial u^s(C_t, H_t, \tau_t)}{\partial C_t}, \tag{B6}$$

[3] As the value function is concave, the first-order conditions are sufficient for an optimum.

we have:

$$C_t^* = \left\{ \delta(1+r)\mathbb{E}_t \frac{\sum_{H_{t+1}\in\{g,b\}} \pi_t^s(H_t, H_{t+1}) \frac{\partial u^s(C_{t+1}, H_{t+1}, \tau_{t+1})}{\partial C_{t+1}} + \pi_t^s(H_t, d)[v^s(W_{t+1})]'}{\alpha^s(1-\omega^s(H_t)\tau_t)^{(1-\alpha^s)(1-\gamma)}} \right\}^{\frac{1}{\alpha^s - \alpha^s\gamma - 1}}, \tag{B7}$$

where $\tau_t = 0$ for $t = T-2, ..., 30$ (age 98–75). At time $t = T-26, ..., 0$ (age 74–45), the labor supply decision τ_t is solved by comparing the value function under the optimal consumption when the individual is working versus the value function under the optimal consumption when the individual is not working.