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Author(s): Selahattin İmrohoroğlu and Sagiri Kitao

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Social Security Reforms: Benefit Claiming, Labor Force Participation, and Long-run Sustainability†

By Selahattin İmrohoroğlu and Sagiri Kitao*

This paper develops a general equilibrium life-cycle model with endogenous labor supply in both intensive and extensive margins, consumption, saving, and benefit claiming to measure the long-run effects of a proposed Social Security reform. Agents in the model face medical expenditure, wage, health, and survival shocks. Raising the normal retirement age by two years increases labor supply by 2.8 percent and the capital stock by 12.6 percent, showing that both margins of adjustment are critical. General equilibrium effects are important to account for the effects of reform on savings, although the effects on labor supply are less important. (*JEL* D91, E21, H55, I13, J22)

The specter of large predicted future deficits associated with the Social Security system has motivated policymakers to consider a range of possible reforms. Two such reforms are to increase the early retirement age and to increase the normal retirement age. In this paper, we assess the effects of these reforms on allocations and the solvency of the system in the long run.

Our objective of assessing the efficacy of proposed reforms compels us to examine labor supply responses as one of the most important mechanisms that determine the effects of these reforms. In addition, a first order issue that needs to be taken into account is that eligibility for Social Security and claiming of Social Security are not the same. Therefore, in order to analyze these types of reforms, it is critical to have a model that captures the key features of the claiming decision and its interaction with labor supply. However, existing general equilibrium studies of Social Security have made claiming exogenous, and are therefore not capable of answering the question of interest. As a result, a model in which both benefit claiming and labor force participation are endogenous in a general equilibrium setting is needed

* İmrohoroğlu: University of Southern California, Marshall School of Business, Finance and Business Economics Department, 3670 Trousdale Parkway, Los Angeles, CA 90089 (e-mail: selo@marshall.usc.edu); Kitao: Hunter College, Department of Economics, 695 Park Avenue, New York, NY 10065 (e-mail: sagiri.kitao@gmail.com). The authors thank Hugo Benitez-Sílva, Eric French, Ayşe İmrohoroğlu, Francesc Ortega, Gianluca Violante, and seminar participants at Canon Institute for Global Studies, the City University of New York Graduate Center, Federal Reserve Board of Minneapolis, Federal Reseve Bank New York, Kyoto University, Midwest Macroeconomics Meetings in Nashville, New York University Alumni Conference, NYU Stern School of Business, SED Meetings in Ghent, State University of New York Stony Brook, University of California Riverside, University of California San Diego, University of Hawaii, Yonsei University, and the 35th Annual Economic Policy Conference at the Federal Reserve Bank of St. Louis for useful comments. İmrohoroğlu and Kitao acknowledge a support from the Advancing Scholarship in the Humanities and Social Sciences program at USC Provost's office, and Kitao from the US Social Security Administration to the Center for Retirement Research at Boston College through the Steven H. Sandell Grant Program.

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to measure the effects of proposed reforms on the macroeconomy and the long-run solvency of the Social Security program.

Our setup is a quantitative general equilibrium model of overlapping generations with endogenous labor supply in both extensive and intensive margins, consumption, asset holding, and benefit claiming. Agents in our model face medical expenditure, wage, health, and survival risks. The model is calibrated to data from the Medical Expenditure Panel Survey (MEPS) and the Health and Retirement Survey (HRS), among other sources. The economic environment contains the current Social Security rules, including the progressive benefit formula as a function of past earnings, the earnings test, actuarial reduction factor for early retirees, and delayed retirement credits for late retirees. Health shocks are calibrated from the MEPS. Most but not all individuals have access to employer provided health insurance, which partially covers the medical expenditures until they become eligible for Medicare at age 65. Our benchmark model generates Social Security benefit claiming and labor force participation behavior that are in line with their observed counterparts in the US data.

We use our model to evaluate the long-run effects of two counterfactual experiments and study how they affect the sustainability of the US pension system in the future with the projected aging of the population. We motivate these experiments as changes in the key parameters of the current status quo without any dramatic change in the nature of the system itself, which we believe to be more politically feasible. In our first experiment, we simulate a reform that raises the earliest retirement age by two years. In this case, most of the macroeconomic indicators remain essentially unchanged, including the Social Security budget. Although the government "saves" on the payment of retirement benefits for individuals at ages 62 and 63, it "loses" by having to pay higher benefits later on because of the permanent increase in the benefits taken at later ages. In the second policy experiment, we increase the normal retirement age by two years. There is a 12.6 percent increase in the capital stock, with a 2.8 percent increase in labor supply. There is a sizeable reduction in the fraction of early benefit takers. Combined with a 6 percentage point increase in the participation rate of older workers, the Social Security budget improves significantly. Therefore, an increase in the normal retirement age by two years goes a long way to restore fiscal balance in the long run, although by itself, it is still not sufficient.

The paper is organized as follows. Section I discusses the related literatures and our contribution to them. The model economy is described in Section II. The calibration of the model is discussed in Section III. Section IV presents the quantitative findings of the paper. The last section concludes.

I. Related Literature

Our paper builds on and contributes to a long tradition in macroeconomics that uses large-scale, discrete-time overlapping generations models pioneered by Auerbach and Kotlikoff (1987). In more recent versions, this class of models is extended to incorporate endogenous heterogeneity within cohorts generated by uninsurable shocks and incomplete markets, and has become the workhorse in addressing quantitative fiscal policy questions.[1] In papers on Social Security and its reforms in the United States along this line of literature, the decision to claim benefits is taken as exogenous, and labor supply, if modeled endogenously, is allowed to adjust only along the intensive margin.[2]

There are several recent papers that focus on labor force participation along the life-cycle and retirement decisions. Rogerson and Wallenius (2009a) and Prescott, Rogerson, and Wallenius (2009) introduce a nonlinear transformation of hours worked to the labor efficiency in a deterministic life-cycle model with endogenous intensive and extensive margins of labor supply, and they study the effect of tax and transfer policies. Rogerson and Wallenius (2009b) allow for home production to explain the pattern of retirement and analyze the degree of nonconvexities in production implied by alternative models. Kitao, Ljungqvist, and Sargent (2011) study the life-cycle pattern of unemployment and labor participation in the United States and Europe, and analyze the effect of labor market policies.[3] To the best of our knowledge, our paper is the first in this line of literature that allows for endogenous decisions in both benefit claiming and labor force participation, and studies how they affect the impact of Social Security reforms in the United States through the adjustment on these margins.

In addition, our paper makes contact with a partial equilibrium and structural estimation tradition that specifies and simulates structural dynamic programming models of life-cycle behavior. Rust and Phelan (1997) develop a dynamic programming model in which individuals face idiosyncratic income and health risks. Assuming that consumption is equal to income at every age, their model explains the two peaks of retirement by market incompleteness in conjunction with the availability of health insurance and Medicare eligibility.[4] Our model is closest to that of French (2005), which allows individuals to accumulate one-period riskless assets and estimates a model to explain the pattern of job exits at old ages and the roles of Social Security benefit rules.[5]

Both papers use a large-scale, life-cycle model in which individuals choose savings, labor supply in both intensive and extensive margins, and Social Security benefit claims, while they face wage, health, and mortality risks. French estimates parameters of the model to match the life-cycle patterns of assets, hours, and participation rates, and he has additional features including spousal income that depend on the individual's wage and age, and private pensions, which provide an incentive to exit the labor

[1] See, for example, Hubbard and Judd (1987); İmrohoroğlu, İmrohoroğlu, and Joines (1995); Huang, İmrohoroğlu, and Sargent (1997); Conesa and Krueger (1999); De Nardi, İmrohoroğlu, and Sargent (1999); and Kotlikoff, Smetters, and Walliser(1999). Recently, health shocks over the life cycle have also been incorporated in this class of models to evaluate the role of medical insurance policies. Attanasio, Kitao, and Violante (2011) and Jeske and Kitao (2009) introduce health shocks in a heterogeneous-agent, overlapping generations model and analyze the policies on Medicare and employer-provided health insurance. De Nardi, French, and Jones (2010) build a model of retirees and investigate the role of longevity risk and health expenditure uncertainty on the savings behavior at old ages.

[2] The work by Díaz-Giménez and Díaz-Saavedra (2009) is an exception, and builds a model of endogenous retirement calibrated to the Spanish economy and studies the effects of increasing the retirement age.

[3] Alonzo-Ortiz (2010) studies the relation between features of Social Security systems and retirement behavior across OECD countries.

[4] Blau and Gilleskie (2006) find that employer-based health insurance has a significant effect on employment of old age individuals.

[5] More recent papers extend the literature by incorporating various features, such as the joint labor supply decision of married couples (van der Klaauw and Wolpin 2008), preference heterogeneity (Gustman and Steinmeier 2005), rules on the benefit adjustment associated with early retirement and earnings test (Benitez-Sflva and Heiland 2008), and uncertainty about the future Social Security rules (Benitez-Sflvaet, Dwyer, and Sanderson 2007) to better understand the pattern of labor supply and retirement behaviors.

market at certain ages, which our paper abstracts from. Being a partial equilibrium model, the paper assumes fixed factor prices and abstracts from the government budget across alternative models and policy simulations. Our approach is to use a calibrated model that matches the key macro statistics as well as selected moments to capture the life-cycle pattern of savings and labor supply and to assess the impact of reforms on aggregate variables and sustainability of the Social Security system under the projected changes in demographics. We quantify the required adjustments in fiscal policy as well as in factor prices in response to a shift in mortality risks and dependency ratios and to potential reforms in retirement ages. We also incorporate medical expenditure risks that evolve stochastically with age and health status, and heterogeneity in the insurance arrangement across individuals through employer-based coverage and Medicare, which French's model abstracts from.

II. Model

A. *Demographics and Health Status*

The economy is populated by overlapping generations of individuals of age $j = 1, 2, \ldots, J$. Agents face exogenous uncertainty about their health status h.[6] The health status evolves according to a Markov chain between two states of good and bad, $\{h^g, h^b\}$, with a transition matrix that depends on age. The lifespan is uncertain and agents of age j in health status h survive until the next period with probability $s_{j,h}$. J is the maximum possible age, and $s_{J,h} = 0$ for any h. The size of a new cohort grows at rate n.

B. *Endowment and Preferences*

Individuals enter the economy with no assets and are endowed with one unit of time that can be used for either leisure or market work. Individuals' earnings are given as $w\varepsilon_j\eta l$, where w is the market wage, ε_j the age-specific productivity, η idiosyncratic labor productivity that follows a first-order Markov process, and l endogenously chosen hours of work.

Individuals value consumption and leisure over the life cycle and order a bundle of consumption and labor supply according to a utility function $u(c, l)$. They derive "warm-glow" utility from leaving bequests, denoted as $u^B(\cdot)$. For simplicity, we assume that bequests are collected by the government and distributed as a lump-sum transfer to the entire population, denoted by q. Individuals discount future utility at a constant rate β.

C. *Medical Expenditures and Health Insurance*

Individuals face medical expenditure shocks every period. Gross medical expenditure $\tilde{m}$ is a random draw from the distribution $\pi_{j,h}$ that depends on age and health status. We assume that some individuals are covered by health insurance provided through employers. Let $i \in \{0, 1\}$ denote the employer-sponsored health insurance

[6] In our model, health affects medical expenditures, survival probabilities, and participation costs.

status with $i = 1$ indicating the coverage tied to employment and $i = 0$ indicating no coverage. A draw at age $j = 1$ determines the insurance state i that is fixed throughout life. Since the insurance is provided through employment, individuals will not have the coverage while they choose to completely withdraw from work. The employer-based insurance covers a fraction κ^{hi} of gross expenditures. Out-of-pocket expenditures are denoted by m.[7] Those covered by the insurance pay a premium p^{hi}, which we include in the out-of-pocket expenditures m.

D. *Technology*

Production is undertaken by a representative firm that operates a constant returns to scale technology, $Y = F(K,L) = AK^{\alpha}L^{1-\alpha}$, where K and L denote aggregate capital and labor inputs and α the capital share. A is the total factor productivity, which we assume is constant. Capital depreciates at rate $\delta \in (0,1)$. The firm rents capital and labor efficiency units from individuals in competitive markets, where factor prices r and w are equated to marginal productivities.

E. *Social Security*

The government operates a pay-as-you-go pension system similar to the current US system. Working individuals pay a proportional tax τ^{ss} on earnings up to the maximum of y^{ss}, above which the Social Security tax rate is zero. Each beneficiary receives the benefit ss, according to a concave function of an individual's average lifetime earnings denoted by e, that captures the progressivity of the US Social Security system. Individuals can begin to receive the Social Security benefit once they reach the earliest claim age j^E, which we call the earliest retirement age. The benefit is adjusted downward if it is claimed before the normal retirement age of j^N, and upward if the claim is postponed until after the normal retirement age. If an individual below the normal retirement age works and receives labor income that exceeds the set earnings limit while receiving Social Security benefits, part of the benefits are taxed away according to the earnings test. The amount of the earnings tax is denoted by τ^{ET}. In exchange for the benefits withheld, the government will undo the penalty on early retirement by partially restoring the downward adjustment on the benefits. We discuss more details of the earnings test and the benefit adjustment in Section IIIE. The benefit is constant over the remaining lifespan of an individual, unless it is subject to the adjustment as a result of the earnings test.

F. *Medicare*

The government provides health insurance for the elderly through Medicare once they reach the Medicare eligibility age of $j^{med} = 46$ (65 years old).[8] Medicare covers

[7] We define m as the payment net of the part of the expenditures paid by insurance and Medicare, as well as health insurance premium or Medicare premium if the individual is a recipient of the benefits.

[8] We assume that everyone becomes covered by Medicare at age 65. We abstract from supplemental insurance besides Medicare.

a fraction κ^{med} of gross expenditures. The program is financed by the combination of the Medicare tax τ^{med} on earnings, Medicare premium p^{med} from each benefit recipient, and the general government budget.

G. *Government Transfer*

The government runs a transfer program that guarantees a minimum level of consumption $\underline{c}$ by providing a transfer *tr* in case individuals' disposable assets fall below $\underline{c}$, as in Hubbard, Skinner, and Zeldes (1995). This policy provides insurance against health expenditures that individuals are unable to pay. It provides the roles of transfer programs, such as Medicaid, that help individuals eliminate medical liabilities.

H. *Fiscal Policy*

The government raises revenues from taxation on income, Medicare premium from beneficiaries, Social Security and Medicare taxes on earnings, consumption tax at rate τ^c, and issuance of one-period riskless debt D. The revenues finance the payment of Social Security and Medicare benefits, expenditures for the government transfer program, an exogenously given level of public purchases of goods and services G, and the servicing and repayment of the debt. Individual income is taxed according to a tax function $T(y)$, where y represents the total income, that is, sum of labor and capital income. One of the parameters that define the tax function is determined in equilibrium so that the consolidated government budget constraint is satisfied every period.

I. *Market Structure*

Markets are incomplete and individuals cannot insure against idiosyncratic productivity and mortality risks by trading state-contingent assets. They can, however, hold one-period riskless assets to imperfectly self-insure against idiosyncratic risks. We assume that agents are not allowed to borrow against future income. For the health expenditure risks, agents are imperfectly protected according to the individual insurance arrangement and Medicare at old ages.

J. *Individuals' Problem*

Individuals are heterogeneous in seven dimensions summarized by a state vector $\mathbf{x} = \{j, a, \eta, h, i, e, b\}$, where j denotes age, a assets carried over from the previous period, η idiosyncratic labor productivity, h health status, and i health insurance coverage. e represents the cumulated labor earnings that determine the Social Security benefit, and it is adjusted downward or upward to account for the actuarial adjustment associated with early or delayed retirement. b is an indicator that takes a value 1 if an individual has already applied for Social Security benefits, and 0 otherwise.

The timing of events is given as follows. At the beginning of each period, each individual is characterized by a state vector $\mathbf{x}$. If individual's assets a are not large enough to cover the minimum consumption, $\underline{c}$, the government intervenes through its transfer program and makes a transfer, *tr*, just enough so that the individual can consume at least the amount $\underline{c}$.[9] Next, individuals make optimal decisions of $\{c, l, b'\}$. The choice is made under uncertainty about medical expenditure shocks that hit each individual later in the period. Individuals then consume, supply labor, lend assets and receive wage and capital income. Earnings based on the choice of labor supply affect the state of cumulated labor earnings e' for the next period. Agents receive Social Security benefits if applicable and pay taxes based on the current income and consumption. Then the medical expenditure shocks are realized and individuals are subject to an out-of-pocket payment m, which affects assets a' available at the beginning of the next period.[10] At the end of the period, the idiosyncratic productivity η' and health status h' for the next period and the mortality shock are realized. Conditional on survival, agents receive accidental bequests from the deceased and enter the next period with the new state vector $\mathbf{x}' = \{j + 1, a', \eta', h', i, e', b'\}$.

We formulate individuals' problem recursively. The value function $V(\mathbf{x})$ of an individual in state $\mathbf{x}$ is given by

$$V(\mathbf{x}) = \max_{c,l,b'} \{u(c,l) + \beta E[s_{j,h} V(\mathbf{x}') + (1 - s_{j,h}) u^B(a')]\},$$

subject to

$$a' = (1 + r)k + w\varepsilon_j \eta l + ss(\mathbf{x}) - m(\mathbf{x}) - \mathfrak{T}(\mathbf{x}) + q, \tag{1}$$

where

$$k = a - (1 + \tau^c)c + tr \geq 0, \tag{2}$$

$$tr = \max\{0, (1 + \tau^c)\underline{c} - a\}, \text{ and} \tag{3}$$

$$e' = f_j(e, w\varepsilon_j \eta l, b'), \text{ and}$$

where k is the saving of individuals that are either invested in the government bond or rent to firms.[11] $\mathfrak{T}(\mathbf{x})$ denotes income and payroll taxes paid by an individual in state $\mathbf{x}$:

$$\mathfrak{T}(\mathbf{x}) = T(rk + w\varepsilon_j \eta l) + \tau^{med} w\varepsilon_j \eta l + \tau^{ss} \min\{w\varepsilon_j \eta l, y^{ss}\} + \tau^{ET}. \tag{4}$$

[9] Note that depending on the realized medical expenditures in the previous period, a can be negative. The variable a represents total resources available to agents as they enter the new period, as in the cash-on-hand variable in Deaton (1991).

We chose the timing to simplify the computation of the transfer amount, but, alternatively, one could assume that the transfer is made at the end of the period based on the assets after the receipt of labor and capital income.

[10] Note that individuals have to make the labor supply decision before observing the medical expenditures for the period. Out-of-pocket expenditures may depend on the labor participation decision if the insurance coverage is tied to employment.

[11] Government bond and firms' capital are perfect substitutes for individuals and pay the same return of r, satisfying no-arbitrage conditions.

The evolution of e is governed by the age-dependent function of labor earnings and Social Security benefit claiming, which we detail in Section IIIE.

K. *Stationary Equilibrium*

In this paper, we focus on the long-run effects of proposed Social Security reforms. Below, we define a stationary equilibrium and a set of conditions that are satisfied in the benchmark economy. Parametrization of the benchmark economy and changes in policy parameters when reforms are undertaken are discussed in Sections III and IV, respectively.

For a given set of exogenous demographic parameters $\{s_{j,h}, n\}$, government policy variables $\{G, D, ss, \tau^{ss}, y^{ss}, \tau^{ET}, tr, \tau^{med}, p^{med}, \tau^{c}\}$ and income tax function T, a stationary competitive equilibrium consists of individuals' decision rules $\{c, l, b'\}$ for each state $\mathbf{x}$, factor prices $\{w, r\}$, private health insurance premium $\{p^{hi}\}$, one of the parameters that define the income tax function T, a lump-sum transfer of accidental bequests $\{q\}$, and the distribution of individuals $\{\mu(\mathbf{x})\}$ that satisfy the following conditions:

- Individuals' allocation rules solve the recursive optimization problem defined in Section IIJ.
- Factor prices are determined competitively, i.e., $w = F_L(K,L)$ and $r = F_K \times (K,L) - \delta$.
- The lump-sum bequest transfer is equal to the amount of assets left by the deceased:[12]

$$q = \sum_{\mathbf{x}} a(\mathbf{x})(1 - s_{j-1,h})\,\mu(\mathbf{x}). \tag{5}$$

- Private health insurance premium p^{hi} is determined so that the insurance provider will break even, that is, the revenues from the insurance premium equal the total spending that covers a fraction κ^{hi} of gross expenditures $\tilde{m}$ incurred by each insured individual:

$$p^{hi} \sum_{\mathbf{x}\,|\,i=1,\,l(\mathbf{x})>0,\,j<j^{med}} \mu(\mathbf{x}) = \kappa^{hi} \sum_{\mathbf{x}\,|\,i=1,\,l(\mathbf{x})>0,\,j<j^{med}} \tilde{m}(\mathbf{x})\mu(\mathbf{x}). \tag{6}$$

- The labor and capital markets clear

$$L = \sum_{\mathbf{x}} \varepsilon_j \eta l(\mathbf{x})\,\mu(\mathbf{x}) \tag{7}$$

$$K = \sum_{\mathbf{x}} k(\mathbf{x})\,\mu(\mathbf{x}) - D. \tag{8}$$

[12] Note that individuals could die in debt if they were hit by large medical expenditure shocks before dying and were unable to pay the bill. We assume that the government will collect all the assets of the deceased, including the negative ones. In all of our equilibrium computation, the sum never goes negative and the bequest transfer is positive.

- The parameter in the income tax function satisfies the consolidated government budget constraint

$$(9)\quad G + (1+r)D + \sum_{\mathbf{x}} ss(\mathbf{x})\,\mu(\mathbf{x}) + \sum_{\mathbf{x}} tr(\mathbf{x})\,\mu(\mathbf{x}) + \sum_{\mathbf{x}|j\geq j^{med}} \kappa^{med}\tilde{m}(\mathbf{x})\mu(\mathbf{x})$$
$$= \sum_{\mathbf{x}} \left[T\{rk(\mathbf{x}) + w\varepsilon_j\eta l(\mathbf{x})\} + \tau^{med}w\varepsilon_j\eta l(\mathbf{x}) + \tau^{ss}\min\{w\varepsilon_j\eta l(\mathbf{x}), y^{ss}\}\right.$$
$$\left. + \tau^c c(\mathbf{x}) + p^{med}I_{\{j\geq j^{med}\}} + \tau^{ET}(\mathbf{x})\right]\mu(\mathbf{x}) + D',$$

where D is the debt issued in the previous period and D' is the proceeds of the debt issued in the current period, which equals $(1+n)D$ in stationary equilibrium.

- The goods market clears

$$(10)\qquad C + K' + M + G = Y + (1-\delta)K,$$

where $C = \sum_{\mathbf{x}} c(\mathbf{x})\mu(\mathbf{x})$ and $M = \sum_{\mathbf{x}} \tilde{m}(\mathbf{x})\mu(\mathbf{x})$. K' is the capital in the next period and equals $(1+n)K$ in stationary equilibrium.

- The distribution $\{\mu(\mathbf{x})\}$ is stationary, that is, the law of motion for the distribution of individuals over the state space satisfies $\mu(\mathbf{x}) = R_\mu\mu(\mathbf{x})$, where R_μ is a one-period recursive operator on the distribution.

III. Calibration

This section describes parametrization of the model. One model period corresponds to a year and the economic decision-making unit of the model is an individual.[13] Given that our objective is to analyze long-run effects of Social Security reforms that are currently debated, our calibration strategy places the US economy in a steady state prior to 2010. Under this assumption, we match selected empirical moments with those from our model in order to determine some of the parameters of the model. Table 3 summarizes the calibrated parameters of the model, as discussed below in more details.

A. *Demographics*

We assume that individuals enter the economy at age 20 ($j = 1$) and live up to the maximum age of 100 ($J = 81$). We set the growth rate n of new entrants to the economy to 1.1 percent, the long-run average population growth in the United States.

[13] The calibration of the model is based on individual data and the average of males and females. One exception is the calibration of the bequest parameter in which we use the wealth profile of households for the target moment. This choice is based on the difficulty to impute assets of individuals within a household and an implicit assumption is that the life-cycle profile of individuals' wealth approximates that of households.

B. *Health, Medical Expenditures, and Health Insurance*

Our main source of micro data related to health status, medical expenditures, and health insurance is the Medical Expenditure Panel Survey (MEPS). The MEPS is an ongoing annual survey of a representative sample of the civilian population with detailed information on demographics, labor supply, health status, health expenditures, and health insurance. We use the most recent panel of individual data to calibrate the health status transition and the distribution of medical expenditures, as well as the coverage provided by health insurance and Medicare.

The measure of health status in the MEPS is self-reported. Every annual MEPS survey has three waves, and this measure is present in each one. We choose to define two levels of an individual's health status, good (h^g) and bad (h^b), based on the responses. First, for each individual, we compute the numerical average of the answer to the subjective health question across the three waves, which ranges from 1–5.[14] We then define an individual to be in bad health that year if the average was strictly above 3. The transition matrices of the health status for different age groups are reported in Table 1.[15] Figure 1 displays the unconditional probability of being in the bad health state over the life cycle, implied by the transition matrices and the initial distribution of health status from the MEPS.

For gross medical expenditures, we use total expenditures reported by individual samples in the MEPS.[16] In order to capture the long tail in the distribution of the medical expenditures and a small probability of incurring very large and catastrophic expenditures, we use three expenditure states with uneven measures (top 5 percent, 35 percent, and 60 percent) for each age and health status. The distribution of medical expenditures by age and health status is displayed in Table 2.[17]

In order to calibrate health-dependent survival probabilities, we use the methodology developed in Attanasio, Kitao, and Violante (2011), who estimate the marginal effect of good health on mortality rates using the Health and Retirement Survey (HRS). The HRS follows samples over a long period of time, and it is the ideal sample to estimate mortality rates.[18]

We use the life table of Bell and Miller (2005) for the current age-dependent conditional survival probabilities in the United States and calibrate health-dependent survival rates so that they are consistent with the estimates in the study.[19] Let $\overline{s}_j$

[14] The exact wording of the survey question on health status is: *In general, compared to other people of (PERSON)'s age, would you say that (PERSON)'s health is excellent* (1), *very good* (2), *good* (3), *fair* (4), *or poor* (5)?

[15] The age variables are top coded at 85 in the MEPS for purposes of confidentiality. Therefore further breakdown of transition probabilities above age 80 is not included in the table. We extrapolate the available data for the estimates of the health variables above the top-coded age.

[16] We use the variable **TOTEXP** in the MEPS that represents total expenditures of each individual. The MEPS makes efforts to impute true expenditures that are actually paid, for example, by replacing missing data and accounting for systematic inconsistency between self-reported insurance payment and actual amount due to over-billing and subsequent discounting. To the best of our knowledge, the MEPS is the best data source available for the calibration of gross, rather than out-of-pocket, expenditures over the entire life-cycle.

[17] In the computation, we linearly interpolate the medical expenditures and the probabilities of remaining in good and bad health across ages so that the expenditures and transition matrices change smoothly over the life-cycle.

[18] The MEPS is a collection of two-year panels, and individuals drop out of the sample when they become institutionalized (e.g., enter a nursing home) and are not followed thereafter. Therefore the number of individuals who are recorded as deceased in the survey is extremely small, and the database is not suitable for estimating the mortality risks.

[19] We take the average of male and female survival rates from the life table of 2010.

TABLE 1—TRANSITION PROBABILITIES BETWEEN GOOD HEALTH AND BAD HEALTH FROM THE MEPS BY AGE GROUP

Age	Health	Good	Bad
20–29	Good	0.9602	0.0398
	Bad	0.4228	0.5772
30–39	Good	0.9600	0.0400
	Bad	0.3182	0.6818
40–49	Good	0.9470	0.0530
	Bad	0.2382	0.7618
50–59	Good	0.9354	0.0646
	Bad	0.2042	0.7958
60–69	Good	0.9259	0.0741
	Bad	0.1447	0.8553
70–79	Good	0.8871	0.1129
	Bad	0.1937	0.8063
80–	Good	0.8491	0.1509
	Bad	0.1802	0.8198

TABLE 2—MEDICAL EXPENDITURES FROM THE MEPS BY AGE GROUP AND HEALTH STATUS (IN 2006 US DOLLARS)

		Percentile		
Age	Health	60%	35%	5%
20–29	Good	111	2,137	13,875
	Bad	616	6,769	30,100
30–39	Good	218	2,827	18,719
	Bad	842	7,665	38,313
40–49	Good	291	2,808	16,126
	Bad	1,235	11,238	62,543
50–64	Good	765	5,227	28,360
	Bad	2,509	15,953	73,619
65–	Good	1,814	8,394	34,780
	Bad	4,177	21,777	76,235

be the average survival rate for age j individuals from the life-table, and Λ_j be the distribution of health status at age j. Then, given values for $\bar{s}_j$, $\Lambda_j(h^g)$ and $\Lambda_j(h^b)$, the following two equations allow us to determine the two unknowns $s_{j,h}(h^g)$ and $s_{j,h}(h^b)$ for each age.

$$\bar{s}_j = \Lambda_j(h^g)s_{j,h}(h^g) + \Lambda_j(h^b)s_{j,h}(h^b)$$

$$survprem_j = s_{j,h}(h^g) - s_{j,h}(h^b),$$

where $survprem_j$ is the above-mentioned good health premium on survival rate for age j individuals estimated by Attanasio, Kitao, and Violante (2011) using the HRS. Figure 2 shows the conditional survival probabilities by age and health status that we use in our benchmark model.

The private insurance covers a fraction $\kappa^{hi} = 70$ percent of gross expenditures, which is based on the average among the MEPS samples who hold private health

Table 3—Parameters of the Model

Parameter	Description	Values/source
Demographics		
n	population growth rate	1.1%
$\{s_{j,h}\}_{j=1}^{J}$	conditional survival probabilities	Bell and Miller (2005), HRS
J	maximum age	81 (100 years old)
Preference		
β	subjective discount factor	0.991
γ	weight on consumption	0.390
σ	curvature parameter	4.0
$\{\phi(h^g), \phi(h^b)\}$	cost of labor force participation	{0.133, 0.306}
ψ_1	weight on bequest utility	805.0
ψ_2	curvature of bequest utility	$400,000
Labor productivity process		
ρ_η	persistence parameter	0.97
σ_η^2	variance	0.018
Technology and production		
α	capital share of output	0.36
δ	depreciation rate of capital	8.9%
A	scale parameter	1.58
Health insurance		
κ^{hi}	expenditures covered by private insurance	70.0%
p^{hi}	health insurance premium	$2,162
Medical expenditures		
$\pi_{j,h}$	distribution of medical expenditures	MEPS
Government		
τ^c	consumption tax rate	5.0%
$\{\lambda_0, \lambda_1, \lambda_2,\}$	personal income tax	{0.258, 0.726, 6.158}
G	government purchases	20% of GDP
D	government debt	40% of GDP
τ^{ss}	Social Security tax rate	10.6%
j^N	normal retirement age	47 (66 years old)
j^E	earliest retirement age	43 (62 years old)
y^{ss}	Social Security maximum taxable earnings	$102,000
	earnings test threshold	$13,560
	earnings test tax rate	50%
τ^{med}	Medicare tax rate	2.9%
p^{med}	Medicare premium	$1,157
κ^{med}	expenditures covered by Medicare	50.0%
j^{med}	Medicare eligibility age	46 (65 years old)
$\underline{c}$	consumption floor	$3,000

insurance.[20] We assume that 70 percent of individuals have access to the employer provided health insurance, based on the average rate that individuals of working age are covered by private insurance in the MEPS data.[21]

[20]The actual share of expenditures covered by an insurance contract varies by the insurance plans and by the size of expenditures. The insurance company's share tends to rise in expenditures due to deductibles or copays, but for most expenditures above $1,000, the rates are in the range of 60–75 percent, and using a flat rate of 70 percent provides a sufficiently good approximation of the actual rates.

[21]The insurance coverage rate varies across groups of individuals, and younger and lower income individuals are less likely to be covered by private insurance. For more details, see Jeske and Kitao (2009), who focus on the insurance offer and take-up decisions, and model their dynamics in a stochastic aging economy.

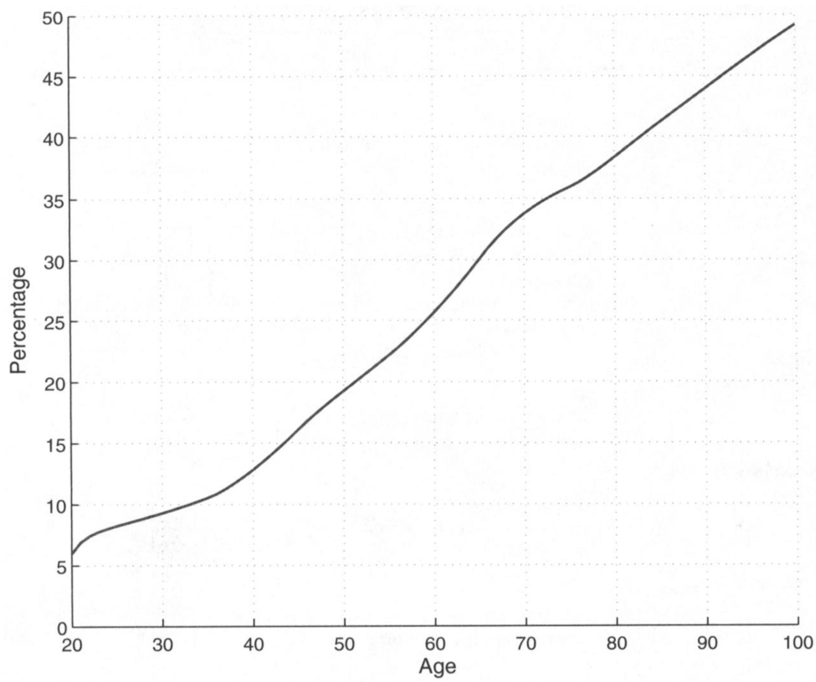

Figure 1. Probability of Being in Bad Health

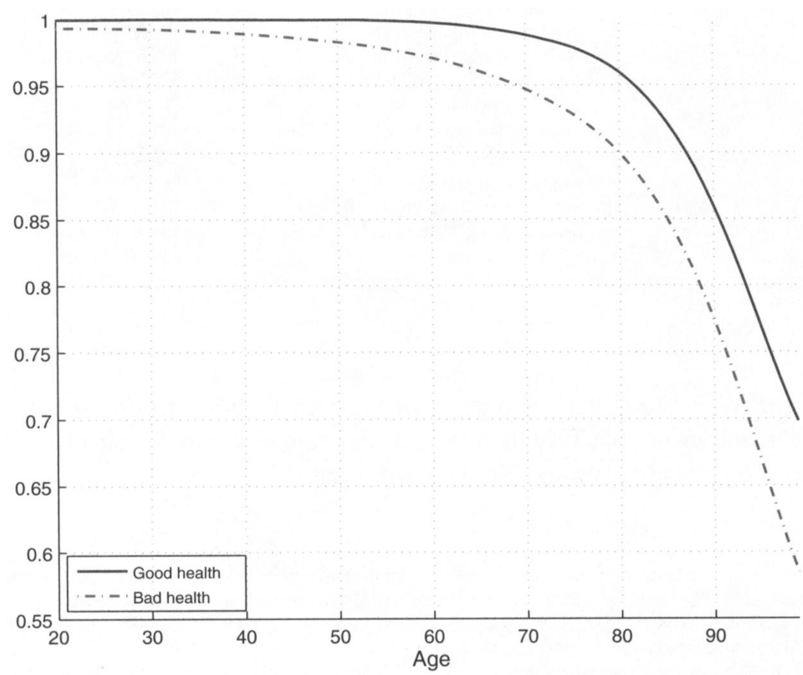

Figure 2. Conditional Survival Probability by Health Status

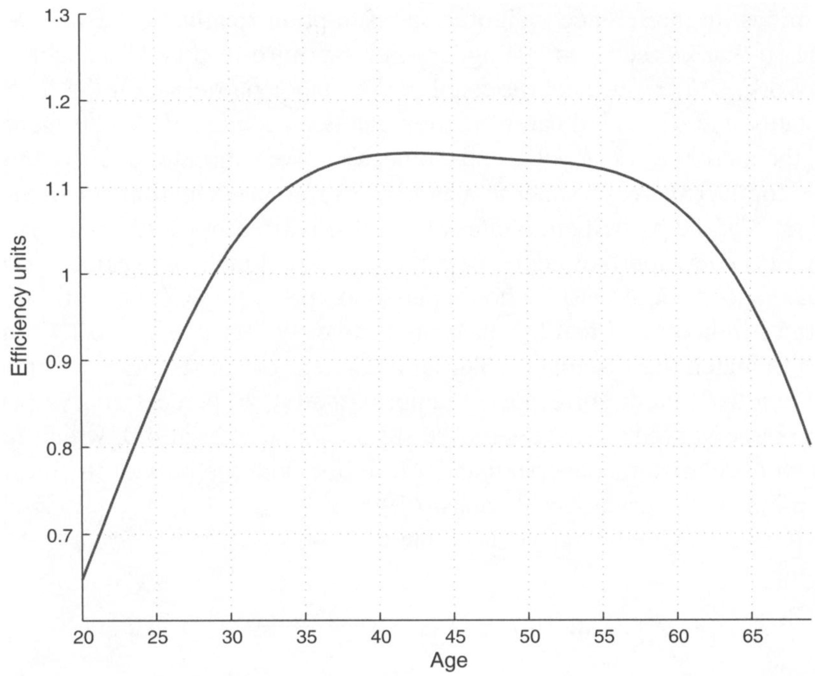

FIGURE 3. AGE-SPECIFIC LABOR EFFICIENCY PROFILE FROM HANSEN (1993)

C. *Endowment and Preferences*

The deterministic, age-dependent labor productivity ε_j is taken from Hansen (1993) and displayed in Figure 3. We assume that $\varepsilon_j = 0$ for $j \geq 51$ (70 years old), i.e., no one will work after age 70.[22]

The idiosyncratic component η is specified as a first-order autoregressive process in log with a persistence parameter $\rho_\eta = 0.97$ and the variance of the white noise $\sigma_\eta^2 = 0.018$, which lie in the range of estimates such as Heathcote, Storesletten, and Violante (2010).[23] We approximate this continuous process with a five-state, first-order discrete Markov process.

We assume the following period utility function:

$$u(c,l) = \frac{[c^{\gamma}(1 - l - \phi(h) \cdot i_l)^{1-\gamma}]^{1-\sigma}}{1 - \sigma}. \tag{11}$$

[22] We abstract from labor supply above age 70 given the fact that fewer individuals work above this age. Also, it is challenging to estimate their labor productivity given the selection bias in the data. It would be interesting to extend this exogenous age limit with the development of new data and estimates, especially in the economy with lower mortality risks and increased longevity.

[23] For the variance, we use the average of their estimates over the period 1991–2000. We assume that agents enter the economy with a common value of η, which is the log average of the stationary distribution implied by the Markov process.

γ determines the preference weight on consumption relative to leisure, which we calibrate so that workers, on average, spend one-third of their disposable time for market work. $\phi(h)$ represents the fixed cost of labor participation that depends on health status, and i_l is an indicator function that takes a value of 1 if the agent participates in the market work ($l > 0$), and 0 otherwise. We calibrate the cost of participation $\phi(h)$ for the two health states to match the overall participation rate of the elderly and the ratio of the participation rates of agents in different health states. According to the MEPS data, approximately 50 percent of individuals between age 60 and 69 participate and work at least 10 hours per week, on average.[24] The ratio of participation rates in good and bad health is about two. We set $\phi(h^g) = 0.133$ and $\phi(h^b) = 0.306$ to match these statistics. These fixed costs of participation for individuals in good and bad health correspond to approximately 40 percent and 92 percent of average hours worked, respectively. We set the value of σ at 4.0, which implies a coefficient of relative risk aversion at 2.17, in line with the bulk of the literature on consumption (for a survey, see Attanasio 1999).[25]

Utility from leaving bequest a' is defined as

$$u^B(a') = \psi_1 \frac{(\psi_2 + a')^{\gamma(1-\sigma)}}{1 - \sigma}. \tag{12}$$

The parameter ψ_1 represents the weight on the utility from bequeathing, which we calibrate so that the ratio of the median wealth held by the individuals aged 75 and above to that of all individuals is 1.8, as reported in the Statistical Abstract of the United States (US Census Bureau 2009, table 699). ψ_2 affects the curvature of the utility from bequeathing. We set it to \$400,000, which is close to the estimates of French and Jones (2011) and the value used in French (2005).

The subjective discount factor β is set so that the capital-output ratio in the benchmark model is 2.5, which is based on private fixed capital plus the stock of durables, with the service flows from the stock of durables added to measured output.

D. *Technology*

The income share of capital α is set at 0.36.[26] The depreciation rate δ is $0.089 = \frac{X/Y}{K/Y} - n$, which is implied by the equilibrium law of motion for the capital in the steady state, where we target an investment-output ratio X/Y of 0.25 and a capital-output ratio K/Y of 2.5. The scale parameter A is used for normalization so that aggregate output in the benchmark economy is unity.

[24] In the MEPS data, we treat an individual as nonparticipating if the average hours of work is not more than 10 per week, and we also exclude full-time students from the data. Unemployed individuals would be categorized as nonparticipating, but since we treat an individual as participating if he or she worked in at least one of the three sub-year survey periods, most of those who experienced a typical unemployment spell are categorized as participating given that the average unemployment duration is much shorter than a year in the year the survey was conducted. Also note that we do not have unemployment in the model, and labor force participation rate is defined as those who work more than the cutoff level divided by the population.

[25] The value is computed as $-cu_{cc}/u_c = 1 - (1 - \sigma)\gamma$.

[26] Consistent with the target capital-output ratio, this measure is based on private fixed capital including the stock of durables.

E. *Government*

Social Security.—The Social Security benefit is computed as a concave function of an individual's average past earnings, e. This is a compromise against the actual formula, in which the average earnings index is computed based on the 35 highest earnings years, given that we are unable to keep track of the entire history of earnings. The average past earnings e is capped above at \$102,000 in 2008, which is the same level as the maximum amount of earnings subject to Social Security taxation. Workers' Primary Insurance Amount (PIA) is computed using a piecewise linear function of e with three bend points. In 2008, the formula is given as follows:[27]

$$(13)\qquad PIA = \begin{cases} 0.9 \times e & \text{if } \; e < \$8{,}532 \\ \$7{,}679 + 0.32 \times (e - \$8{,}532) & \text{if } \; \$8{,}532 \leq e < \$51{,}456 \\ \$21{,}414 + 0.15 \times (e - \$51{,}456) & \text{if } \; e \geq \$51{,}456. \end{cases}$$

The above *PIA* formula is for an individual who first applies and receives the benefit at the normal retirement age of 66. Individuals are eligible to apply for Social Security once they reach the earliest retirement age, 62. Early receipt, however, permanently reduces the benefit by the Actuarial Reduction Factor (ARF). The *PIA* of early takers is reduced by 25 percent, 20 percent, 13.3 percent, and 6.7 percent for each year between the ages of 62 and 65. Individuals who initiate the claim at age 67 or above are rewarded through the Delayed Retirement Credit (DRC), and benefits are raised by 8.0 percent for every year up to age 70, when the benefit reaches 132 percent of the *PIA*.[28] Individuals decide when to begin collecting benefits between age 62 and 70. We assume that everyone at age 70 receives Social Security benefits.

According to the earnings test, part of Social Security benefits can be taxed away if earnings of a benefit recipient below the normal retirement age exceed a certain exempt level. In 2008, the earnings threshold is \$13,560, and \$1 of benefits for every \$2 of earnings in excess of the exempt amount is withheld until all the Social Security benefits are exhausted. The less well-known feature of the Social Security system associated with the earnings test that we also incorporate in our model is the following. In order to account for the benefits withheld due to the earnings test, the benefit entitlement is adjusted upward once they reach the normal retirement age. Individuals can receive the benefits thereafter as if they had not claimed the portion of the benefits prior to the normal retirement age. To capture this adjustment of "undoing" the early retirement penalty, we adjust the state variable e, which summarizes the past earnings and determines the benefit level, according to the fraction of the benefit withheld due to the earnings test and to the

[27] The benefit (*PIA*) is capped above since e is capped. The maximum *PIA* is \$28,995.6 when e is at \$102,000.

[28] The normal retirement age has been gradually raised and the normal retirement age of 66 and above adjustment rates apply to individuals born 1943–1954. For those individuals born after 1954, the normal retirement age will rise by 2 months for each birth year; and the normal retirement age will be 67 for persons born in and after 1960. For details, see http://www.ssa.gov/OACT/ProgData/ar_drc.html.

ARF for early retirement.[29] Earnings at or above the normal retirement age are not subject to the retirement test.[30]

Medicare.—We assume that Medicare covers a fraction $\kappa^{med} = 50$ percent of the gross medical expenditures of eligible individuals, which is based on the average fraction of eligible individuals' medical expenditures covered by Medicare among the MEPS samples. Each Medicare beneficiary pays the annual Medicare premium p^{med} of $1,156.8.[31] The Medicare tax rate τ^{med} on earnings is 2.9 percent.

Government Transfer.—The minimum consumption floor $\underline{c}$ is set at $3,000, which is close to the values estimated in De Nardi, French, and Jones (2010) at $2,700 (in 1998, equivalent to $3,321 in 2008 dollars using GDP deflators) and Palumbo (1999) at $2,000 (in 1985, $3,540 in 2008 dollars). In the model, the government transfer is intended to approximate programs, such as Medicaid, that would absorb the unpayable debt from the medical expenditure shocks. Since we do not explicitly model more active welfare programs, such as the Temporary Assistance for Needy Families (TANF) or Food Stamps, we use a lower value than in other papers, such as Hubbard, Skinner, and Zeldes (1995), who use a much higher value of $7,000 (in 1984 dollars).

Taxes, Expenditures and Public Debt.—We set the government spending G at 20 percent of output, which is the average ratio of government consumption and investment expenditures to GDP in the post-war period. The ratio of federal debt held by the public to GDP is set at 40 percent. We set consumption tax at 5 percent based on Mendoza, Razin, and Tesar (1994).

For income taxation, we employ a tax schedule of the form

$$T(y) = \lambda_0\{y - (y^{-\lambda_1} + \lambda_2)^{-1/\lambda_1}\}, \tag{14}$$

where $\{\lambda_0, \lambda_1, \lambda_2\}$ are parameters that define the tax function. This functional form, proposed and estimated by Gouveia and Strauss (1994), has been employed in many quantitative studies including Castañeda, Díaz-Giménez, and Ríos-Rull (2003); Conesa and Krueger (2006); and Conesa, Kitao, and Krueger (2009). λ_0 controls the level of the average tax rate, λ_1 determines the progressivity of the tax code, and λ_2 is a scaling parameter. We use the estimates of Gouveia and Strauss (1994)

[29] Note that this is an approximation of the actual adjustment, in which the rise in benefits by having the benefit withheld does not begin until the recipient reaches the normal retirement age. In order to save the cost of keeping track of when the initial claim was made and how much was withheld, we assume that the adjustment is reflected in the immediate increase in the benefit entitlement. We do, however, try to capture the time cost associated with the later adjustment by using the ARF. For example, a $1 rise in the benefit starting at the normal retirement age of 66 would correspond to the rise of the benefit entitlement at age 63 by 80 cents, given the ARF for the age 63 retirement is 80 percent. See Benitez-Sílva and Heiland (2007, 2008) for more on this rule and its incentive effects.

[30] The earnings test above the normal retirement age of 65 was repealed in 2000. The model assumes the same and the test is applicable only for the amount earned before reaching the normal retirement age. A different rate is applied for the earnings in the year before the month of reaching the normal retirement age. In 2008, $1 in benefits for every $3 of earnings in excess of a higher amount of $37,680 is withheld. Our model is in annual frequency, and we abstract from this milder penalty at the normal retirement age.

[31] It accounts for the Medicare part B monthly premium of $96.4 in 2008.

for the values of the first two parameters, λ_0 and λ_1, to preserve the shape of the tax function and adjust the value of λ_2 to satisfy the government budget constraint in benchmark equilibrium.

When we simulate the economy with alternative demographic assumptions or Social Security reforms, we add a proportional term $\tau^y y$ to the tax function (14) and adjust the value of the proportional tax rate τ^y to satisfy the government budget, while keeping the values of all the three parameters $\{\lambda_0, \lambda_1, \lambda_2\}$, as in the benchmark economy.

IV. Numerical Results

In this section, we present life-cycle decision profiles of individuals and macroeconomic variables in the economy that we modeled and calibrated to approximate the US economy, in which the government operates a pay-as-you-go Social Security system as described in Section II. We call this economy the benchmark economy. We will then simulate the model under different demographic assumptions and introduce alternative Social Security rules in order to assess the long-run effects of reforms.

A. *Benchmark Model*

Figure 4, panel A compares retirement (claiming of Social Security benefits) in the data and the benchmark economy. The data are based on the Social Security Administration's (SSA) Annual Statistical Supplement for retirement statistics in 2000–2009.[32] As we discussed in the introduction, the majority of individuals claim benefits at the earliest retirement age of 62 in the data. Our model captures the fraction of earliest retirees well, and approximately 57 percent of retirees initiate the claim at 62. By the time individuals reach the normal retirement age of 66, more than 95 percent of individuals have started to receive benefits both in the model and the data.[33]

To better understand the pattern of claiming behavior, we study four factors that are likely to affect the decision: the actuarial adjustment factors for early and delayed claims, heterogeneity in health status, heterogeneity in income and wealth, and the earnings test.

First, we examine how the agents in our model perceive the benefit adjustment factors for early and delayed retirement (ARF and DRC) of the current Social Security system. Figure 5 compares the ARF and DRC and model-implied actuarially fair adjustment factors of the benefits for the claims initiated between age 62 and 70.[34]

As shown in the figure, the ARF relative to the benefits initially claimed at the normal retirement age of 66 is more than actuarially fair. This gives an incentive

[32] Consistently with the numbers reported in the SSA's Annual Statistical Supplement, the plot for the model in Figure 4A represents the fraction of all retirees whose initial entitlement is at a particular age. As in Figure 4B, the retirement by health status is based on the fraction of individuals in particular age and health status that are already retired.

[33] We do not distinguish between the claiming behavior of males and females in the model. Although claims distributions for both males and females exhibit similar patterns, more women claim at the earliest retirement age. The fraction of females who claim at 62 is 57 percent, while that of males is 52 percent.

[34] For the model-implied factors, we use conditional survival probabilities of 2010 from Bell and Miller (2005) and the equilibrium interest rate in our benchmark model for discounting future benefits. We normalize the factors by the level of benefits at the normal retirement age.

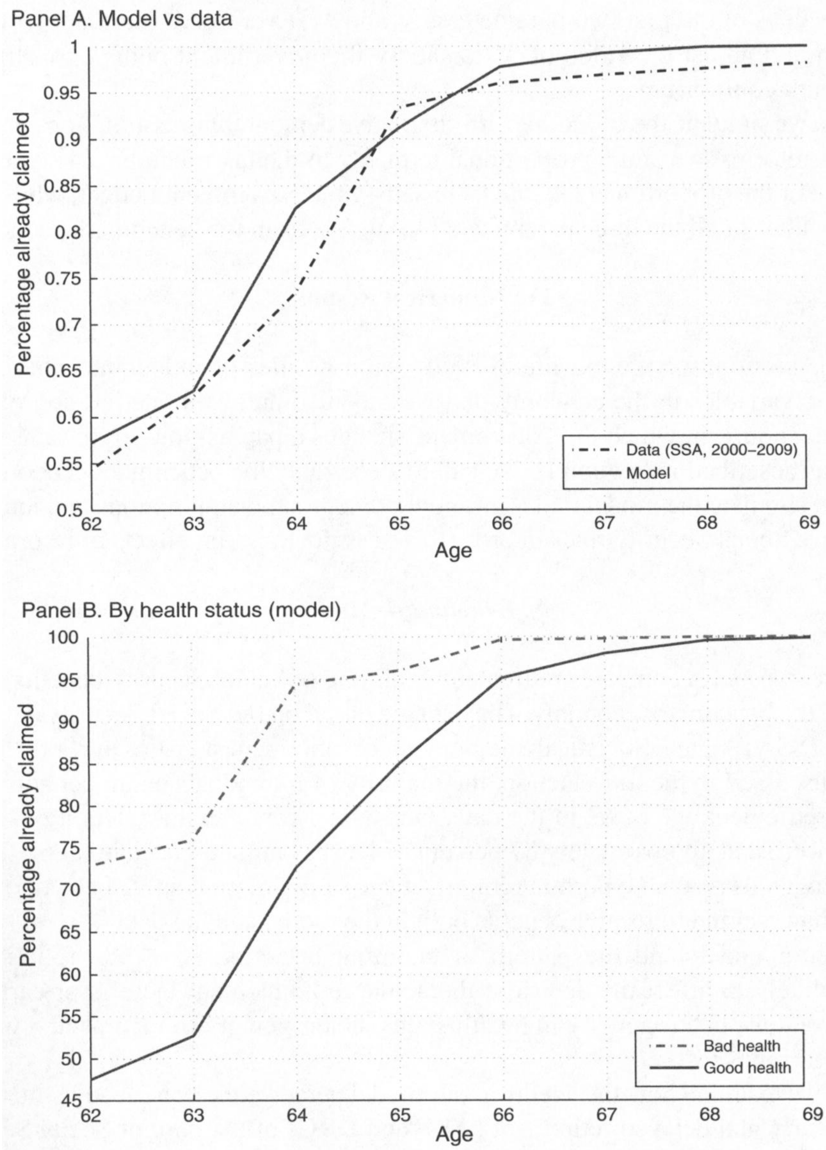

Figure 4. Social Security Benefit Entitlement

to claim benefits prior to the normal retirement age, provided that all individuals faced the same average survival rates and markets were complete. Under incomplete markets, however, the value of Social Security is not simply the present value of the benefits based on the average survival rates, and it gives an additional value of insurance. Given the uninsurable uncertainty in old ages from longevity and medical expenditure risks and the level of expenditures that have to be paid if they live longer than expected, the higher annuity value of Social Security that one can obtain by postponing retirement may be more appreciated than its actuarial value.

Second, we consider the effect of health. Individuals who expect to live longer than average would value a high annuity. Figure 4, panel B displays the benefit

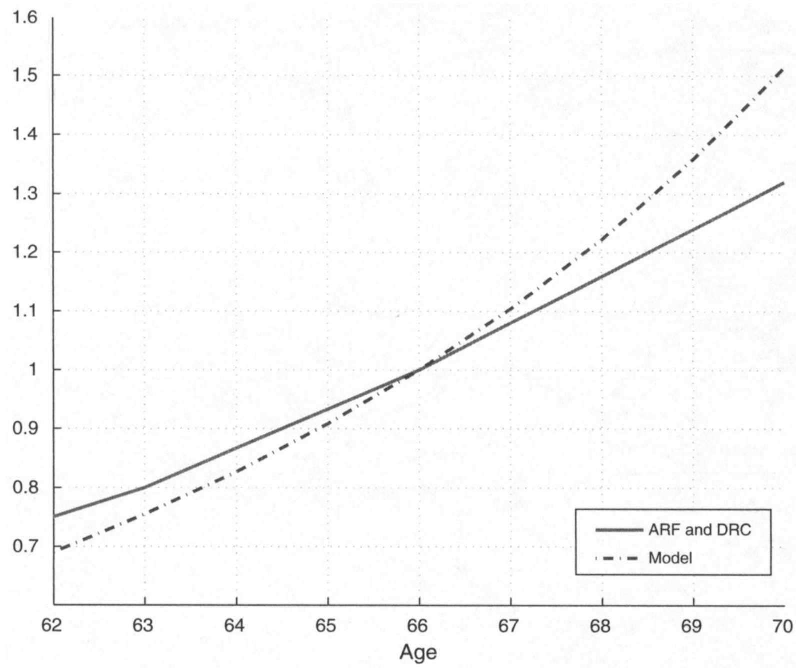

Figure 5. ARF/DRC and Actuarially Fair Adjustment Factors of the Model

claim by health status. Our model implies that unhealthy individuals are more likely to claim benefits early. This is mainly due to the difference in the life expectancies between individuals in good and bad health status, whereas the early retirement penalty is common across individuals of the same age. Waldron (2004) combines the data from the Survey of Income and Program Participation (SIPP) and Social Security administrative data, and reports the health status distribution of different groups by the age of first entitlement. She finds that the health of early takers is worse than the postponers at the time of their retirement. Sixty-seven percent of individuals who retire at 62 are in good health, while the fraction increases to 75 percent among age 65 retirees. The corresponding figures in our model are 65 percent and 83 percent, so that we capture the patterns found for health quality among new retirees at different ages. We also point out, however, that unhealthy individuals expect to incur much higher expenditures if they survive to a very old age and they have to weigh the risk of living longer against the expected duration of retirement periods to collect benefits. The net effect depends on the magnitude of both forces and our model suggests that the latter will dominate and induce the unhealthy to claim benefits earlier rather than later, consistently with data.

Third, we expect poor individuals with lower buffer stock savings against shocks to appreciate the additional insurance more. For them, the annuity value of Social Security is large and they have an incentive to delay claiming and raise the permanent benefit. The average assets of early takers at age 62 is 37 percent higher than the postponers in the model. The Social Security wealth of early takers is higher as well and the average wage index (the state variable e) of early takers at age 62 is

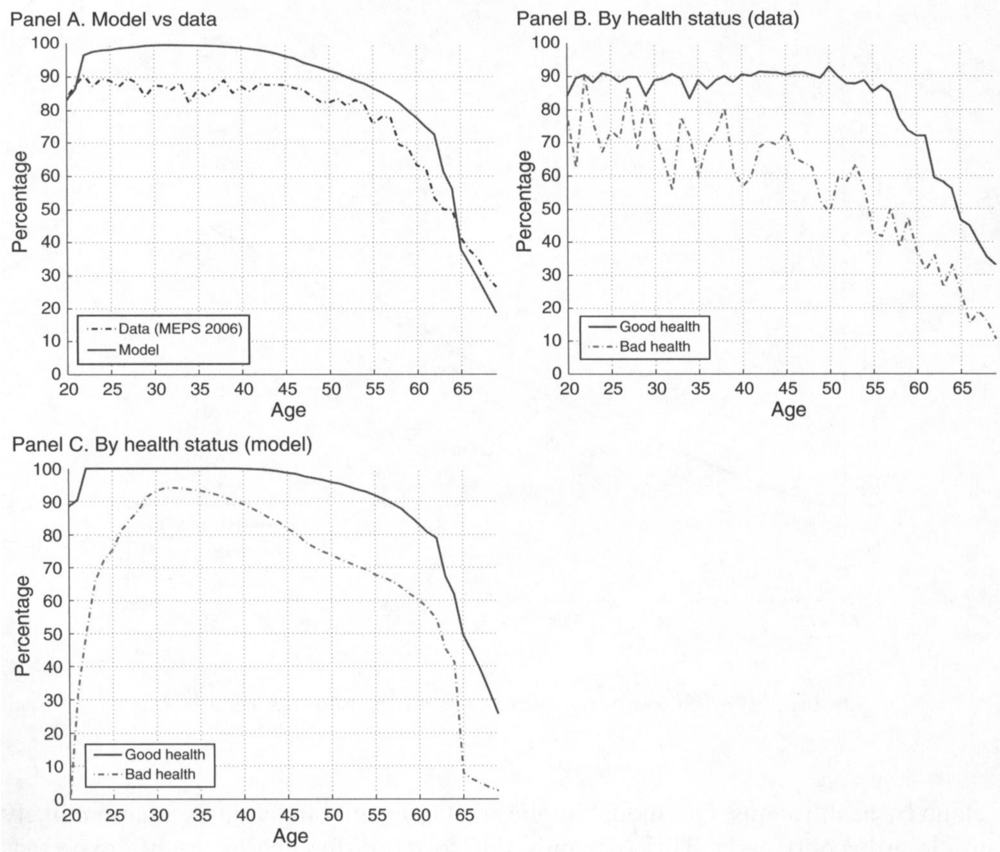

Figure 6. Labor Force Participation

about 15 percent higher than postponers. It is consistent with the empirical study of Burkhauser, Couch, and Phillips (1996) that finds much larger net worth held by early takers than postponers.

While early takers are wealthier, on average, their current labor productivity tends to be lower than postponers. The average labor productivity (the state variable η) of early takers at age 62 is about 24 percent lower than postponers, implying that individuals with large assets and substantial Social Security wealth, but low current wages, have a strong incentive to collect benefits early.

Lastly, those who intend to work above a certain level may want to postpone claiming benefits in order to avoid the earnings test. According to the sensitivity analysis, 67 percent of individuals would claim benefits at 62 if there were no earnings test, rather than 57 percent in the benchmark economy. See the Appendix B for more details of the sensitivity analysis.

Figure 6 compares the labor participation rates in the MEPS data and the benchmark model, overall and by health status. The dataset is based on our individual MEPS samples, where they are asked about their employment status during the interview year. The profile in the data is very flat until one is in his/her mid-50s, at which point the participation rate starts to decline, eventually reaching below

30 percent in the late 60s. Our model generates higher participation rates among young individuals in their 20s and 30s, partly because we do not capture some of the reasons, such as the time for human capital investment or child-bearing that may prevent individuals from participating.[35] The model generates a gradual decline in labor force participation starting in a persons 50s and more sharply in his/her 60s. The participation rate shows a large drop at age 65. This is the age when everyone becomes eligible for the Medicare coverage. In the Appendix B, we simulate a model with different insurance arrangements and the participation rate among old-age individuals is shown to be much higher if there was no Medicare.

Figure 7 shows hours worked over the life cycle among individuals that participate in the labor market, expressed as a fraction of total disposable time. For healthy individuals, hours are mostly in the range of 0.3 and 0.4, which decline gradually as they age. Hours are consistently lower for individuals in bad health.[36] The overall pattern of the hours profile is consistent with the data, for example as reported and simulated in French (2005, figures 2 and 3).

Figure 8 displays average asset holdings by health status over the life cycle. In an OLG model with income uncertainty, individuals accumulate wealth even in the very early stage of a life cycle. In our model, they do so for two main reasons as described in Gourinchas and Parker (2002), first, in order to accumulate buffer-stock savings against uncertainty about the income, longevity, and health expenditures, and second, to build the stock of savings for old-age consumption. Our model also captures the fact that individuals continue to possess a significant amount of wealth at very old ages, as documented in De Nardi, French, and Jones (2010). Although our model does not attempt to generate the extreme concentration of wealth at the very top of the wealthiest individuals in the United States, where 1 percent of the wealthiest own 35 percent of the wealth held by all the households (Budría Rodríguez et al. 2002), we capture a fair amount of wealth inequality. Individuals in the top, second, and third quintile of wealth distribution own 51 percent, 77 percent, and 92 percent of the entire wealth respectively, and the corresponding data in the United States are 82 percent, 94 percent, and 99 percent according to the study of Budría Rodríguez et al. (2002). Individuals in bad health accumulate less wealth than those in good health due to their lower lifetime earnings.

B. *Policy Experiments*

In this section, we will study the effects of two policy experiments of raising the earliest and normal retirement ages under the projected demographics for 2080. Our conditional survival probabilities are taken from the projections of Bell and Miller (2005) in 2080, and we set the population growth rate at 0.1 percent, which, together with the projected survival rates, yields an old-age dependency ratio of

[35] We also underestimate the decline in participation that starts at around age 55 in the data. We conjecture that the additional disincentive to participate provided by the features of defined benefit pension plans may help to fill the gap. See Ippolito (1997) on the incentives to quit jobs early generated by typical defined benefit pension plans. We chose not to model defined benefit pension plans and other forms of pensions in the current paper mainly for computational difficulties, and we leave the issues of private pensions for future research.

[36] There is an increase in the hours among the bad health individuals after age 65, due to the change in the decomposition and most of those who remain in the labor force are the ones with the highest labor productivities.

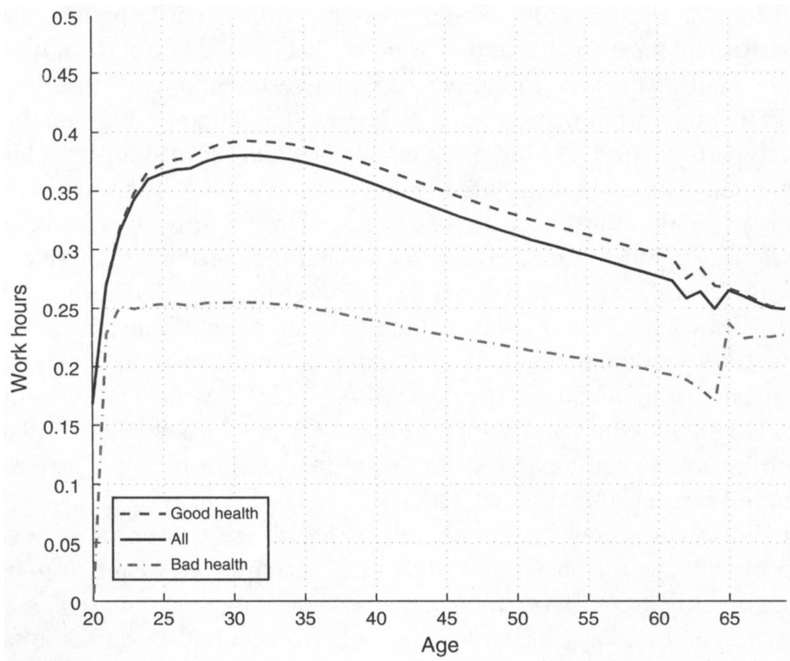

FIGURE 7. WORK HOURS

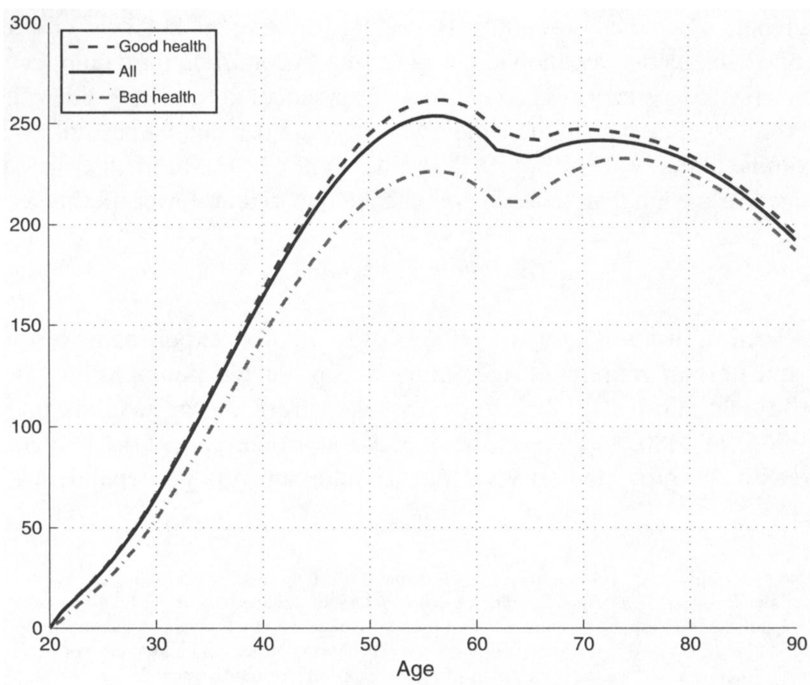

FIGURE 8. ASSETS (MODEL, IN $1,000)

TABLE 4—EFFECTS OF SOCIAL SECURITY REFORMS IN ECONOMY WITH AGING

	Benchmark	Economy w/aging	Earliest ret. age 62 → 64	Normal ret. age 66 → 68
Capital (per capita)	—	−14.3%	−1.5%	+12.6%
Labor (per capita)	—	−11.0%	−0.2%	+2.8%
Average work hours	—	+0.5%	−0.1%	+0.6%
Wage	—	−1.4%	−0.5%	+3.3%
Interest rate	5.50%	5.86%	5.98%	5.02%
Proportional income tax rate τ^y	—	8.2%	8.5%	4.5%
Soc. Sec. budget balance (% of GDP)	+0.32%	−4.42%	−4.51%	−2.87%
Average assets at 62 (in 2008 $1,000)	237.0	180.2	180.1	215.0
	—	−24.0%	−0.1%	+19.3%
Retirement (Social Security already claimed)				
at 62	57.3%	33.3%	—	18.9%
by 66	97.8%	88.4%	88.0%	69.8%
by 69	100.0%	100.0%	100.0%	100.0%
Labor force participation				
Age 60–69	50.0%	53.0%	53.6%	59.1%
Age 20–59	94.8%	93.6%	93.2%	95.3%

Note: The changes in the second column "Economy w/aging" are expressed as the distance from the Benchmark (first column), and those in the last two columns are expressed as the distance from the Economy w/aging (second column).

about 40 percent, nearly twice as large as the ratio in the benchmark economy. As mentioned in Section IIIE, we add a proportional term $\tau^y y$ to the progressive income tax function calibrated in the benchmark economy and adjust the value of the tax rate τ^y to satisfy the government budget equation.

Before analyzing the effects of reforms, we discuss the changes in the economy due to the aging of the population, in which the current Social Security system is maintained. We call this economy with the projected demographic structure as the economy with aging; it is essentially a "do-nothing" policy despite the projected aging in the society. The results of the benchmark economy with aging are summarized in the second column of Table 4. The increase in longevity and a higher dependency ratio deteriorate the Social Security budget and the annual deficit of the program reaches 4.42 percent of GDP. The income tax rises by 8.2 percentage points for any given level of income. The relative size of working population falls and both per capita labor and capital decline significantly by more than 10 percent. Since the annuity value of Social Security rises with improved survival rates and the lower level of assets as they approach the retirement age, fewer individuals choose to claim the benefits at the earliest retirement age of 62.

The results of the policy experiments are summarized in the last two columns of Table 4. We compare the effects of reforms as the changes relative to the benchmark economy with aging, rather than the economy with the current demographics, in order to understand the effect of reforms in isolation from the effects of difference in demographics.

The first experiment raises the earliest retirement age by two years, from 62 to 64. As shown in the second to the last column of Table 4, there is no significant change in macro aggregates. The only notable change is in the labor force participation rate of 60-69 year old individuals, which rises by 3.6 percentage points. As a result, a somewhat greater fraction of retirement consumption is financed by increased labor income at older ages, and the capital falls slightly by 1.5 percent. The Social Security budget balance, computed as payroll taxes collected minus total retirement benefits, is almost unchanged. Although the government saves on the benefits to individuals ages 62 and 63, their benefits are raised permanently higher and this offsets the positive fiscal effects of fewer early retirees.

The second experiment raises the normal retirement age by two years, from 66 to 68. To receive a full amount of benefits, individuals have to wait until age 68 to retire and start collecting benefits. Early and delayed retirement will result in upward and downward adjustments of the benefits as in the benchmark economy. We assume that the benefits are scaled relative to the full benefits according to the factors implied by the SSA's ARF and DRC schedule. In the benchmark model without reform, if individuals retire at 68 years of age, the benefit amount (the PIA) is raised permanently by a factor of 1.16, with a 16 percent credit for delayed retirement. In the experiment, we assume that the ARF and DRC schedule will shift down across retirement ages by a common factor of $1/1.16$. The last column of Table 4 shows the effects of this experiment. The reform induces more savings and the capital stock rises significantly relative to the "do-nothing" policy. The aggregate capital will increase by 12.6 percent, as individuals need accumulate more savings to support their consumption at old ages. The average assets when individuals reach the earliest retirement age rise by 19.3 percent from the benchmark economy with aging.

Labor supply increases by 2.8 percent and most of the adjustment comes from a change in the extensive margin, with the average hours worked rising by only 0.6 percent. The labor force participation rate for individuals at ages 60–69 rises significantly, by 6.1 percentage points. Since capital becomes more abundant relative to labor, the interest rate falls by about 0.5 percentage points and the wage rate rises by 3.3 percent. The Social Security budget balance improves significantly, from a deficit of 4.42 percent of GDP under the "do-nothing" policy to 2.87 percent. Not only does the total retirement outlay declines, but the Social Security tax revenues also rise as a result of the increase in labor supply in both extensive and intensive margins and the higher wage rate. More individuals postpone their claiming of benefits and only 18.9 percent of retirees take up benefits at age 62, compared to 33.3 percent in the benchmark economy with aging.

In the baseline experiment of raising the normal retirement age, we assumed that the range of possible retirement ages remains the same as in the benchmark economy without reform. Alternatively, one could assume that the earliest retirement age and/or the maximum retirement age are raised at the same time by the same two years. Quantitative results of these alternatives are very similar, however. As we saw in the first policy experiment, raising the earliest retirement age does not have a large impact on the Social Security budget or macroeconomic aggregates. Extending the maximum retirement age beyond 70 has little impact, since few individuals wait to claim the benefits until the last age of retirement.[37]

[37] We have simulated alternative reforms in which the earliest retirement age and the maximum retirement age are also raised to 64 and 72, respectively, and results are available from authors upon request. In extending the

TABLE 5—EFFECTS OF SOCIAL SECURITY REFORMS WITH FIXED PRICES

	Economy w/aging (%)	Earliest ret. age 62 → 64 (%)	Normal ret. age 66 → 68 (%)
Assets net of debt	—	−3.9	+33.3
Labor	—	+0.3	−2.0
Average work hours	—	+0.1	−1.6
Proportional income tax rate τ^y	8.2	8.5	4.6
Soc. Sec. budget balance (% of GDP)	−4.42	−4.48	−3.01
Retirement (Social Security already claimed)			
at 62	33.3	—	37.7
by 66	88.4	86.8	84.5
by 69	100.0	100.0	100.0
Labor force participation			
Age 60–69	53.0	54.4	50.6
Age 20–59	93.6	93.4	94.0

C. *Effects of Price Changes: Partial Equilibrium Analysis*

In order to understand the roles of general equilibrium adjustment in prices, we simulate reforms under the assumption of fixed prices. Table 5 summarizes the results of the two reforms, where the interest rate and the wage rate are fixed at the levels in the benchmark economy with aging.[38]

When the normal retirement age is raised by two years, total assets net of government debt rise by 33.3 percent, significantly more than the rise of 12.6 percent in the benchmark simulation with general equilibrium price adjustments.[39] Since the interest rate is fixed at an exogenous level, which is higher than the level that would prevail in the general equilibrium model, individuals allocate more resources to savings as the optimal consumption growth rate is much higher. The wage, on the other hand, is fixed at the low benchmark level. The massive rise in asset holdings generates a strong wealth effect and the aggregate labor supply declines by 2.0 percent, a result that is in stark contrast with the finding in the general equilibrium model, where the same reform increases aggregate labor by as much as 2.8 percent. In the general equilibrium economy, when the retirement age is raised and benefits are cut, agents respond by supplementing the retirement consumption by a combination of additional saving and hours worked, especially at older working ages. If we restricted attention to partial equilibrium, we would overestimate the positive effects on private saving and reach the conclusion that the reform would discourage labor supply, rather than encourage it.

maximum retirement age, we assumed an additional 8 percent of benefits per year, the same percentage adjustment per year for delayed retirement beyond the normal retirement age.

[38] This experiment also can be considered as a policy simulation under the assumption of a small open economy, in which capital flows freely across countries and the capital-labor ratio is adjusted to achieve given factor price levels.

[39] Note that the assets net of the government debt do not coincide with the capital used in production since the market for capital does not clear under partial equilibrium. We compute the total assets of individuals net of the government debt so that the results are comparable to those under experiments in general equilibrium.

Table 6—Effects of Benefit Reduction: Models with Endogenous vs Exogenous Labor Supply and Retirement

Labor/Retirement	Endogenous (%)	Exogenous (%)
Output	+6.2	+3.6
Capital	+12.6	+10.5
Labor	+2.8	—
Average work hours	+0.6	—
Wage	+3.3	+3.6
Interest rate	5.02	5.37
Proportional income tax rate τ^y	4.5	8.5
Soc. Sec. budget balance (% of GDP)	−2.87	−3.01

The effects are relatively small in the reform of raising the earliest retirement age from 62 to 64, since factor prices move only marginally in this experiment under general equilibrium.

D. *Exogenous Labor Supply and Retirement*

In order to understand the role of endogenous labor supply and retirement in the evaluation of Social Security reforms, we simulate a reform in a model where the labor supply and retirement age are exogenously determined. We assume that all agents work the same hours until the mandatory retirement age of 66, when they also start to collect Social Security benefits. We recalibrate the model to match the same set of target moments in the benchmark, except for the targets associated with the labor supply decisions. We then simulate a reform in which Social Security benefits for a given level of past earnings shift down by a factor of $1/1.16$, the same magnitude of decline in the benefit schedule under the reform of raising the normal retirement age by two years.

As shown in Table 6, the effects of the reform on aggregate variables are much smaller with the assumption of exogenous labor supply and retirement. Since there is no increase in the labor supply in both margins and the expansion of the income tax base is limited, the income tax rate will have to rise by much more to satisfy the government budget. The Social Security budget balance will be more negative as well.

V. Conclusion

In this paper, we build a quantitative general equilibrium model of overlapping generations of individuals who make decisions on consumption, saving, labor supply on both extensive and intensive margins, and claims of Social Security benefits. The model produces realistic cross-sectional heterogeneity among individuals in the dimensions of wealth, labor productivity, health, health insurance, and average earnings that determine Social Security benefits. In addition, our calibrated model approximates the pattern of labor force participation and Social Security claiming behavior of old-age individuals as in the data, where more than 50 percent of retirees claim benefits at the earliest retirement age of 62, and the participation rate declines rapidly as they approach the retirement ages.

We show that Social Security reform to raise retirement ages can have a large impact on the sustainability of the US pension system through changes in life-cycle savings and labor supply. In particular, labor force participation of older workers and their benefit take-up behavior react strongly to certain reforms. An increase in the normal retirement age from 66 to 68 is shown to have a significant positive effect on both saving and labor supply. The participation among older workers in their 60s rises by 6 percentage points. More individuals choose to postpone the benefit take-up, and the claim rate at age 62 declines by about 15 percentage points.

Currently the Social Security program runs a surplus and revenues from payroll taxes exceed the benefits paid to retirees. The surplus is expected to decline and eventually turn to a deficit. Our model predicts an annual budget deficit of 4.4 percent of GDP under the 2080 demographics unless reform is undertaken. Increasing the normal retirement age from 66 to 68 will reduce the deficit by 1.5 percentage points of GDP since more individuals will postpone retirement and the benefit spending will fall, while labor participation among the old-age individuals rises and the payroll tax revenues increase. An increase in the earliest retirement age will not have any significant effect on the budget of the Social Security system since the benefits will be permanently raised by forcing individuals to postpone retirement. Our study suggests that policies that encourage the participation and work effort of older workers, as well as individuals' own saving for retirement, can help enhance the sustainability of the system.

Finally, we note that the focus of our study is long-run effects of Social Security reforms and their impact on the sustainability of the US pension system in the future. Another important issue is the study of short-run effects of reforms. There are, in principle, a large set of possible fiscal policy options on how to treat current and future generations and therefore alternative paths to reach the long-run state of the economy, including the ones that we have investigated. We leave this interesting extension to be explored in future research.

Appendix A. Computation of Equilibrium

We solve for an equilibrium using value functions in a discretized space of individual states. For each state in the state vector, we use the grid points of 81 (age j), 100 (assets a), 5 (idiosyncratic productivity η), 2 (health status h), 2 (insurance access i), 100 (past earnings e), and 2 (benefit claim status b).

Computation Steps.—

- Guess a set of equilibrium variables, which consist of aggregate capital, labor supply, tax parameter, bequests, and health insurance premium.
- Solve individuals' problems and derive policy functions at each state.
- Compute the distribution of individuals across states.
- Compute aggregate moments implied by the distribution and verify if equilibrium conditions are satisfied. If not, update guesses for the equilibrium variables and return to step 2.

Table B1—Sensitivity Analysis

	Benchmark (%)	No earn test E1 (%)	No ARF adj. with earn test E2 (%)	No hlth exp. E3 (%)	No hlth insurance E4 (%)	No Medicare E5 (%)
Aggregate capital	—	+0.35	−0.21	−6.60	+3.29	+9.33
Aggregate labor	—	+0.04	−0.30	−8.94	−0.17	+3.15
Average work hours	—	−0.01	+0.15	−5.81	+1.41	+1.32
Wage	—	+0.11	+0.03	+0.92	+1.23	+2.12
Interest rate (%)	5.50	5.47	5.49	5.27	5.19	4.97
Retirement (Social Security already claimed)						
at 62	57.3	66.7	53.8	65.7	55.9	45.8
by 66	97.8	97.9	97.3	99.0	97.2	94.7
by 69	100.0	100.0	100.0	100.0	100.0	100.0
Labor force participation						
Age 60-69						
all	50.0	50.1	47.3	38.1	46.3	55.6
good health	58.3	58.4	55.2	50.6	57.5	64.0
bad health	28.2	28.5	26.8	5.2	16.9	33.7
Age 20–59						
all	94.8	94.9	94.9	92.2	93.7	96.0
good health	97.5	97.5	97.5	7.2	98.2	98.4
bad health	76.9	77.0	76.9	58.4	63.5	80.1

Appendix B. Sensitivity Analysis

In this section, we will run sensitivity analysis to study how various features of the model including the rules about the Social Security benefit and the treatment of the health expenditures affect the outcome of the model.

Earnings Test and ARF Adjustment with Earnings Test (E1 and E2).—To understand the role of the earnings test, we run the benchmark model without the earnings test, as well as the readjustment in the Social Security benefits. To account for the part of the benefits collected through the earnings test, we run two counter-factual models, where each of these rules about the Social Security is removed. In the first experiment (E1), we assume that Social Security benefits are no longer subject to taxation no matter how much one earns, while receiving benefit prior to the normal retirement age. In the second experiment (E2), we maintain the earnings test as in the benchmark model, but assume away the ARF readjustment as a result of the benefit reduction through the earnings test.

The results of the first experiment are shown in the column labeled E1 in Table B1. Without the earnings test, the benefit claim at the earliest retirement age will rise significantly from 57.3 percent to 66.7 percent. Those who postpone the claim in the benchmark economy, since they intend to earn more than the threshold of the earnings test, may be inclined to claim benefits early, now that there is no penalty on earnings. The participation rate among the elderly will rise though the change is almost negligible. The effect on the participation is smaller than what other papers have found, in which only the taxation part of the earnings test is captured but not the "undoing" part of the test, which will restore the penalty imposed by the ARF. In other words, the participation would have been lower in the benchmark economy if there was not the second part of the earnings test, and we would have observed a larger effect in participation by eliminating the earnings test. Benitez-Sîlva and Heiland (2007) study the effect of the ARF adjustment associated with the earnings test and show that the adjustment will raise the participation of the elderly between the ages of 62 and 65 by 4 to 9 percentage points. The second experiment (E2) verifies this empirical finding and shows that the participation rate among the elderly would have been lower without the benefit readjustment. For the individuals between the ages of 62 and 65, the participation rate falls by 6.5 percent, which lies in the range of estimates by Benitez-Sîlva and Heiland (2007).

Health Expenditures (*E*3).—In order to understand the role of health expenditures, we compute an equilibrium in which health expenditures are eliminated. Accordingly, we also assume away private health insurance and Medicare. The results are shown in Table B1 in the column labeled E3. The saving falls significantly without expenditure risks and aggregate capital and labor decline by 6.6 percent and 8.9 percent, respectively. The labor participation of the elderly at age 60–69 will fall by about 12 percentage points to 38.1 percent. The decline is more pronounced among the elderly in bad health, who incur more disutility from working, since they do not have to work as hard as they did in the benchmark in order to pay for the high medical costs. The experiment demonstrate that health expenditures are important to explain the saving and labor supply behavior of individuals, especially among the elderly.

Private Health Insurance (*E*4).—To understand the role of health insurance, we run a model assuming that all agents pay the entire gross expenditures out of pocket until they reach the age of Medicare eligibility and there is no employer-provided health insurance. As shown in Table B1, there is a decline in the labor force participation, which is concentrated among those in bad health status. Since the coverage by the employer-based health insurance was conditional on employment, some individuals, especially those in bad health and expecting to incur larger expenditures stay at work in the benchmark economy mainly because they would like to keep the coverage. There is an incentive to do so at least until age 65, when everyone becomes eligible to be covered by Medicare, which is less generous in terms of coverage rate than the employer-based insurance, but still covers a significant amount of expenditures. The job exit rate (defined as the change in participation rate) at age 65 falls from 18.4 percent in the benchmark economy to 7.9 percent in the economy without private health insurance. Rust and Phelan (1997) also emphasize the distortions on the participation decisions caused by the Medicare eligibility. Our finding is consistent with theirs, though the magnitude of the exit at this particular age is smaller in the benchmark, since the agents in our model can also self-insure against the expenditure risks by accumulating riskless assets, whereas Rust and Phelan (1997) focus on poor households and abstract from saving decisions.

Medicare (*E*5).—In the last experiment, we assume that there is no Medicare and all individuals above age 65 pay the entire gross expenditures out of pocket. The additional expenditure risks and the need to cover large expenditures at old ages will raise the precautionary savings demand, and aggregate capital will increase by 9.3 percent. The early benefit claiming at age 62 will fall from 57.3 percent to 45.8 percent. More individuals choose to postpone the benefit take-up and increase the value of annuity at older ages in order to supplement the loss of insurance provided by Medicare.

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