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A life-cycle model of unemployment and disability insurance

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ABSTRACT

A general equilibrium life-cycle model is developed, in which individuals choose a sequence of saving and labor supply faced with search frictions and uncertainty in longevity, health status and medical expenditures. Unemployed individuals decide whether to apply for disability insurance (DI) benefits if eligible. We investigate the effects of cash transfer and in-kind Medicare component of the DI system on the life-cycle employment. Without Medicare benefits, DI coverage could fall significantly. We also study how DI interacts with reforms of Social Security and Medicare and find that DI enrollment amplifies the effects of reforms.

1. Introduction

According to the Social Security Administration (SSA), more than 8 million individuals received disability insurance (DI) benefits in 2011.[1] The likelihood of receiving DI benefits rises in age and more than 1 in 7 individuals at age 60–64 are DI recipients. Most, if not all, DI recipients are out of labor force and constitute a large fraction of non-employed population before the retirement age. To understand the pattern of labor force participation over the life-cycle, it is important to identify the roles played by DI in the context of risks individuals face, and the work incentives associated with this public insurance program.

This paper builds a structural life-cycle model of heterogeneous agents to study consumption, saving and labor supply decisions focusing on the roles of DI. Understanding the effects of public insurance requires a model that captures key risks individuals observe over the life-cycle and other insurance opportunities available to them, both privately and through the government. In our model, individuals face risks in longevity, employment, health status and medical expenditures. Markets are incomplete without state-contingent assets to insure away the risks, but individuals can engage in precautionary saving. The government provides partial insurance through transfer programs including unemployment insurance, disability insurance, means-tested welfare programs and Social Security. Individuals optimally choose allocations given the incentives embedded in the transfer system.

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[1] The figure is for disabled workers only and recipients of the federal Social Security Disability Insurance (SSDI), based on the SSA's Annual Statistical Supplement 2011. The total number including disabled widow(er)s and children is 10.3 million in 2010, according to the Annual Statistical Supplement to the Social Security Bulletin, 2011.

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0304-3932/

Employed individuals in our model can be separated from a job either exogenously or endogenously by quitting. Unemployed individuals choose search intensity, which affects the likelihood of finding a job. Once an individual is unemployed for a given period, he can apply for DI benefits if eligibility conditions are met. Individuals who have received DI benefits for two years automatically become entitled to Medicare benefits. Upon reaching the retirement age, individuals start to receive both Social Security benefits and the Medicare coverage.

The model is calibrated to key features of the U.S. economy using micro databases including the Medical Expenditure Panel Survey (MEPS) and the Panel Study of Income Dynamics (PSID). We use the model to address two questions. First, how do the cash and in-kind Medicare benefits of the DI system affect employment status over the life-cycle? Second, how do reforms of other transfer programs, including Social Security and Medicare, interact with DI enrollment?

Experiments show that both cash and in-kind benefits through Medicare are important in explaining patterns of employment and DI coverage. Eliminating the Medicare benefit for DI recipients can lower DI coverage by more than one-third and the employment rate can be higher by 1.3 percentage points. DI coverage is sensitive to the level of cash benefits as well. A 20% reduction of the benefits, for example, can reduce the coverage by a similar magnitude and raise the employment rate by 1.4 percentage points.

We simulate reforms of Social Security, Medicare and unemployment insurance. When a reform affects the incentives to apply for DI, quantitative assessment of a reform can differ from that in a model without DI. When a reform implies a need for more savings for retirement, individuals may choose to stay in the labor force longer and accumulate more wealth, rather than opting for "early retirement" through DI coverage. For example, when Social Security benefits are reduced by one-third, the employment rate of individuals at age 60–64 rises by 1.5 percentage points, much more than a rise of 0.4 percentage point in a model without DI.

Our model is an extension of incomplete market models pioneered by Bewley (1986), Huggett (1993) and Aiyagari (1994) in a life-cycle framework of Auerbach and Kotlikoff (1987), augmented with labor market frictions, stochastic health and medical expenditures and disability insurance. There have been recent papers that incorporate health shocks over the life cycle in this class of models to evaluate the roles of health status, medical expenditures and insurance arrangements. French (2005) estimates a life-cycle model of employment with stochastic health status and explains the pattern of job exits at old ages and the roles of Social Security benefit rules. De Nardi et al. (2010) build a model of retirees to study the effect of longevity risk and health expenditure uncertainty on the savings. French and Jones (2011) analyze labor supply and retirement behavior of old-age individuals, focusing on the roles of employer-based health insurance, Medicare and Social Security. Kopecky and Koreshkova (2014) use a life-cycle model to analyze the effect of nursing home expenses and Medicaid. İmrohoroğlu and Kitao (2012), Attanasio et al. (2011) and Jeske and Kitao (2009) analyze Social Security, Medicare, employer-based health insurance, respectively, in a model with health and medical expenditure uncertainties. Hsu (2013) studies the role of employer based health insurance on the distribution of precautionary savings.

A few recent papers added disability insurance in a structural life-cycle model. Low et al. (2010) build a dynamic model of consumption, labor supply and job mobility, estimate employment and productivity risks and quantify precautionary responses in labor supply and job mobilities. Low and Pistaferri (2011) add disability health shocks to Low et al. (2010) and study the impact of changes in the details of the DI program. Benitez-Sílva et al. (2011) analyze the effect of a policy that would encourage DI recipients to return to work through tax incentives. The three papers abstract from medical expenditures and Medicare benefits are not included in the DI system. To the best of my knowledge, this is the first paper in the line of the literature that builds a life-cycle model of consumption-saving and employment with medical expenditures and health uncertainty, augmented with endogenous DI coverage that consists of cash and Medicare benefits. Of course there are numerous papers that analyze reforms of transfer programs including Social Security and Medicare. The paper also contributes to this vast literature by investigating the interaction of reforms with the DI system.

The rest of the paper is organized as follows. The model economy is described in Section 2. The calibration of the model is discussed in Section 3. Section 4 presents the quantitative findings of the paper. Section 5 concludes.

2. Model

This section presents the model.

2.1. Demographics, preferences and labor market

There is a continuum of individuals with stochastic life-spans. Individuals go through a finite number of age groups stochastically, indexed by $j = 1, 2, \ldots, J$. The probability of transitioning from age j to $j+1$ is denoted by ϕ_j. Individuals face mortality risk and the probability of surviving until the next period is denoted by ρ_j and depends on the age of an individual. Bequests are accidental and they are transferred to the entire population in a lump-sum manner, denoted as x. The size of new entrants to the economy grows at rate n.

Preferences are time-separable and individuals derive utility from consumption c and leisure l according to the function $u(c, l)$. Future utility is discounted by the subjective discount factor β. Assets that are not consumed are rented out and earn the market interest r. Each individual has a unit of time, which can be spent for leisure, market work or job search. Individuals who participate in the labor market lose B_h^e units of disposable time, which can depend on health status h.

Unemployed individuals choose a search intensity $s \in [0,1]$, which costs disutility $B_h^s(s)$. With the search effort s, an unemployed individual finds a job offer with probability $\pi^s(s)$, which he chooses to accept or reject.

Employed individuals earn labor income, that depends on each individual's skill level g and the market wage w. Skills accumulate while being employed and decumulate while being unemployed, within the range of $[\underline{g}, \overline{g}]$. An employed individual of age j with the current skill level of g faces the transition probability $\Gamma_j^E(g,g')$ that his skills will be g' next period. A non-working individual's skills evolve according to the transition probability of $\Gamma_j^N(g,g')$. New entrants start a career with the skill level $\underline{g}$. Employment can be terminated exogenously with probability σ or endogenously when a worker chooses to quit.

2.2. The health, medical expenditures and health insurance

The health status of an individual evolves stochastically. An individual of age j with the current health status h faces the probability $\pi_j^H(h,h')$ that his health status will be h' in the following period.

In the model health affects the distribution of medical expenditures, the disutility from work and job search, and the likelihood of receiving a disability shock. Individuals of age j and health status h face gross medical expenditure $m(j,h,\psi)$, where ψ denotes a draw of medical expenditures from the distribution $\Pi^M(m;j,h)$, which is age and health specific. $\overline{m}(j,h)$ denotes average medical expenditures of age j and health h individuals.

We assume that employed individuals have access to group health insurance and have a fraction q_{HI} of expenditures covered by the insurance in exchange for a premium of p_{HI}, which is subtracted from the wage bill.[2] The premium is set so that there is no profit earned by a provider of group health insurance.

2.3. The government

Disability insurance (DI): Unemployed individuals can apply for DI provided that eligibility conditions are met. The Social Security Administration (SSA) requires that individuals wait for at least five months before receiving DI benefits.[3] We assume that individuals can apply for DI after the second period of unemployment (after the fourth month). Unemployed individuals of age j with health status h are assumed to face a "disability shock," which arrives with probability $\theta_{j,h}$. Individuals receiving the disability shock are able to apply for DI benefits. Applications are accepted with probability π_D and benefits start to be paid in the following period.

Successful applicants will receive DI benefits $b_D(e)$, which depend on the index e, that summarizes each individual's past earnings. After receiving DI benefits for two years, individuals automatically become entitled to Medicare benefits. Both cash and Medicare benefits continue until the recipients either die or reach the retirement age, when DI benefits convert to Social Security benefits and the same amount of benefits continue to be paid.

Social insurance: The government provides a means-tested transfer denoted as b_{SI} when the disposable assets of an individual at the beginning of the period fall below the threshold level of $\underline{a}$. The transfer enables individuals to consume at least $\underline{a}$ in each period.

Unemployment insurance: Individuals whose jobs are terminated exogenously are entitled to unemployment benefits denoted as b_U for up to the maximum duration of $\overline{d_U}$ periods.[4]

Social Security and Medicare: Individuals at or above the retirement age j_R receive Social Security benefits $ss(e)$, which are a function of past earnings e. They are also enrolled in Medicare, which pays the fraction q_M of medical expenditures of covered individuals. The same coverage rate applies to DI recipients with Medicare eligibility.

Government expenditures and taxes: The government imposes taxes on labor income at rate τ^l, consumption at τ^c and capital income at rate τ^k. Government spending on programs other than those described above is denoted as G.

2.4. Individual problem

Individuals in the model are heterogeneous in several dimensions and we group them into four groups, employed (E), unemployed (U), DI recipients (D) and retirees (R), and define value functions for each group. The state vector of an employed individual is $S_E = (j,a,g,h,e)$, where j represents age, a assets carried over from the previous period, g skills and h health status. e represents past earnings and affects the amount of unemployment insurance benefits as well as disability insurance and Social Security.

An unemployed individual's state vector is $S_U = (j,a,g,h,e,d_U,i_U)$. d_U denotes the elapsed duration of unemployment. The indicator $i_U \in \{0,1\}$ indicates whether the individual currently receives unemployment insurance benefits or not. The state

[2] We assume that all employers offer health insurance and all employees are covered by group health insurance at work. See Jeske and Kitao (2009) for a dynamic equilibrium model where insurance offers arrive stochastically and the insurance take-up is an endogenous decision. The model abstracts from the complex heterogeneity in private health insurance access and coverage for simplicity.

[3] See http://www.ssa.gov/disability/ for more details about eligibility and application procedures.

[4] The eligibility of unemployment insurance requires that recipients must be actively searching for work and accept suitable work. We assume, however, that the monitoring of such requirements is less than perfect and individuals can maintain the unemployment insurance for the maximum period even if the search effort is minimal or zero, or job offers are rejected.

vector of a DI recipient is $S_D=(j,a,h,e,i_M)$, where the indicator $i_M\in\{0,1\}$ represents eligibility to receive Medicare benefits. Individuals retire at the mandatory retirement age j_R and start to receive Social Security benefits. A retiree's state vector is $S_R=(j,a,h,e)$.

The timing of events is as follows. At the beginning of each period individuals choose the level of consumption and the government gives a social insurance transfer to individuals with assets below the threshold level. Unemployed individuals learn about the disability shock and also choose the search effort s and whether to apply for DI benefits if eligible. The indicator i_D takes a value 1 if an unemployed individual applies for DI benefits and 0 otherwise. Note that the timing convention is such that consumption and search take place after the social insurance transfer is made, but before individuals realize their skill level and earn capital and labor income. Individuals consume and rent remaining assets to earn interest and employed workers receive the wage. Medical expenditures are realized and out-of-pocket expenses are paid.

At the end of the period, health status h' and skills g' for the next period are realized and individuals learn about demographic shocks, that is, whether they survive to the next period and if they move to the next age group. Employed individuals face the probability σ that the job is terminated exogenously. Individuals that do not face exogenous termination can choose whether to quit their job or remain employed. Unemployed individuals find a job offer with probability $\pi^s(s)$, which they decide to accept or reject. If an unemployed individual applied for DI, he learns the outcome of the application before the start of the next period. DI applications are accepted with probability π_D.

The value functions and budget constraints of the employed, unemployed, DI recipients and retirees are presented below.[5] Rented capital k and the social insurance transfer b_{SI} are defined as

$$k=a-(1+\tau^c)c+b_{SI},\quad k\geq 0 \tag{1}$$

$$b_{SI}=\max\{0,\underline{a}-a\} \tag{2}$$

Eqs. (1) and (2) apply to all four types of individuals.

Employed individuals: Employed individuals choose consumption at the beginning of the period, and conditional on no exogenous separation, they also decide whether to remain employed or quit the job and become unemployed.

$$V^E(j,a,g,h,e)=\max_c\{u(c,1-B_h^e)+\beta\rho_j E[(1-\sigma)\max\{V^E(j',a',g',h',e'),V^U(j',a',g',h',e',1,0)\}+\sigma V^U(j',a',g',h',e',1,1)]\} \tag{3}$$

subject to

$$a'=(1-\tau^l)(g\cdot w-p_{HI})+[1+r(1-\tau^k)]k-(1-q_{HI})m(j,h,\psi)+x \tag{4}$$

$$e'=f_j(e,g\cdot w) \tag{5}$$

The expectation in Eq. (3) is with respect to the realization of the stochastic age j', the new health status h', the skills g' that follow the transition matrix $\Gamma_j^E(g,g')$, and the medical expenditures shock ψ and $m(j,h,\psi)$, which in turn affect the assets a' that individuals carry over to the next period. The index e', which represents average prior earnings, and the last two state variables of the unemployed, unemployment duration and eligibility for unemployment insurance, are all known when agents make their decisions. Eq. (5) summarizes the law of motion for the index of past earnings e, which will be updated based on the current earnings $g\cdot w$.

Unemployed individuals: Unemployed individuals choose consumption, search effort and whether to apply for DI or not. Note that only eligible individuals can apply for DI, with $i_D=0$ otherwise

$$\begin{aligned}V^U(j,a,g,h,e,d_U,i_U)=\max_{c,s,i_D}\{&u(c,1-B_h^s(s))+\beta\rho_j E[(1-i_D)\pi^s(s)\max\{V^E(j',a',g',h',e),V^U(j',a',g',h',e,d_U+1,i_U{}')\}\\&+(1-i_D)(1-\pi^s(s))V^U(j',a',g',h',e,d_U+1,i_U{}')+i_D(1-\pi_D)V^U(j',a',g',h',e,d_U+1,i_U{}')\\&+i_D\cdot\pi_D\cdot V^D(j',a',g',h',e,0)]\}\end{aligned} \tag{6}$$

subject to

$$a'=[1+r(1-\tau^k)]k+i_U\cdot b_U-m(j,h,\psi)+x \tag{7}$$

DI recipients: DI recipients choose consumption. If eligible to receive Medicare benefits, the indicator state $i_M=1$ and the fraction q_M of gross expenditures are paid by Medicare

$$V^D(j,a,h,e,i_M)=\max_c\{u(c,1)+\beta\rho_j EV^D(j',a',h',e,i_M{}')\} \tag{8}$$

subject to

$$a'=[1+r(1+\tau^k)]k+b_D(e)-(1-i_M\cdot q_M)m(j,h,\psi)+x \tag{9}$$

[5] Note that with probability ϕ_j individuals in the age group $j=j_R-1$, right before the retirement, will reach the retirement age and become a retiree next period. The value function will then be that of a retiree, $V^R(j+1,a',h',e')$. This is not displayed in the value functions for employed and unemployed individuals and DI recipients for simplicity and to avoid the equations from becoming too long.

Retirees: Retired individuals receive Social Security and Medicare benefits and choose the level of consumption

$$V^R(j,a,h,e) = \max_c \{u(c,1) + \beta\rho_j EV^R(j',a',h',e)\} \tag{10}$$

subject to

$$a' = [1+r(1+\tau^k)]k + ss(e) - (1-q_M)m(j,h,\psi) + x. \tag{11}$$

2.5. Competitive stationary equilibrium

Individual states are $S_E = (j,a,g,h,e)$, $S_U = (j,a,g,h,e,d_U,i_U)$ and $S_D = (j,a,h,e,i_M)$ for employed individuals, unemployed and disability recipients, respectively, and $S_R = (j,a,h,e)$ for retirees. Let the state space of four types of individuals be denoted as $\mathbb{S}^E$, $\mathbb{S}^U$, $\mathbb{S}^D$ and $\mathbb{S}^R$, and the entire state space of all individuals as $\mathbb{S}$ with $S \in \mathbb{S}$ being the general state vector of an individual including the employment and retirement state $N \in \{E,U,D,R\}$.

The equilibrium is given by allocation functions of individuals in each state; a health insurance premium; accidental bequests; taxes on labor income, capital income and consumption; unemployment insurance, disability insurance, social insurance, Social Security and Medicare programs; a set of value functions $\{V^E(S_E)\}_{S_E \in \mathbb{S}^E}$, $\{V^U(S_U)\}_{S_U \in \mathbb{S}^U}$, $\{V^D(S_D)\}_{S_D \in \mathbb{S}^D}$ and $\{V^R(S_R)\}_{S_R \in \mathbb{S}^R}$; and a distribution of individuals over the state space given by $\mu(S)$, such that

1. The allocations solve the maximization problem of individuals in each state as described in Section 2.4.
2. The health insurance premium is determined as

$$p_{HI} = \frac{\int q_{HI} \cdot \overline{m}(j,h)\mu(S|N=E)\, dS}{\int \mu(S|N=E)\, dS} \tag{12}$$

3. The accidental bequest transfer x equals the assets of the deceased per surviving individual

$$x = \frac{\int \tilde{x}(S)(1-\rho_j)\mu(S)\, dS}{\int \rho_j \mu(S)\, dS} \tag{13}$$

   $\tilde{x}(S)$ denotes accidental bequests left by an individual in state S and $\tilde{x} \equiv a' - x$, where a' is as defined in Section 2.4 for each employment type
4. The government budget is satisfied

$$\tau^l \int (g \cdot w - p_{HI})\mu(S)\, dS + \tau^k \cdot r \cdot K + \tau^c \cdot C = G + \int [b_U + b_D + ss + T_{SI}]\mu(S)\, dS + \int q_M \cdot \overline{m}(j,h)\mu(S_R, S_D|_{i_M=1})\, dS \tag{14}$$

   where aggregate saving K and aggregate consumption C are defined as $K = \int k\mu(S)\, dS$ and $C = \int c\mu(S)\, dS$.
5. The distribution of individuals across the state space is stationary, that is, $\mu_{t+1}(S) = \mu_t(S)$ for any $S \in \mathbb{S}$.

3. Calibration

This section discusses the parametrization of the model. The model period is two months. The unit of the model is an individual. The wage rate w is normalized so that the average annual earning in the model is 1. The interest rate r is set at 4% annually. Tables 3–5 summarize calibrated parameters.

3.1. Demographics

The life-span is stochastic and individuals face mortality risk every period, based on the life-table of Bell and Miller (2005). We assume stochastic transitions across age groups.[6] Individuals go through four age groups, $j = 1,2,3$ and 4, which correspond to the annual age groups of 20–34 years old, 35–49, 50–64, and 65–100. Individuals at the working age, $j=1$, 2 and 3, move to the next age group with probability $1/(15 \times 6) = 0.0111$ such that they will remain in a given working age group for 15 years on average, conditionally on surviving. The size of new entrants to the model grows at a constant rate $n=0.011$, the average population growth rate since 1950.

[6] We follow the method developed by Yaari (1965) and Blanchard (1985) and extended by papers including Gertler (1999) and Cagetti and De Nardi (2009) in overlapping generation models.

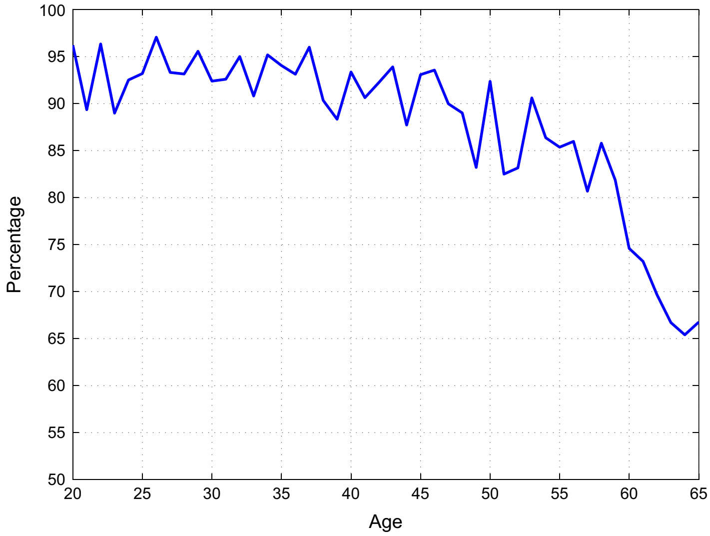

Fig. 1. Employment rate over the life-cycle (*source*: PSID).

3.2. Preference, endowment and labor market

Utility from consumption c and leisure l takes the form

$$u(c,l) = \frac{(c^{\eta} l^{1-\eta})^{1-\gamma}}{1-\gamma} \tag{15}$$

The risk aversion parameter γ is set at 2.0.[7] η is set at 0.5, that is, individuals are assumed to put an equal weight on consumption and leisure. The subjective discount factor β takes the value 0.988 on an annual basis so that individuals accumulate wealth over the life-cycle and hold wealth worth about four times as large as the economy-wide average earnings prior to retirement (at age 50–64), as in the Survey of Consumer Finance (SCF) data.[8]

Work and search reduce leisure time in amounts that vary with health status. Fig. 1 shows the employment rates of household heads from the Panel Study of Income Dynamics (PSID) in 2006.[9] Employment rates are at around 90–95% before reaching age 50 and then fall rapidly thereafter. The average employment rate across all individuals is 89%. Besides the difference by age, the participation rate of individuals declines in health status. Although we use the PSID data for life-cycle employment rates, we look at employment data in the MEPS to assess the effect of health on participation, to be consistent with the measure of health status that we use to calibrate health-related parameters in the model, as discussed in Section 3.3. The employment rate of individuals in bad health falls by 12% from age 35–49 to 50–64. Individuals in the third health status of work limitation work even less, especially at older ages and the employment rate is only about 26% of that of healthy individuals at age 50–64. The participation cost at each health status is calibrated to match these statistics and B_h^E is set at 0.06, 0.24 and 0.85 for each of the three health status.

An unemployed individual incurs disutility $B_h^s(s) = \overline{B}_h^s[(1-s)^{\zeta} - 1]/\zeta$ by extending search effort $s \in [0,1]$. The parameter $\overline{B}_h^s$ is set at $-B_h^e \zeta$ so that it takes the same value as the participation cost when the maximum search effort is extended. The curvature parameter ζ is set at 0.98, making the search cost close to linear as in Alvarez and Veracierto (2001).

The labor skill of an individual g lies in the range $[\underline{g}, \overline{g}] = [0.1, 1.0]$. Skills accumulate while individuals are employed and depreciate when they are not working. The transition matrix of skills $\Gamma_j^E(g,g')$ for employed individuals in each age group is calibrated based on the earnings growth rate in the Census data in 2010. The skills of individuals are assumed to grow at the average annual rate of 9.5% at age 20–34, 1.0% at age 35–49 and 0.0% at age 50–64, and the transition matrix $\Gamma_j^E(g,g')$ is computed to match these statistics. The transition matrices are displayed in Appendix A.

Empirical estimates of skill depreciation rates while out of labor force come in a wide range. Keane and Wolpin (1997) estimate an annual human capital depreciation rate of 30.5% (white collar) and 9.6% (blue collar). Jacobson et al. (1993)'s estimates are lower, at around 10%. We assume that skills of non-employed individuals fall at an annual rate of 15%, the value used in Pavoni and Violante (2007), and discretize the process into a transition matrix $\Gamma_j^N(g,g')$.

[7] The parameters imply a coefficient of relative risk aversion at 1.5 and intertemporal elasticity of substitution at 0.667, which lie in the range of estimates in the literature. See Attanasio (1999) and Blundell and MaCurdy (1999) for surveys.

[8] In the Survey of Consumer Finance (SCF) 2004, the average amount of assets held by age 50–64 households was \$306,000. Assuming two-member households and given the average earnings of \$39,000 in 2004 from the Census, an individual's assets are about 4 times as large as the average earnings.

[9] We exclude full-time students and assume that an individual is employed if he or she works at least 10 hours per week. Heads can be male or female.

The search technology is linear in the search effort, $\pi^s(s) = \xi \cdot s$, and the parameter ξ is set at 0.5, which implies that an unemployed individual finds a job in two periods, or four months, on average when the maximum search effort is extended.[10] The exogenous job separation rate σ is set at 2.7%, which is the average rate of layoffs and discharges in recent years according to the Jobs Opening and Labor Turnover Survey (JOLTS) by the Bureau of Labor Statistics (BLS).[11]

3.3. Health, medical expenditures and health insurance

The Medical Expenditure Panel Survey (MEPS) is used to calibrate parameters related to health status, medical expenditures, health insurance and Medicare. The MEPS is an annual survey of a representative sample of the civilian population with detailed information on demographics, health status, medical expenditures, and health insurance arrangement. We use the most recent panel of individual data (2009–2010) for the calibration.

The MEPS reports a measure of health status for each individual, which is self-reported and ranked from 1 (excellent) to 5 (poor). Every annual MEPS survey has three waves and the health measure is present in each wave. We choose to define two levels of individuals' health status, good and bad, based on the responses and define health as bad if the response is 4 or 5 in at least one of the waves in a particular year. The MEPS also asks a question if the person is limited in any way in the ability to work at a job because of an impairment of a physical or mental health problem.[12] We consider a working-age individual who is in bad health status and answers positively to this question as being in the third health status, which we call "work limitation." As discussed below, we consider that being in this third health status is a necessary condition to be eligible to apply for DI. There are only two health status, good and bad, for the group of retired individuals.[13] The transition matrices of health status are reported in Table 1.

Medical expenditures $m(j, h, \psi)$ are i.i.d. conditional on age and health status and we use total gross expenditures reported by individual samples in the MEPS.[14] For each age group and health status, we compute three expenditure levels with unequal probabilities (top 5%, next 35%, and bottom 60%), 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. The distribution of medical expenditures by age and health status is displayed in Table 2.[15]

Based on the average expenditures covered by private health insurance and Medicare reported in the MEPS, the expenditure coverage ratio of q_{HI} is set at 0.75 and q_M at 0.60, respectively. The premium of the private health insurance p_{HI} paid by each employed individual is set at \$2300 in 2009 dollars so that the insurance provider will break even, that is, revenues from premiums cover the fraction q_{HI} of the gross medical expenses incurred by private insurees in the benchmark equilibrium. The insurance premium is subtracted from the pre-tax wage bill.

3.4. Government

The model assumes mandatory retirement at age 65, or once reaching age group $j=4$ of the model. Individuals receive Social Security benefits and gain access to Medicare coverage thereafter. Social Security benefits are determined as a function of the index e that summarizes each individual's past earnings. According to the formula set by the SSA, an individual's Social Security benefits depend on the Average Indexed Monthly Earnings (AIME), which is the average of the individual's 35 highest annual earnings. Since it is not possible to keep track of the entire history of an individual's past earnings, the value of the index is updated recursively in an age-dependent way. More precisely, when an individual is at the first two age groups of age 20–34 and 35–49, we update average earnings every period based on the new earnings, assuming that the individual has worked $15/2=7.5$ and $15+15/2=22.5$ years (or 7.5×6 and 22.5×6 model periods), respectively, which are based on the average age of individuals in the two age groups, and earned the average earnings of e in each year. We also assume earnings of zero for the remaining years out of the 35 years that are used for the basis of the AIME computation. For an individual in the third age group (50–64), the index is updated only if the new earnings exceed

[10] As discussed in Section 4, most unemployed individuals who choose non-zero search intensity ($s>0$) extend the maximum search effort in the benchmark model. Therefore the calibrated parameter implies an average duration of about 4 months among those who search for a job.

[11] The layoff and discharge rate was 2.6–2.8% (bimonthly) in 2005–2007 before rising during the financial crisis and then declining to an average of 2.7% in 2010–2011.

[12] The variable that reports the answer to the question is `WRKLIM`.

[13] The purpose of adding the third state is to have a variable that indicates some health limitation at work, which is stronger than the more general condition of bad health based on the self-reported health status. Therefore it is not necessary to keep the three health status for the retirees. The medical expenditures of the last age group are very similar in the group of individuals in the two health status of bad health and work limitation, even if we distinguish between them.

[14] We use the variable `TOTEXP` in the MEPS that represents total expenditures of an 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.

[15] Although the MEPS is an excellent source of calibrating medical expenditures for the entire life-cycle with detailed information on sources of payment, the database does not capture institutionalized individuals, including those in nursing homes. Although we choose to use the MEPS as being the most comprehensive dataset for the purpose of calibrating our full life-cycle model and distinguishing sources of payment, we note that papers such as De Nardi et al. (2010) and Kopecky and Koreshkova (2014) argue that expenses for long-term care and nursing homes are important factors for life-cycle saving motives.

Table 1
Health status: annual transition matrices (*source*: MEPS).

Age	Health	Good	Bad	Work lim.
20–34	Good	0.945	0.047	0.008
	Bad	0.593	0.339	0.068
	Work lim.	0.407	0.164	0.429
35–49	Good	0.941	0.052	0.007
	Bad	0.476	0.430	0.094
	Work lim.	0.180	0.152	0.668
50–64	Good	0.910	0.064	0.026
	Bad	0.445	0.389	0.166
	Work lim.	0.184	0.138	0.677
Above 65	Good	0.847	0.153	–
	Bad	0.300	0.700	–

Table 2
Medical expenditures by age group and health status (*Source*: MEPS in 2010).

Age	Health	Percentile		
		60%	35%	5%
20–34	Good	115	2330	15,298
	Bad	240	5166	40,233
	Work lim.	3220	17,214	41,696
35–49	Good	272	3408	20,702
	Bad	590	7300	41,994
	Work lim.	4823	24,777	86,436
50–64	Good	745	5848	33,803
	Bad	1800	14,504	61,458
	Work lim.	3794	27,143	100,961
Above 65	Good	1888	9796	48,216
	Bad	5105	27,058	89,544

the average prior earnings e. The law of motion for $e' = f_j(e, g \cdot w)$ is expressed as follows:

$$e' = \begin{cases} (e \times 7.5 \times 6 + g \cdot w)/(35 \times 6) & \text{for age 20–34} \\ (e \times 22.5 \times 6 + g \cdot w)/(35 \times 6) & \text{for age 35–49} \\ \max\{e, [e \times (35 \times 6 - 1) + g \cdot w]/(35 \times 6)\} & \text{for age 50–64} \end{cases} \tag{16}$$

Given the index of past earnings e, the benefits are set according to the formula (17) below. Benefits, the Primary Insurance Amount (*PIA*), are computed using a piecewise linear function of past earnings e with three bend points, \$8928, \$53,796 and \$106,800 in 2009 dollars. The benefit (*PIA*) is capped above with the maximum base for the past earnings e of \$106,800.

$$PIA = \begin{cases} 0.9 \times e & \text{if } e < \$8928 \\ \$8035 + 0.32 \times (e - \$8928) & \text{if } \$8929 \le e < \$53,796 \\ \$22,393 + 0.15 \times (e - \$53,796) & \text{if } e \ge \$53,796 \end{cases} \tag{17}$$

DI benefits are set according to the same formula as the Social Security benefits. Once individuals are unemployed for more than two model periods (4 months), they can apply for DI benefits if they face a disability shock, which occurs with probability $\theta_{j,h}$. The third health status of work limitation, which we discussed above in Section 3.3, aligns with a condition that must be met to be eligible to apply for DI, although it is likely to be a necessary rather than a sufficient condition. According to the SSA, in addition to facing work limitations, one needs to be unable to “do work that he did before and cannot adjust to other work” and the disability must have “lasted or is expected to last at least one year or result in death.” We assume that both being in the third health status and having a disability shock that arrives with probability $\theta_{j,h}$ are necessary to be eligible to apply for DI. Disability shocks are i.i.d. conditional on age and health status and repeatedly drawn every period. The value of $\theta_{j,h}$ is set to zero for the health statuses of $h=1$ and 2.

According to the Annual Report of the SSA (2007), the percentage of the population covered by DI was 0.97%, 2.92% and 8.92% for age groups of 20–34, 35–49 and 50–64, respectively. The parameter $\theta_{j,3}$ is calibrated to target these average

Table 3
Parameters of the model (1).

Parameter	Description	Values/source
Demographics		
n	Population growth rate (annual)	1.1%
$\{\rho_j\}_{j=1}^{J}$	Conditional survival probabilities	Bell and Miller (2005)
$\{\phi_j\}_{j=1}^{J-1}$	Age-transition probabilities	See text
Preference		
β	Subjective discount factor (annual)	0.988
$u(c,l)$	Consumption-leisure utility	
	Risk aversion γ	2.0
	Consumption weight η	0.5
B_h^e	Disutility from participation	{0.06, 0.24, 0.85}
$B_h^s(s)$	Search disutility	
	Scale parameter $\overline{B}_h^s$	$-\overline{B}_h^e\zeta$
	Curvature parameter ζ	0.98
Labor market frictions		
$\pi^s(s)$	Search technology (job finding rate)	
	Linear coefficient ξ	0.5
σ	Prob. of exogenous separation	2.7%
Skill process		
$\Gamma_j^E(g,g')$	Skill transition, employed	
	Skill growth rate (annual)	{9.5%, 1.0%, 0.0%}
$\Gamma_j^N(g,g')$	Skill transition, non-working	
	Skill depreciation rate (annual)	15%

Table 4
Parameters of the model (2): health, expenditures and health insurance.

Parameter	Description	Values/source
$\pi_j^H(h,h')$	Health transition	MEPS
$m(j,h,\psi)$	Medical expenditures	MEPS
Health insurance		
p_{HI}	Health insurance premium	Set in equilibrium
q_{HI}	Expenditure coverage rate	75%, MEPS

statistics. It is set at 0.160 for age 20–49 and 0.086 for 50–64.[16] In the data, about 1% of individuals at the youngest age group receive DI benefits. It is, however, difficult to generate such young individuals opting for the permanent disability coverage given the features of the model. Therefore we add an assumption that some individuals enter their (adult) lives with a permanent disability and are automatically enrolled in the DI program. The probability of this disability is set so that 1% of individuals in the model's youngest age group are covered by DI.

Autor and Duggan (2010) report that out of the 1.766 million applications for DI benefits, 902,000, or 51%, were awarded benefits in 2005. The figure includes awards obtained not only in the initial stage of process but also in subsequent stages of reconsideration and appeals. The probability π_D that the applications are accepted and individuals are granted DI benefits is set at 50%. We assume that if the application is unsuccessful and benefits are not awarded, unemployed individuals can reapply but have to wait for at least four months (2 model periods) before initiating a new application. The assumption is based on the fact that the average wait time for the initial decision is 4.3 months.[17]

The model assumes that DI benefits will continue for the rest of the recipients' working-age life and they are terminated upon death or retirement, whichever comes first. In reality there is a probability that DI benefits are terminated exogenously as a result of the Continuing Disability Review (CDR). The probability, however, of the termination is very small. Also there are few individuals who return to work and engage in the Substantial Gainful Activity (SGA) that triggers a termination of

[16] The rate is higher for younger age groups but since there are more individuals in the third health status as they age, unconditionally of health status, 0.60% of individuals at age 20–49 and 0.80% of those at age 50–64 will receive the disability shock.

[17] Kreider (1999) estimates the likelihood of DI application and award by individual characteristics and finds that age has a positive effect on the award probability, based on the Survey of Disability and Work in 1978. Given the lack of estimates that are more recent and applicable for our study, we chose to use the common acceptance rate and calibrate age-dependent probability of DI shocks $\theta_{j,h}$ to match realized coverage rates by age.

Table 5
Parameters of the model (3): government.

Parameter	Description	Values/source
Taxes		
τ^l	Labor income tax rate	25%
τ^c	Consumption tax rate	5%
τ^k	Capital income tax rate	30%
Social Security		
$ss(e)$	Benefit formula	SSA (see text)
j_R	Retirement age	65 years old
Medicare		
q_M	Expenditure coverage rate	60%, MEPS
Unemployment insurance		
b_U	UI Benefit	50% of avg earn. (max 6 months)
Disability insurance		
$b_D(e)$	Benefit formula	SSA (see text)
π_D	Application acceptance rate	50%
$\theta_{j,h}$	Disability shock	See text
π_M	Medicare eligibility shock	8.33% (in 2 yrs avg)
Social insurance		
$\underline{a}$	Consumption floor	$4000 (annual)

the benefits. According to the Annual Report of the SSA (2007), the probability of termination for reasons related to medical standards and employment was 0.74%, which implies that the termination event will occur every 135 years on average.

Once an individual has received DI for two years, he or she will automatically have access to Medicare coverage. In the model, DI recipients without Medicare coverage will face probability π_M of becoming eligible for Medicare and the value is set so that they will gain the access in two years on average.

The asset threshold level $\underline{a}$ for the social insurance transfer is set to guarantee the minimum consumption level of $4000 on annual basis. The level is close to the values estimated in De Nardi et al. (2010) at $2700 (in 1998, equivalent to $3600 in 2009 dollars) and Palumbo (1999) at $2000 (in 1985, $4000 in 2009 dollars). In the model, the social insurance stands in for means-tested transfer 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 et al. (1995), who use a value of $7000 (in 1984, $14,500 in 2009 dollars).

When individuals lose a job exogenously through a layoff, they become entitled to unemployment insurance benefits for the maximum duration of 6 months. The benefit is set at 50% of average earnings in the model. Medicare covers $q_M = 60\%$ of gross expenditures for eligible individuals, based on the average expenditure coverage rate among Medicare recipients in the MEPS. Tax rates on consumption, labor income, and capital income are set at 5%, 25% and 30%, respectively, close to the estimates of effective tax rates in Mendoza et al. (1994). Residuals from the government budget are assumed to be the expenditures of the government that are not associated with the programs that are explicitly modeled.

4. Numerical results

This section presents the benchmark model and discusses the results of numerical experiments.

4.1. Benchmark model

This section will discuss the performance of the benchmark model in key dimensions of an individual's life-cycle, focusing on the profiles of employment status and DI coverage.

Individuals enter the model economy with no assets and start to accumulate savings for precautionary and retirement reasons. The initial health status is randomly determined to match the health status distribution of age 20–34 individuals in the MEPS samples.[18] Average assets are about 1.3 times as large as the average annual earnings at age 20–34, or $56,000 in 2009 dollars. The assets grow to reach $137,000 at age 35–49 and $177,000 ($354,000 per two-member household) at age 50–64, or 4.0 times the average earnings. Table 6 compares the life-cycle profile of wealth to the data from the Survey of

[18] In the initial period of adult life, individuals are in good health with probability 89.8%, bad health 8.1% and work limitation 2.1%.

Table 6
Assets by age (individuals, in 2009 dollars).

Age	Model	Data (SCF)
20–34	58,000	31,000
35–49	144,000	101,000
50–64	178,000	174,000
65–100	93,000	134,000
All ages	113,000	112,000

Table 7
Consumption by age (individuals, in 2009 dollars).

Age	Consumption
20–34	24,000
35–49	25,300
50–64	25,700
65–100	18,600
All ages	23,600

Consumer Finance (SCF).[19] As shown in Table 7, the consumption profile exhibits a hump shape along the life-cycle as in the asset profile, although the growth prior to retirement is more moderate than assets.

Table 8 shows the distribution of employment status by age group, compared to the data that are shown in the top section. The data are based on the PSID for employment rates and the SSA for DI coverage, both in 2007. The unemployed are defined as those who are not employed or receiving DI benefits. The employment rate is above 90% before age 50, but falls quickly thereafter as more individuals start to leave the labor market. Both the number of unemployed individuals and DI recipients rise as individuals age. About 30% of the unemployed in our model are not searching at all (i.e. $s = 0.0$) and the percentage of individuals who are searching (i.e. $s > 0.0$) is about 5.0% of the working-age population in the model.

Recall from Section 3 that we calibrated the model to target average employment rates and the percentage of individuals covered by DI. As discussed in Section 3.2, in the model the disutility of participation for individuals increases as their health status deteriorates. The participation disutility of individuals in bad health is four times as high as for those in good health and the ratio is as high as 14 times for those in the health status of work limitation. The additional disutility helps explain lower participation rates among less healthy individuals, and in particular, the sizeable decline in participation that occurs after age 50, when a larger fraction of individuals are in bad health or have a work limitation.

Since the search effort of unemployed individuals incurs disutility that rises with the deterioration of health status in the same way as the disutility of work, search incentives are significantly lower among those with bad health and work limitations and at higher ages, as shown in Table 9. The majority of individuals who extend positive search effort choose the maximum search intensity. The possibility of receiving DI benefits also discourages search efforts among those with work limitations.

4.2. *Experiments on disability insurance system*

In this section, the model is simulated with alternative assumptions about the DI system in order to understand the effects of various features of the program, and in particular to analyze the incentives to apply for DI and the distribution of employment status driven by each component of the system. The experiments can also be considered as an analysis of reforms to the DI system.

The benchmark model assumed that residuals from the government budget constraint are government expenditures, G, which are "thrown into the ocean" and do not play a role in the model. When balancing the government budget under alternative DI systems, we do not change these residual expenditures, but adjust the tax rate τ^l instead. The same assumption will be made in the policy experiments presented in Section 4.3.

Medicare and cash benefits of the DI system: One of the novel features that we introduced in our model was the in-kind Medicare benefit that DI recipients are entitled to once they have received DI benefits for 2 years. To quantify the effect of the in-kind medical benefit, the model is simulated without Medicare for DI recipients. Medicare benefits continue to be paid for retirees.

As shown in the second section of Table 10, there is a sizeable drop in DI coverage when Medicare benefits were eliminated. The percentage of DI recipients declines from 2.9% to 1.8% among age 35–49 individuals and from 8.9% to 5.1% at

[19] The data is based on the SCF in 2004 and the figures are adjusted for 2009 dollars using the CPI. The average is based on the cross-sectional data, which is not adjusted for cohort effects.

Table 8
Employment status distribution by age.

Age	Employed (%)	Unemployed (%)	Disability (%)
Data (PSID and SSA, 2007)			
20–34	93.5	5.5	1.0
35–49	91.2	5.9	2.9
50–64	81.6	9.5	8.9
Model			
20–34	93.8	5.3	1.0
35–49	90.3	6.8	2.9
50–64	77.9	13.2	8.9
All ages	88.4	7.9	3.7
Model: good health			
20–34	95.0	5.0	0.0
35–49	93.2	5.3	1.5
50–64	85.6	7.9	6.6
All ages	92.1	5.8	2.1
Model: bad health			
20–34	94.7	5.3	0.0
35–49	91.2	6.3	2.5
50–64	80.0	11.0	9.0
All ages	88.8	7.5	3.7
Model: work limitation			
20–34	55.6	11.4	33.0
35–49	37.6	34.2	28.2
50–64	21.6	53.2	25.3
All ages	33.3	39.0	27.7

Table 9
Average search effort of the unemployed.

Age	All	Good health	Bad health	Work lim.
20–34	0.948	1.000	1.000	0.216
35–49	0.745	0.974	0.975	0.043
50–64	0.535	0.967	0.865	0.019

age 50–64. As shown in Table 11, fewer individuals that satisfy eligibility conditions for DI will apply.[20] Many individuals, not just the old but also the middle-aged, choose to remain in the labor force since they would have to pay for medical expenditures on their own, not only when they are younger and expenditures are relatively low, but all the way until retirement when Medicare benefits are granted for retirees. Staying out of the labor force for a long time can result in their assets falling so low that they have to rely on social insurance. In fact, the coverage of the social insurance rises from 4.91% of the population to 5.35% as shown in the table.

The bottom row in Table 11 shows the labor income tax rates that balance the government budget in each experiment. Without Medicare benefits for DI recipients, the government is able to reduce expenditures in the amount corresponding to 0.9 percentage points of labor income, which also encourages labor participation.

The above experiment shows the importance of Medicare benefits that DI recipients will have access to. The benefits, however, are not available immediately, as there is a waiting period of 2 years before Medicare starts to cover DI recipients. The third section of Table 10 shows employment outcomes when Medicare is immediately available for all DI recipients without a waiting period. Compared to the benchmark model, there are more individuals covered by DI, but the effect is relatively small quantitatively. The percentage of DI recipients increases from 3.7% of the working-age population to 4.1%, which is a much smaller change in magnitude than when Medicare benefits are eliminated. At its current length, the wait for Medicare benefits does not seem to reduce their value in a significant way.

In order to understand the role of medical benefits, we also simulate a model where the Medicare component of DI is replaced with a constant cash payment to DI recipients. The payment is set to 60%, the coverage rate of Medicare, of average medical expenditures at each age. The annual payment is about \$2070, \$3280 and \$6110 at age 20–34, 35–49 and 50–64, respectively. When Medicare is replaced by a constant payment, more individuals choose to apply for DI benefits.

[20] Note that the table displays the likelihood of applying for the benefits for only two age groups, 35–49 and 50–64, since there are only a very few individuals at the youngest group that apply in the benchmark and other experiments.

Table 10
Employment status with alternative DI systems.

Age	Employed (%)	Unemployed (%)	Disability (%)
Benchmark model			
20–34	93.8	5.3	1.0
35–49	90.3	6.8	2.9
50–64	77.9	13.2	8.9
All ages	88.4	7.9	3.7
No Medicare for DI recipients			
20–34	93.8	5.3	1.0
35–49	91.3	6.9	1.8
50–64	81.3	13.6	5.1
All ages	89.7	8.0	2.3
Medicare w/o 2-year waiting period			
20–34	93.8	5.3	1.0
35–49	90.2	6.8	3.0
50–64	76.7	13.2	10.1
All ages	88.1	7.9	4.1
Medicare replaced by constant payment			
20–34	93.8	5.2	1.0
35–49	89.6	6.6	3.8
50–64	76.5	13.1	10.4
All ages	87.8	7.8	4.4
DI benefit cut by 20%			
20–34	93.8	5.3	1.0
35–49	91.5	6.9	1.6
50–64	81.5	13.6	4.9
All ages	89.8	8.0	2.2

Table 11
DI application, social insurance coverage and labor income tax rate with alternative DI systems.

	Benchmark	No Medicare for DI recipients	Medicare w/o waiting period	No Medicare, const pmt	DI benefit cut by 20%
DI application conditional on eligibility					
Age 35–49	0.25	0.10	0.25	0.42	0.08
Age 50–64	0.42	0.22	0.51	0.46	0.22
Social insurance coverage					
% of population	4.91	5.35	4.90	5.32	5.15
Labor income tax rate					
τ^l (%)	25.0	24.1	25.2	25.3	24.0

The number of DI recipients increases from 3.7% to 4.4% of working age individuals. Among those at age 35–49, the coverage rate increases from 2.9% to 3.8% and it rises from 8.9% to 10.4% among age 50–64 individuals.

Medical expenditures of individuals in the work limitation health status are very high, about $15,900 at age 35–49 and $16,800 at 50–64 on average. Individuals who remain in this health condition for fairly long periods are likely to run down and deplete assets and income to pay for out-of-pocket medical expenditures and become eligible for social insurance. For those individuals, whether Medicare covers part of the expenditures or they receive a cash payment does not matter much since large expenses they cannot pay will be covered by social insurance and they can consume only at the minimum consumption floor.

Other DI recipients whose health status has recovered and gross medical expenditures have come down may find the constant cash benefit more beneficial, especially when the payment exceeds what Medicare would cover. Of course, even for those DI recipients that are not covered by social insurance, it is very important that there exists a program that guarantees a decent level of consumption and pays for large medical expenses in case bad health shocks repeat in future.

If social insurance were less generous, Medicare would be valued more by risk-averse individuals. When the consumption floor is lowered from the benchmark level of $4000 to $2000, the change in DI coverage when the Medicare benefit is replaced by a constant payment declines from +0.7% (3.7–4.4%), to +0.1% (3.1–3.2%). When the consumption floor is set at a very low level of $1000, DI coverage declines by 0.11% (1.9–1.8%). As the consumption floor declines, individuals

Table 12
Employment status with 50% higher medical expenditures.

Age	Employed (%)	Unemployed (%)	Disability (%)
Benchmark model			
20–34	93.8	5.3	1.0
35–49	90.3	6.8	2.9
50–64	77.9	13.2	8.9
All ages	88.4	7.9	3.7
Higher medical expenditures			
20–34	93.5	5.5	1.0
35–49	89.1	6.8	4.2
50–64	76.6	12.6	10.8
All ages	87.6	7.8	4.6

Table 13
Employment status with reforms of other programs: models with DI.

Age	Employed (%)	Unemployed (%)	Disability (%)
Benchmark model			
20–34	93.8	5.3	1.0
35–49	90.3	6.8	2.9
50–64	77.9	13.2	8.9
All ages	88.4	7.9	3.7
Social Security: 1/3 benefit reduction			
20–34	93.8	5.2	1.0
35–49	90.5	6.7	2.8
50–64	79.2	12.7	8.1
All ages	88.9	7.7	3.5
Medicare: coverage rate 30%			
20–34	93.7	5.3	1.0
35–49	90.4	6.8	2.9
50–64	80.0	13.2	8.8
All ages	88.5	7.9	3.7
UI: benefit 70% *of avg. earn*			
20–34	93.7	5.3	1.0
35–49	89.8	7.3	2.9
50–64	77.4	13.8	8.8
All ages	88.2	8.2	3.7

accumulate much more wealth due to stronger motives for precautionary saving. Despite this better self-insurance, individuals value Medicare benefits through DI more when the benefit of the social insurance is highly limited.[21]

DI coverage is also sensitive to the level of the cash benefits. In the last section of Table 10, DI benefits are reduced by 20%, by scaling down the benefit schedule proportionally. The total number of DI recipients will decline by 1.5 percentage points of the working-age population, and the overall employment rate would rise by 1.4 percentage points. The benefit cut is most effective in encouraging participation of older individuals and the employment rate at age 50–64 rises by 3.6 percentage points, from 77.9% to 81.5%. Reducing the cash benefits by one-fifth would enable the government to reduce the labor income tax by a full percentage point, giving individuals more incentives to work.

A rise in medical expenditures: As shown above, Medicare benefit is an important part of DI and gives major incentives to apply for DI benefits. As is well known, the growth of the medical expenditures has surpassed the growth of overall economy in the past decades and the share of medical expenses in the GDP rose sharply from less than 10% in early 1980s to 18% in 2009.[22] To assess the impact of a further rise in medical expenditures, we simulate the model assuming that medical expenditures rise by 50% relative to the level in the benchmark model. As shown in Table 12, such a change will lead to a rise in DI coverage, from 3.7% to 4.6% and the employment rate falls by 0.8 percentage points. Disability benefits and Medicare payments for both DI recipients and retirees rise in response to the increase in medical expenditures, and the labor income tax rate has to rise significantly to 31% to balance the government budget.

[21] Full results for experiments with the consumption floor of $3000, $2000 and $1000 are available from the author upon request.
[22] The figures are from the Centers of Medicare and Medicaid Services (CMS.gov).

4.3. *Reforms of other programs: Social Security, Medicare and unemployment insurance*

This section investigates reforms of other government programs and studies how they interact with DI enrollment. Reforms of Social Security, Medicare for retirees and unemployment insurance are considered. A new policy is implemented in the model that is built and calibrated above, then the same reform exercise is repeated in a model without DI that otherwise is identical to the benchmark model. This allows us to quantify the effects of DI in the assessment of reforms.

Social Security reform: It is known that the current Social Security system is not sustainable as we face the demographic shift in coming decades. Papers argue that either a sizeable reduction in benefits or a rise in payroll taxes is necessary. For example, Kitao (2014) shows that it is necessary to reduce the benefits by one-third to balance the program's budget. To replicate this in our model, we reduce Social Security benefits by shifting down the formula that determines the benefit. More precisely, the coefficients for the piecewise linear function in (17), 0.9, 0.32 and 0.15, are reduced by one-third so that the benefits are cut by that magnitude for given past earnings. Results on employment status are summarized in Table 13.

As shown in other papers such as Nishiyama and Smetters (2005), İmrohoroğlu and Kitao (2012) and Kitao (2014), such reforms generate a strong incentive to save more to support consumption during retirement periods and aggregate saving will rise significantly. In our model the aggregate savings, the sum of assets a across individuals, will rise by 31% relative to the benchmark. Incentives to work longer to earn more disposable income are mitigated by additional wealth from higher saving, but the former effects dominate in our model and individuals stay in the labor force longer. The average employment rate rises by 0.5 percentage points and there is an increase of 1.3 percentage points, from 77.9% to 79.2% at age 50–64. Fewer individuals will apply for DI benefits and the DI coverage rate drops from 3.7% of the working age population to 3.5%.

Table 14 shows the employment effect of the same reform in a model without DI. The reform generates the same effects qualitatively, inducing more savings and more work, especially near retirement, but the magnitude is much smaller than in our baseline model with DI. The employment rate increases by 0.6 percentage points at age 50–64 while it was 1.3 percentage points in a model with DI, where the rise in employment came from both the pool of the unemployed and DI recipients.

Medicare reform: Next we study the effect of reducing Medicare benefits for retirees. The coverage rate q_M is reduced from 60% to 30%. The effects are somewhat similar to the reduction in the Social Security benefits. As individuals need to save more to pay for medical expenditures after retirement, the aggregate saving will increase by 7.2% relative to the benchmark model. The incentive to work longer is partially offset by the wealth effect but not completely dominated in our baseline model. The employment rate rises by 0.1 percentage points overall. There is little change in the number of unemployed individuals and DI coverage falls slightly from 8.9% at age 50–64 in the benchmark to 8.8%. Those DI recipients are in worse health than the average population and expect to face higher medical expenditures. They appreciate Medicare coverage as part of DI benefits prior to retirement, but they will eventually face more out-of-pocket expenditures after retirement with the lower coverage rate of retirees' Medicare. Some individuals that were covered by DI in the baseline model choose to remain in the labor force when retirees' Medicare benefits are reduced. In a model without DI, there is no

Table 14
Employment status with reforms of other programs: models without DI.

Age	Employed (%)	Unemployed (%)
Benchmark model		
20–34	93.7	6.3
35–49	91.9	8.1
50–64	84.5	15.5
All ages	90.7	9.3
Social Security: 1/3 benefit reduction		
20–34	93.8	6.3
35–49	92.1	7.9
50–64	85.1	14.9
All ages	90.9	9.1
Medicare: coverage rate 30%		
20–34	93.7	6.3
35–49	92.0	8.0
50–64	84.4	15.6
All ages	90.7	9.3
UI: benefit 70% of avg. earn		
20–34	93.7	6.3
35–49	91.5	8.6
50–64	84.0	16.0
All ages	90.4	9.6

such shift to employment from early retirement through disability coverage and the employment rate remains essentially unchanged, slightly declining from 84.5% to 84.4% at age 50–64.

The reduction of Medicare benefits also causes a significant rise in the social insurance coverage. The fraction of retirees covered by social insurance increases by 6.0 percentage points, from 15.5% to 21.5%. In a model without DI, there is a similar but quantitatively smaller increase of 5.6 percentage points.

Unemployment insurance reform: Finally, we simulate a model with more generous unemployment insurance, by raising the benefits from 50% of average earnings to 70%. More generous benefits reduce search effort of unemployed individuals who are qualified to receive the benefits and raise the unemployment rate from 7.9% to 8.2%. As there is little change in the number of DI recipients, this will reduce the size of employment by a similar magnitude. Since the tax has to increase by 1.2 percentage points to 26.2% to cover the additional cost of benefits, the lower after-tax wage also discourages labor supply. Effects are similar in a model without DI, where the unemployment rate increases by 0.3 percentage points.

Experiments in this section suggest that when a reform of another program has an impact on the incentives to apply for DI, the overall effects of a reform on key statistics such as employment, unemployment and saving can differ quantitatively compared to a model without DI. In particular, when individuals face a greater need to save for retirement, they may have a stronger incentive to stay in the labor force and accumulate more wealth rather than opting for early retirement through DI coverage. Of course, this exposes workers to a high disutility of work and out-of-pocket medical expenditures that can be higher than with the Medicare that comes with DI. We find that, however, the net effect of such reforms on labor supply was positive and the effect was stronger in our baseline model than in a model with no DI system.

5. Conclusion

A life-cycle model of heterogeneous agents is built, in which individuals face various sources of uncertainty including employment, health status and medical expenditures. Individuals accumulate wealth for precautionary and retirement reasons, while the government provides partial insurance against the shocks through redistributive programs. Eligible individuals can apply for disability insurance (DI), which provides both cash and Medicare benefits, with the latter available after a waiting period of two years. The model is calibrated to approximate the pattern of employment status over the life-cycle.

The paper makes a contribution to the literature by endogenizing enrollment in the DI system, which consists of both cash and in-kind medical benefits, and investigating how DI interacts with reforms of other programs including Social Security and Medicare. The model allows us to quantify the role of each element of the DI system in the employment decisions of individuals. We have shown that not only the cash benefits but also Medicare benefits are important to account for the level of DI coverage among both young and old-age individuals. DI coverage could drop significantly if its Medicare benefits were eliminated. To the extent that a reform of another transfer program impacts the incentives to enroll in DI, the quantitative assessment of Social Security and Medicare reforms can differ if a model incorporates DI enrollment decisions.

One of the interesting extensions of the paper would be to study the role of DI during business cycles, and explore how it interacts with other programs and acts as amplification or compression mechanisms in response to labor market downturns. A model would need be extended to deal with aggregate uncertainty, and the topic is left for future research. Similarly, we note that our analysis is focused on the steady state equilibrium and does not explicitly consider the evolution of DI enrollment and its impact on the life-cycle behavior of households. Studies have acknowledged the incidence of disability and payments of disability benefits as a potential factor that explains trends in the labor market.[23] Given the high dimensionality of the model populated with heterogeneous agents, which is essential for the current paper, we do not compute transition dynamics and explore the implications of DI for changes in the labor market over time. This is another important avenue of research which is left to be explored in future work.

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Appendix A. Calibration: the transition of skills g

Skills of individuals evolve according to the transition matrix $\Gamma_j^E(g,g')$ while employed and $\Gamma^N(g,g')$ while not working. The skills lie in the range of $[\underline{g},\overline{g}]=[0.1,1.0]$ The grid of the skills $\overrightarrow{g}$ and the transition matrices over the model period of

[23] See, for example, Juhn et al. (2002), Autor and Duggan (2003) and Erceg and Levin (2013).

two months are displayed below. As discussed in Section 3.2, the transition matrix $\Gamma^N(g,g')$ for non-working individuals is age independent with the common skill depreciation rate and the transition matrix $\Gamma_j^E(g,g')$ for age $j=3$ is an identity matrix as the average growth rate of skills is 0%.

$$\vec{g} = [0.100\ \ 0.111\ \ 0.144\ \ 0.200\ \ 0.278\ \ 0.378\ \ 0.500\ \ 0.644\ \ 0.811\ \ 1.000]$$

$$\Gamma_1^E(g,g') = \begin{bmatrix} 0.863 & 0.137 & 0.0 & 0.0 & 0.0 & 0.0 & 0.0 & 0.0 & 0.0 & 0.0 \\ 0.0 & 0.949 & 0.051 & 0.0 & 0.0 & 0.0 & 0.0 & 0.0 & 0.0 & 0.0 \\ 0.0 & 0.0 & 0.960 & 0.040 & 0.0 & 0.0 & 0.0 & 0.0 & 0.0 & 0.0 \\ 0.0 & 0.0 & 0.0 & 0.961 & 0.039 & 0.0 & 0.0 & 0.0 & 0.0 & 0.0 \\ 0.0 & 0.0 & 0.0 & 0.00 & 0.958 & 0.042 & 0.0 & 0.0 & 0.0 & 0.0 \\ 0.0 & 0.0 & 0.0 & 0.00 & 0.0 & 0.953 & 0.047 & 0.0 & 0.0 & 0.0 \\ 0.0 & 0.0 & 0.0 & 0.00 & 0.0 & 0.0 & 0.947 & 0.053 & 0.0 & 0.0 \\ 0.0 & 0.0 & 0.0 & 0.00 & 0.0 & 0.0 & 0.0 & 0.941 & 0.059 & 0.0 \\ 0.0 & 0.0 & 0.0 & 0.00 & 0.0 & 0.0 & 0.0 & 0.0 & 0.935 & 0.065 \\ 0.0 & 0.0 & 0.0 & 0.00 & 0.0 & 0.0 & 0.0 & 0.0 & 0.0 & 1.000 \end{bmatrix}$$

$$\Gamma_2^E(g,g') = \begin{bmatrix} 0.985 & 0.015 & 0.0 & 0.0 & 0.0 & 0.0 & 0.0 & 0.0 & 0.0 & 0.0 \\ 0.0 & 0.994 & 0.006 & 0.0 & 0.0 & 0.0 & 0.0 & 0.0 & 0.0 & 0.0 \\ 0.0 & 0.0 & 0.996 & 0.004 & 0.0 & 0.0 & 0.0 & 0.0 & 0.0 & 0.0 \\ 0.0 & 0.0 & 0.0 & 0.996 & 0.004 & 0.0 & 0.0 & 0.0 & 0.0 & 0.0 \\ 0.0 & 0.0 & 0.0 & 0.00 & 0.995 & 0.005 & 0.0 & 0.0 & 0.0 & 0.0 \\ 0.0 & 0.0 & 0.0 & 0.00 & 0.0 & 0.995 & 0.005 & 0.0 & 0.0 & 0.0 \\ 0.0 & 0.0 & 0.0 & 0.00 & 0.0 & 0.0 & 0.994 & 0.006 & 0.0 & 0.0 \\ 0.0 & 0.0 & 0.0 & 0.00 & 0.0 & 0.0 & 0.0 & 0.993 & 0.007 & 0.0 \\ 0.0 & 0.0 & 0.0 & 0.00 & 0.0 & 0.0 & 0.0 & 0.0 & 0.993 & 0.007 \\ 0.0 & 0.0 & 0.0 & 0.00 & 0.0 & 0.0 & 0.0 & 0.0 & 0.0 & 1.000 \end{bmatrix}$$

$$\Gamma^U(g,g') = \begin{bmatrix} 1.000 & 0.0 & 0.0 & 0.0 & 0.0 & 0.0 & 0.0 & 0.0 & 0.0 & 0.0 \\ 0.042 & 0.958 & 0.0 & 0.0 & 0.0 & 0.0 & 0.0 & 0.0 & 0.0 & 0.0 \\ 0.0 & 0.018 & 0.982 & 0.0 & 0.0 & 0.0 & 0.0 & 0.0 & 0.0 & 0.0 \\ 0.0 & 0.0 & 0.015 & 0.985 & 0.0 & 0.0 & 0.0 & 0.0 & 0.0 & 0.0 \\ 0.0 & 0.0 & 0.0 & 0.015 & 0.985 & 0.0 & 0.0 & 0.0 & 0.0 & 0.0 \\ 0.0 & 0.0 & 0.0 & 0.00 & 0.016 & 0.984 & 0.0 & 0.0 & 0.0 & 0.0 \\ 0.0 & 0.0 & 0.0 & 0.00 & 0.0 & 0.017 & 0.983 & 0.0 & 0.0 & 0.0 \\ 0.0 & 0.0 & 0.0 & 0.00 & 0.0 & 0.0 & 0.019 & 0.981 & 0.0 & 0.0 \\ 0.0 & 0.0 & 0.0 & 0.00 & 0.0 & 0.0 & 0.0 & 0.020 & 0.980 & 0.0 \\ 0.0 & 0.0 & 0.0 & 0.00 & 0.0 & 0.0 & 0.0 & 0.0 & 0.022 & 0.978 \end{bmatrix}$$

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