The General Equilibrium Welfare Value of Social Security in the Presence of Disability

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1 Introduction

Economic analyses typically find social security systems, of the type that exists in the United States, difficult to justify on efficiency grounds. As has been well documented in the literature, the net welfare value of modern social security systems depends on a tradeoff between negative general equilibrium costs generated through distortions to saving and work decisions and the positive individual insurance benefits that social security provides against various types of lifecycle risk. The computational literature has generally found that the former outweigh the latter, even for tightly-calibrated simulations of the U.S. economy featuring heterogeneous agents who face realistic income and mortality risk (Kotlikoff et al. [1998], Storesletten et al. [1999], Nichiyama and Smetters [2005], Huggett and Parra [2006], Hong and Rios-Rull [2006]).[1]

Models attempting to gage the welfare effect of social security have so far focused primarily on its role as a public pension provider - i.e. on the retirement and survivor components of social security programs. Such models have avoided explicitly including the disability insurance component, which typically comprises 15-20% of a country's social security payouts (Autor and Duggan [2006]). There are two intuitive reasons for this exclusion. First, universal public disability insurance could be provided by stand-alone program if the public pension with which it is bundled was privatized or dissolved. As well, in the U.S. as in many other developed countries, public disability insurance is provided both through social security contributions and through a separate means-tested program offered by the Social

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[1] An important caveat is that the discussion in this paper is limited to analyses across steady states. For instance, Nichiyama and Smetters [2005] find net long-run welfare losses to (partially) privatizing social security when the transition path between steady states is explicitly modeled and all households alive at the time of the transition must be compensated for welfare losses. This is despite the fact that the post-social security steady state economy is better off than the pre-reform economy, net of these compensations. Bohn [2005] also provides some analytical support for a defined-benefit system in a three-period general equilibrium when fertility and mortality rates, and productivity shocks, are allowed to vary across cohorts. Limiting the discussion to previous analyses across steady states, the inefficiency of public pensions seems fairly, though not entirely, robust to experimentation with non-standard preferences such as time inconsistency (Imrohoroglu et al. [2003]) and bequest motives (Kotlikoff et al. [1998]). The only exception I have found to the trend described here is Fuster et al. [2003], who find that intergenerational altruism combined with differing mortality profiles can generate welfare benefits for a majority of households.

Security Administration, the benefits of which are independent of work history. As I assume in my own results, the welfare effects of changing social security disability benefits are likely to depend on the policy and political relationship one assumes between the formal social security and the means-tested benefit formulas, making the actual benefit of disability insurance provided through social security difficult to quantify. Second, capturing disability risk and costs explicitly requires arbitrary assumptions and at least some reliance on subjective reporting in household surveys. Disability-induced shocks to income can be implicitly accounted for in lifecycle models by modelling productivity processes from microdata that combine a persistent autoregressive term with sufficiently large negative stochastic shocks. A relatively large and separate literature examining the effects of disability benefits on labour supply and participation (Autor and Duggan [2003], Kreider [1999]) and on household outcomes (Stephens [2001], Charles [2005], Bound et al. [2002], Bound et al. [2004], Meyer and Mok [2006]), have discussed some of the complications of more explicitly capturing the disability process and quantifying its costs, both in terms of income loss and of added disutility of work.[2]

The purpose of the following paper is to establish some bounds for assessing the welfare value of social security accounting for disability insurance. I proceed in two parts. In my first model, I examine an economy in which the experience of disability by individuals is limited to extreme, or effectively work-ending illness or injury. Permanent disability of this type is a fairly rare event, but because the associated costs are so high, agents desire to hold a good deal of insurance against the contingency, and the general equilibrium labour costs are fairly low. While this model may overstate the "cost" of disability in the individual case, it avoids the risks and difficulties inherent in the quantification of subjective disability costs. The second model encompasses a broader, more prevalent, definition of disability in which the costs of being disabled vary over time and in which some disabled agents may find it optimal to continue working some or all of the time. Each model is defined by a transition process for work and disability estimated from micro panel data in the American Panel Study of Income Dynamics (PSID).

I find that, in general, disability insurance is an important part of social security and its inclusion has fairly strong welfare effects for most specifications of the model economy. Whether the presence of SSD bundled with retirement and survivor benefits is sufficient to make social security at current replacement rates preferable to a no-social security steady state, however, depends heavily on modelling assumptions about how disability is experienced and also whether low income individuals are protected by alternative policy. Social security with SSD performs better in the model with "complete" and permanent disability than in a model of "partial" and chronic

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[2] The disability literature has shown signs of converging with the compuational social security literature. Some notable contributions from the perspective of this paper are Burkhauser et al. [2004], who develop a dynamic programming model of SSD application for older agents and a welfare analysis of the SSD program from survey data, and Bound et al. [2004] who has conducted a welfare analysis of SSD independent of the retirement program with which it is bundled. As well, Rus have proposed developing a model of social security incorporating disability benefits.

disability. In the latter model, when disability costs are not so high as to preclude work and/or when disabled individuals may experience periods during which their disability is less acute, the general equilibrium costs of permanently removing them from the labour force tend to outweigh the insurance benefits of SSD.

The rest of this paper proceeds in six parts. Following the Introduction, in Part 2 I introduce the basic computational model used for the analysis. Part 3 provides a description of the calibration to the U.S. economy, both in terms of macroeconomic conditions and the current policy environment. I also introduce my two possible employment-disability transition processes, estimated from the individual and/or family files from the Panel Study of Income Dynamics (PSID) for the years 1978 to 1997. Parts 4 and 5 provide basic welfare results for social security including disability insurance under each of the three estimated transition processes. I report results from social security elimination assuming three possible relationships between social security and the means-tested benefit for the "blind, aged and disabled" (the American Supplemental Security Income or SSI program). In Part 4 I also include decompositions of the insurance benefits of social security into its component parts (removing the calibrated sources of risk one by one). Section 6 returns to the idea that SSDI and SSI may be politically linked, offers some ideas for future research, and concludes.

2 Computation

2.1 Model Economy

The model economy consists of a countable infinite number of individual agents of measure one, representing the entire population who were either already disabled or were economic participants at maturity (model age 1). Agents live for a maximum of 70 model periods: J=70, and may be one of an (assumed) finite number of different ex-ante ability types (*type*). A model period corresponds to a year. Agents enter the model as adults, so age real 21 is model age 1 and J corresponds to a maximum lifespan of 90 years. Agents face mandatory retirement at age $j^* = 45$ (real age 65); they may retire at any age before then if they qualify for benefits. Their retirement age is R where $R \leq j^*$. Lifespan is uncertain ex-ante. ψ_j is the exogenous, time invariant probability of living from age j to $j+1$, which I take to be identical across health states.

Agents are distributed across states of nature, linked through history as a Markov chain. For every (exogenous) age and type, agents find themselves in one of a theoretically infinite number of three-dimensional states corresponding to (endogenous) accumulated non-human wealth holding, (exogenous) labour force or (partially endogenous) retirement status, and (endogenous) personal work history. The state realization x lies in the state space $X_.$, whose shape differs for workers and retirees:

$$x_{work}(j, type) = \{a, lfh, wh\} \in X_{work} = [[0, \overline{A})\{1, 4\}[0, \overline{W}]] \tag{1}$$

$$x_{ret}(j, type) = \{a, R, wh\} \in X_{ret} = [[0, \overline{A})\{1, j^* + 1\}[0, \overline{W}]] \tag{2}$$

In some of the following summations, I drop the subscripts and assume $x \supset \{x_{work}, x_{ret}\}$. In theory, $\overline{A} \rightarrow \infty$, while $\overline{W}$ is the accumulated earnings an individual can count toward his social security benefit. Agents' personal wealth, a, is determined by past saving decisions. *lfh* for pre-retirees is a string variable capturing agents' labour force and health (lfh) status. For retirees, R is an unchanging variable capturing the normalized date of retirement. For working agents, transitions between *lfh* states are experienced as shocks. The states are ranked, first over healthy states from "full employment" - that is, agents can offer any percentage of the 100 hours in the represenative work week - to states of successive "underemployment" or constrained-labour supply states (the highest "healthy" *lfh* state is $\overline{healthy}$; then over disabled states, with the cost of the disability - either in terms of persistence or magnitude - increasing with *lfh*.[3] The transition between states follows a two-stage Markov process with transition matrix:

$$\Pi(lfh', lfh) = [\pi_{k,l}], \pi_{k,l} = prob\{lfh' = k | lfh = l\} \tag{3}$$

As well, agents in the model are heterogeneous with respect to their productivity or endowment stream: $\epsilon_{j,type}$ captures the relative efficient labour input or endowment entitlement for an individual of age j and type *type*. There is exogenous population growth at rate n and exogenous labour-augmenting productivity and wage growth at rate g.

Agents at every age are distributed across states with measure $\lambda_j(x., type)$ where $\sum_{type} \int_x \lambda_j(x., type)dx = 1, \forall j$. Given this invariant distribution and survival probabilities, cohort shares are μ_j, where:

$$\mu_j = \frac{\psi_j \sum_{type} \int_{x_{work}} \lambda_{j-1}(x_{work}, type)\mu_{j-1} + \sum_{type} \int_{x_{ret}} \lambda_{j-1}(x_{ret}, type)\mu_{j-1}}{1 + n} \tag{4}$$

$$\sum_{j=1}^{J} \mu_j = 1 \tag{5}$$

2.2 Firms

Firms in the economy are standard neoclassical CRTS operations that produce net output $F(K, L)$ and gross output Y:

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[3] The employment transition matrix is modified from Imrohoroglu et al. [1995], Imrohoroglu et al. [1999].

$$F(K,L) = (AL)^{\alpha} K^{1-\alpha} - \delta K \tag{6}$$

$$Y = F(K,L) + \delta K \tag{7}$$

The wage and net interest rate are:

$$w = \alpha (AL)^{\alpha-1} K^{1-\alpha} \tag{8}$$

$$r = (AL)^{\alpha}(1-\alpha) K^{-\alpha} - \delta \tag{9}$$

And δ is the exogenous rate of capital depreciation.

2.3 Individual Optimization

In the healthy, disabled and retired states, agents value and optimize over consumption and leisure. The CRRA utility function for a healthy individual is given by:

$$u_h(c,l) = \frac{((\frac{c}{(1+\tilde{n})^{\zeta}})^{\gamma}(1-l)^{1-\gamma})^{1-\omega}}{1-\omega} \tag{10}$$

The CRRA period utility function for a retired/disabled individual is given by:

$$u_d(c,l) = \frac{max[(\frac{c}{(1+\tilde{n})^{\zeta}})^{\gamma}(1-l)^{1-\gamma} - p_{age,lfh,type}\widetilde{d}(l,.)w^{\gamma}, \epsilon]^{1-\omega}}{1-\omega}, \quad \epsilon \longrightarrow 0$$

Parameter γ measures the consumption share in utility and ω measures the intertemporal rate of substitution. $\tilde{n}$ captures the number of dependents per productive individual in the economy and ζ the fraction of a productive agent's consumption required by a dependent. The disability cost $p_{age,lfh,type}\widetilde{d}(l,.)$ - which is a state-dependent constant multiplied by a (possibly convex) function of labour supply [4] - captures the additional, absolute state-dependent "pain" cost to working when an agent is disabled.

These utility functions have the advantage of generating constant labour time-shares in both the healthy and the disabled states, so that total labour supply is constant on a balanced growth path.[5] They are not ideal. For healthy individuals,

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[4] To insure that the optimal choice of l always falls on the smooth part of the function and is decreasing in p, I require $\widetilde{d}_l(l,.) \geq 0$, $\widetilde{d_{ll}}(l,.) \geq 0$, and $\widetilde{d}(0) = 0$. These conditions are satisfied by letting $d\widetilde{(l,.)} = l$, and letting $p - .$ capture all variations across states and types, and is the assumption I adopt here.

[5] Alternative utility functions, in which for instance the intertemporal elasticities of substitution may differ between consumption and leisure, are provided by Huggett and Parra [2006] and by Kotlikoff et al. [1998]. However, Huggett and Parra [2006] assume an open economy, while in the latter paper, without the constant-shares property, computation of a balanced-growth steady state requires assuming that newborns' time endowment increases at the rate of economic growth.

the Cobb-Douglass specification is problematic in that it cannot simultaneously support calibrations to the fraction of time spent working and to the empirically observed low Frisch elasticity of labour supply. (See Heathcote et al. [2005], p.29 for further discussion.) For disabled individuals, allowing total disability cost to grow as a concave function of per-capita income could be objectionable if we expect economic progress to lead to a generic substitution away from physically intensive labour. However, if economic growth also makes consumption more felicitous over time, then it may make sense to assume, as these preferences imply, that the disutility of working when disabled has the same relative consumption cost regardless of the state of the economy. At any rate, these assumptions are necessary to preserve balanced growth.

In some disabled states, agents can choose to try to permanently quit the labour force and take up disability insurance. They face this option every period they remain in the appropriate *lfh* state, but take-up of disability benefits and labour market exit is irreversible. Upon application for benefits, individuals are accepted with probability q_{lfh}. Upon acceptance, agents who have made sufficient contributions during their careers to date receive an SSD benefit (converted to retirement benefits at j^*). The size of the benefit is a function of their retirement date R (since, in the US system, benefits are inflated up to the wage level in the year prior to the year they are calculated) and of personal earning history, wh. There is a minimum benefit that agents receive if their accumulated SSD benefits do not fall, subject to an asset-holdings means test ($a < \overline{mt}$). This alternative benefit grows at rate g. It may be provided either by SSD or by an alternative means-tested program (hereafter SSI, after the American Supplemental Security Income), depending on the relevant modelling assumption.

Given their state vector, x, agents face the following control vectors (primes denote carry-forward values):

$$lfh = \{1, ...\overline{healthy}\} : \qquad y(j, x, type) = (a^{'}, c, l) \tag{11}$$

$$lfh = \{\overline{healthy}+1, ...\overline{lfh}\} : \qquad y(j, x, type) = (a^{'}, c, l, d_{\cdot}) \tag{12}$$

$$R = \{1, 2...j^*+1\} : \qquad y(j, x, type) = (a^{'}, c) \tag{13}$$

$d_{\cdot} \in \{0, 1\}$is a state-dependent binary decision variable associated with the decision to apply for SS or SSI (or temporary ui benefits if appropriate) benefits and, upon acceptance, to move permanently from state space x_{work} to x_{ret}:

$$d_{\cdot} = d_{\cdot}(lfh, R|d > 0, wh, q) = \{d_{ui}, d_{ss}, d_{ssi}\} \in \{0, 1\} \tag{14}$$

That is, the applicable $d_{\cdot}$ is a function of current *lfh* state (which determines whether an agent applies for temporary or permanent benefits), retirement date conditional on being accepted for SSD or SSI and earnings history, and the probability of being accepted into SSI/SSD. Applicants to SSD/SSI are precluded from providing positive labour in the period of application, so when $q < 1$, the application is not costless. For notational simplicity, in what follows, once $d_.$ is changed from zero to one it becomes a fixed state variable (omitted because the information it contains is replicated in x). If the benefit is temporary or if the individual is rejected from the progam for which he has applied, it automatically resets to zero.

2.4 Government

The government performs at most four explicit functions: (1) It consumes a fixed percentage G of output net of depreciation. (2) It pays out an unemployment benefit (ui) to individuals who are disabled but ineligible to apply to SSD or SSI (in what follows, because they are temporarily disabled) and choose not to work. (3) It runs a means-tested program for individuals who do not qualify for benefits under social security. And (4) it runs a social security program consisting of a paygo public pension (SSR) and disability insurance (SSD). Social security is funded from a special flat payroll tax $\tau_s(.)$ levied up to a maximum amount of annual wage income and from income tax levied on social security benefits. The other three programs are funded out of general revenues which consist of a 100% estate tax on unintentional bequests, a progressive income tax $\tau_g(.)$ levied on labour and rental income, and a flat sales/ consumption tax, τ_c.

Agents are assumed to have no bequest motive and no social altruism. However, in the assumed absence of annuity markets, some agents will die holding positive levels of assets. The government's general budget is therefore:

$$\begin{aligned} GF(K,L) + \sum_j \mu_j \sum_{type} \int_x \lambda_j(x,type)dx(d_{ssi}{=}1)SSI + \sum_j \mu_j \sum_{type} \int_x \lambda_j(x,type)dx(d_{ui}{=}1)ui \\ = \sum_j \mu_j \sum_{type} \int_x \lambda_j(x,type)adx(1-\psi_j) + \tau_c \sum_j \mu_j \sum_{type} \int_x \lambda_j(x,type)cdx \\ + \sum_j \mu_j \sum_{type} \int_x \lambda_j(x,type)[ra + l\epsilon_{j,type}, w]\tau_g(a, \epsilon_{j,type}y(.))dx \end{aligned} \tag{15}$$

And its social security budget (written in terms of net benefits) is:

$$\begin{aligned} \sum_j \mu_j \sum_{type} \int_x \lambda_j(x,type)dx(d_{ss}{=}1)[SS(R|d_{ss}{=}1, wh) - \tau_g(SS,a)SS(R|d_{ss}{=}1, wh)] \\ = \sum_j \mu_j \sum_{type} \int_x \lambda_j(x,type)\tau_s(l, \epsilon_{j,type})wl\epsilon_{j,type}dx \end{aligned} \tag{16}$$

2.5 Dynamic Optimization

The intertemporal problem faced by agents of all types can be represented as a set of interlocking dynamic programs:

$R > 0$:

$$V(j, x_{ret}, type) = \max_{c \in \Omega_{j,type}(x_{ret})} \{u(c, 0) + \psi_{j+1} \beta V(j+1, x', type)\} \tag{17}$$

$lfh \in \{1, \overline{healthy}\}$:

$$V(j, x_{work}, type) = \max_{c,l \in \Omega_{j,type}(x_{work})} \{u(c, l) + \psi_{j+1} \beta E_{\Pi}[V(j+1, x', type)|j, x]\} \tag{18}$$

$lfh \in \{\overline{healthy}, \underline{eligd} - 1\}$:

$$\begin{aligned} V(j, x_{work}, type) &= \max\{V^{d=0}(j, x_{work}, type), V^{d=1}(j, x_{work}, type)\} \\ V^{d=0}(j, x_{work}, type) &= \max_{c,l \in \Omega_{j,type,d=0}(x_{work})\}} \{u(c, l, d{=}0) + \psi_{j+1} \beta E_{\Pi}[V(j+1, x'_{work}, type)|j, x]\} \\ V^{d=1}(j, x_{work}, type) &= \max_{c \in \Omega_{j,type,d=1}(x_{work})} \{u(c, 0, d{=}1) + \psi_{j+1} \beta E_{\Pi}[V(j+1, x'_{work}, type)|j, x]\} \end{aligned} \tag{19}$$

$lfh \in \{\underline{eligd}, \overline{lfh}\}$:

$$\begin{aligned} V(j, x_{work}, type) &= \max\{V^{d=1,q=1}(j, x_{work}, type), V^{d=1,q=0}(j, x_{work}, type)\} \\ V^{d=0}(j, x_{work}, type) &= \max_{c,l \in \Omega_{j,type,d=0}(x_{work})\}} \{u(c, l, d{=}0) + \psi_{j+1} \beta E_{\Pi}[V(j+1, x'_{work}, type)|j, x]\} \\ V^{d=1,q=0}(j, x_{work}, type) &= \max_{c \in \Omega_{j,type,d=1}\{(x_{work})} \{u(c, 0, d{=}1) + \psi_{j+1} \beta E_{\Pi}[V(j+1, x'_{work}, type)|j, x]\} \\ V^{d=1,q=1}(j, x_{work}, type) &= V(j, x_{ret}, type) \end{aligned} \tag{20}$$

The programs, for retired agents and healthy workers are straightforward. The only difference between them is that agents who have retired by going on SSR, SSI or SSD provide no labour and face no uncertainty about future health/employment states, other than over survival into the next period. For individuals in disabled working states the program is slightly more complex. Individuals who apply for any type benefit are constrained to supply zero labour in their period of application. I assume $q = 1$ for any temporary benefit, applied for in lfh states $\overline{lfh}$ to $\underline{eligd - 1}$. $V^{d=0}$ is the value of not applying and $V^{d=1}$ is the value of applying, the q-weighted average of being accepted and entering the program and of being rejected and enduring a period with no earned income. Individuals in SSD/SSI eligible disability states receive their benefits immediately (in the same period) upon acceptance, but it is easy to incorporate an intermediate state during which successful applicants do not receive a benefit.[6] Obviously, the program requires calculating the values of all retired states first so they may be substituted into the dynamic program for the SSD/SSI-eligible disabled.

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[6] Experiments with a waiting period did not signficantly affect the results.

Agents face budget constraints:

$$\begin{aligned}
a^{'} + \frac{c}{(1-\tau_c)} &= [1 + r(1-\tau_g(\epsilon, l, a))]a + [1 - \tau_g(\epsilon, l, a) - \tau_s(\epsilon, l)]w\epsilon_{j,type}l, && lfh = \{1, ...\overline{healthy}\} \\
a^{'} + \frac{c}{(1-\tau_c)} &= (1 + r(1-\tau_g(\epsilon, l, a)))a \\
+(1-d_{ui})(1 - \tau_g(\epsilon, l, a) - \tau_s(\epsilon, l))&w\epsilon_{j,type}l + uid_{ui}, && lfh = \{\overline{healthy} + 1, ...eligdisabled - 1\} \\
a^{'} + \frac{c}{(1-\tau_c)} &= [1 + r(1-\tau_g(\epsilon, l, a))]a \\
+(1-d_{ss}-d_{ssi})[1 - \tau_g(\epsilon, l, a) - \tau_s(\epsilon, l)]&w\epsilon_{j,type}l + SSId_{ssi} + SS(R, wh)d_{ss}, && lfh = \{eligdisabled, ...\overline{lfh}\} \\
a^{'} + \frac{c}{(1-\tau_c)} &= [1 + r(1-\tau_g(a))]a + SS(R, wh), && R \in \{1, ...j^*\} \\
a^{'} + \frac{c}{(1-\tau_c)} &= [1 + r(1-\tau_g(a))]a + SSI, && a < \overline{mt}, R = \{j^*+1\} \\
a^{'} + \frac{c}{(1-\tau_c)} &= [1 + r(1-\tau_g(a))]a, && a \geq \overline{mt}, R = \{j^*+1\}
\end{aligned}$$

Since SSI is a means-tested benefit, $\overline{mt}$ is the wealth level above which agents are ineligible. Also, per $X_.$ as defined above, agents in every age-state-type must hold non-negative assets:

$$a(j, x_., type) \geq 0 \; \forall \; j, x_., type \tag{27}$$

And the optimal choice must lie in the age-state-type-specific feasible set:

$$Y(j, x_., type) \in \Omega_{j,type}(x_.) \tag{28}$$

Starting at J, the problem can be solved recursively backward, so that every age-state-type contingency with positive probability has an associated optimal feasible policy. Given the utility function chosen, if the tax system is such that $\Omega_{j,type}(x_.)$ is convex, then a single solution to the program exists.[7] A description of the algorithm used to compute the optimal rules and associated steady state is provided in Appendix 7.1.

2.6 Equilibrium

A stationary general equilibrium for a given set of policy arrangements $\{SS(R, wh)$, ui, SSI, G, $q\}$ is a full contingency set of value functions and associated optimal policy functions $\{c(j, x_., type)$, $l(j, x_., type)$, $d(j, x_., type)$, $a^{'}(j, x_., type)\}$, a price vector $\{w, r\}$, taxes $\{\tau_s(.), \tau_g(.), \tau_c\}$, a time-invariant age structure $\{\mu_j\}$ and, for each age, a time invariant distribution of agents across states $\{\lambda_j(x_., type)\}$ such that:

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[7] This is not quite true of my model because of the top limit on social security contributions (see the discussion in Kotlikoff et al. [1998], Appendix 2). However, in tests it converges consistently to a single point in {K,L} space, suggesting that non-convexity and potential multiple equilibria are not a problem.

- $\{c(j, x_., type), l(j, x_., type), d_.(j, x_., type), a^{'}(j, x_., type)\}$ solves (17)-(19) subject to (21)-(25) for every age, state and type.

- Labour and capital are paid their marginal products and profits are zero; (8) and (9) hold.

- Social security (16) and non-social security government expenditures (15) achieve budget balance.

- Output and factor markets clear:

$$\sum_j \sum_{type} \int_x (c(j, x, type) + a(j, x, type))dx + GF(K, L) = (AL)^{\alpha} K^{1-\alpha} + (1-\delta)K \tag{29}$$

$$\sum_j \sum_{type} \int_x (a(j, x, type)(1 - \psi_{j+1}))dx = (1+n)(1+g)K \tag{30}$$

$$\sum_j \sum_{type} \int_x (l(j, x, type)\epsilon_{j,type})dx = L \tag{31}$$

- The time-invariant measures of agents are derived from exogenous survival and *lfh* transition probabilities and optimization (capital letters here denote the solution set to the optimization problem for a given state):

$$\begin{aligned}
\lambda_j(x^{'}_{work}, type) &= \sum_{type} \sum_{lfh} \int_{a^{'}:a^{'} \in A_j(x)} \int_{wh^{'}:wh^{'} \in WH_j(x)} ((\lambda_{j-1}(x_{work}, type))da)dwh \\
\lambda_j(x^{'}_{ret}, type) &= \sum_{type} \sum_{lfh=4} \int_{a^{'}:a^{'} \in A_j(x)} \int_{wh^{'}:wh^{'} \in WH_j(x)} d_.(x_{work}, type)((\lambda_{j-1}(x_{work}, type))da)dwh \\
&\quad + \sum_{type} \sum_{R} \int_{a^{'}:a^{'} \in A_j(x)} \int_{wh^{'}=wh} ((\lambda_{j-1}(x_{ret}, type))da)dwh
\end{aligned} \tag{32}$$

3 Calibration to the U.S. Economy

The first three subsections of Part 3 overview the calibration procedures that are common features of the models used to assess the welfare contributions of American Social Security in Parts 4 and 5. The last subsection discusses the two possible employment/disability transition processes for the model, called Π_1 and Π_2, and the final calibrations that are dependent on the process for $\Pi_.$.

3.1 Macroeconomic aggregates

Table 1 gives the exogenous preference and technology parameter values chosen for the model, and the corresponding parameters from some other well known models

Table 1: Basic model calibration parameters

Parameter name	My model	Storesletten et al 1999	Huggett & Ventura 1999	Kotlikoff et al 1998	Imrohoroglu et al 1995	Imrohoroglu et al 2003
J (real-world J)	70 (90)	87 (99)	81 (100)	55 (75)	65 (85)	65 (85)
j^* (real world j^*)	45 (65)	44 (65)	46 (65)	45 (65)	45 (65)	45 (65)
$\{\psi_j\}$	2003 female period rate	1991 female period rate	1994 SSA data	Certain lifespans	Faber 1982	Faber 1982
$\{\epsilon_{j,type}\}$	Hansen 1993	Derived from PSID	Hansen 1993	Derived from PSID	Hansen 1991	Hansen 1991
g(TFP or LAPG)	1.0% (LAPG)	1.5% (TFPG)	2.1% (LAPG)	1.0% (LAPG)	0	1.65% (TFPG)
n	1.2%	1.0%	2.1%	1.0%	1.2%	1.2%
α	0.64	0.60	0.64	0.75	0.64	0.69
δ	4.7%	7.8%	6.0%	0%	8.0%	4.4%
G^*	19% (see discussion)	20% of benchmark	19.5%	21.4%	0	0
ω	2	2	2	3	2	1 and 3
γ	0.352 (see discussion)	1	0.33	0.50	1	0.33
ϕ	0	n/a	n/a	n/a	n/a	n/a
β	1.011 (Hurd [1989])	1.011	1.011	0.985	1.011	0.985
q	Part 4: 1	n/a	n/a	n/a	n/a	n/a
	Part 5: $q \in 0, 1$					
p	Part 4: 10	n/a	n/a	n/a	n/a	n/a
	Part 5: $p \in [0.05, 1]$					

in the literature. For all results reported here I set $\tilde{n} = 0$ and $\zeta = 1$ – that is, I ignore the dependent population, including non-participant adults and children. For the most part, my remaining parameter choices are fairly standard and should not drive any differences between my results and those from the literature. The positive discount factor comes from Hurd [1989], and produces a hump-shaped profile of lifetime savings and consumption. The depreciation rate is taken from Nichiyama and Smetters [2005], which the authors calculated from NIPA data. I pick the relatively low labour-augmenting g from Kotlikoff et al. [1998] to reflect the fact that wage growth at the mean has lagged total factor productivity growth in the U.S. I assume that the female mortality profile (CDC 54(14) National Vital Statistics Report 2003) is constant across type and health-disability status. The value given in Table 1 for government share is G^*, the share of gross output Y. For simulations other than the benchmark, however, I use the parameter G, the fixed share of *net* output that replicates the value of G^*Y in the benchmark model (around 23%). I discuss the reasoning behind this assumption further in foonote 15.

For the results reported in Parts 4 and 5 I set $\widetilde{d}(l) = l$. The choices of p and q are discussed in parts 3.4.1, 4 and 5 below.

3.2 Ability shocks and lifecycle risk

A large literature assessing the efficiency value of public policy generates income processes by imposing functional forms on earnings micro-data, particularly from the University of Michigan's Panel Study of Income Dynamics (PSID) - see, for instance, Laibson et al. [1998]; Storesletten et al. [1999]; Kotlikoff et al. [1998]. In order to better separate out the sources of lifecycle risk, I instead follow a calibration procedure as an amalgam of the approaches employed by Imrohoroglu et al. [1995] and Imrohoroglu et al. [2003] in which individuals face shocks in the form of period-by-period employment and health risk; and Huggett and Ventura [1999], in which the potential income or productivity process is modeled as an exogenous shock (combining a gender shock and a separate shock roughly capturing "ability") experienced at birth, the distribution of which is targeted to match the gender-specific distributions of hourly wages in the United States as observed in recent Current Population Survey (CPS) data. The employment/ disability shock is discussed in part 3.4.1 below. Here I turn to the estimation of the "fixed" component of lifecycle income and income risk, which is constant across the two model specifications.

Agents are subject to a 'type" shock at maturiy comprising two elements: gender and (gender-dependent) "ability". The latter encorporates the observed lower returns to labour market experience experienced by women (and, theoretically, other fixed-effect determinants of wage that may not depend strictly on ability, such as being born into a stable or wealthy family). In a variation of Huggett and Ventura [1999]'s "fixed effect" approach, I assume that the type shocks follow Weibull(k,λ) distributions with four possible "types" spaced χk apart in ln space. χ is chosen to cover the wage distribution up to the 99.75 percentile. The λ term allows an extra degree of freedom in capturing the observed left skew of the wage distribution. This "type" shock then fully determines the path of individuals' future wage rate, which I estimate separately for males and females using the growth-adjusted January, May and September waves of the CPS (final outgoing rotations) for the years 2001 to 2004.

Table 2 reports the estimated values for k, λ for men and women and shows how well these parameters, combined with the estimated wage return to age, fare in approximating moments of the observed wage distributions in the U.S. Figure 3.2 shows the same information graphically for men, women, and both genders combined. Finally, Figure 3.2 gives an idea of how well the simulated variance of hourly wages tracks the observed variance by age. The simulations slightly overpredict the spread of the wage distribution, at each age and overall, but generally they capture the (static) U.S. wage distribution quite well. Of course, without recourse to panel data, I cannot be sure that the model does not seriously underpredict variation in the wage over the lifecycle for a given individual.

Table 2: Observed and simulated hourly wage distributions

Target	U.S. male hourly wage distribution	Weibull (k=1.29, λ=2.38)
90/10	4.24	4.23
50/10	1.95	1.96
90/50	2.18	2.16
St.dev (normalized)	0.620	0.629
Skewness	1.81	1.86
Gini	0.315	0.318
Target	U.S. female hourly wage distribution	Weibull (k=1.19, λ=2.21)
90/10	3.72	3.70
50/10	1.78	1.77
90/50	2.09	2.09
St.dev (normalized)	0.617	0.607
Skewness	1.73	1.95
Gini	0.300	0.302

3.3 Taxation, Social Security and SSI

I loosely replicate the progressivity of the U.S. income tax system, then let agents' behaviour interacted with the exogenously set government expenditures (including social security policy) determine the levels of the tax. In addition to the 100% estate tax, I follow Imrohoroglu et al. [2003] in setting a flat-rate consumption tax of 5.5%. I treat capital and labour income identically and assume three tax brackets, reported in Table 3, whose (smoothed) proportional structure has remained fairly constant over recent American history.[8]

Social security benefits are taxed at a special rate modeled on federal legislation from 1983 and 1993. Under the 1983 legislation, up to 50% of social security benefits became taxable at standard rates if total non-social security income plus 50% of benefits fell above a certain threshold (taken to be 67% of GDP per capita) - taxable benefits are then the lesser of 50% of benefits or the difference between total income including benefits and the legislated threshold. In 1993, a second threshold was added above which a maximum of 85% of social security benefits became subject to tax. I incorporate the 1993 revision to the law by assuming that a maximum of 60% of social security benefits above the 1983 threshold can be taxed. The revenue from income tax on social security contributions enters the government's social security rather than its general budget. Benefit taxation generates roughly 1% of social security revenues in the benchmark full-replacement rate model, compared to 2.1%

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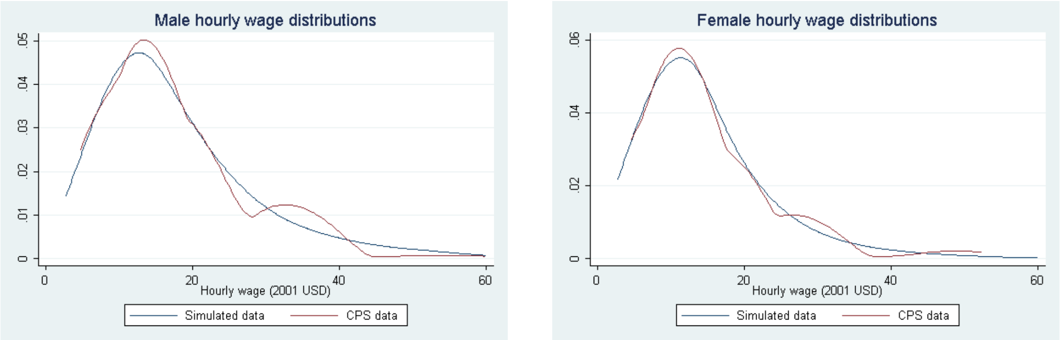
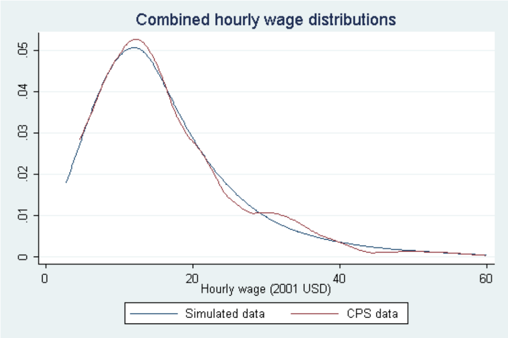
[8] Figures are based on the IRS' Schedule X faced by a single individual. Running the model with five tax brackets, under current U.S. policy, does not affect the results.

Figure 1: Hourly wage distributions



(a) Male (b) Female



(c) Both genders

in 2006 in the U.S.[9].

Table 3 shows the simulated distribution of tax-filers across U.S. brackets from a preliminary run of the model vs. an estimate of the actual distribution in 1997 from the American Enterprise Institute. The model under-predicts the proportion of earners who do not pay any income tax (in part because marginal participants, those who supply less than 12 hours a week on average when healthy, are excluded from the model population) but otherwise gives a good approximation of the observed distribution across brackets conditional on paying tax.

I calculate social security and SSI benefit formulas using the U.S. federal rate formulas topped up with average state supplementation in the case of SSI:

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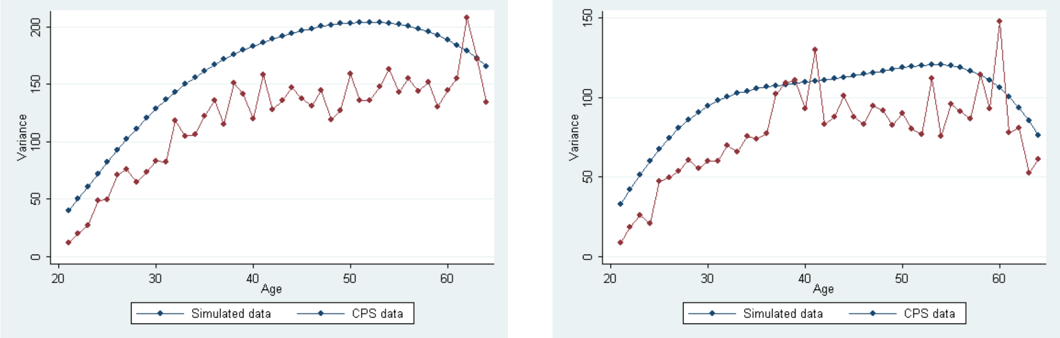
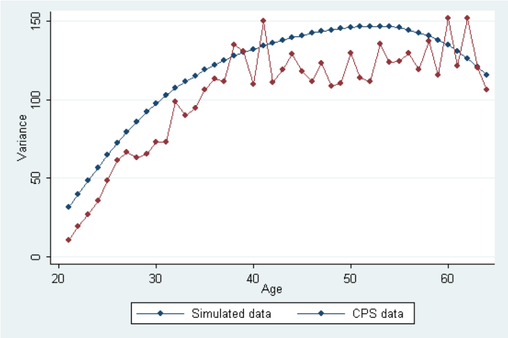
[9] Data is from the Social Security Administration (SSA), Summary of 2006 Annual Report

Figure 2: Variance of wages by age



(a) Male

(b) Female



(c) Both genders

$$
\begin{aligned}
SS(R, wh_R) &= 0.9 \min\left(0.2\overline{we}, wh_R\right) \\
+0.32(\max\left(\min\left(wh_R - 0.2\overline{we}, 1.3\overline{we} - 0.2\overline{we}\right), 0\right) \\
+0.15 \max\left(wh_R - 1.3\overline{we}, 0\right)(1+g)^R & \qquad (33) \\
SSI &= 0.22\overline{we} \qquad (34)
\end{aligned}
$$

$\overline{mt}$ is set to 20% of per-capita output. The payroll tax rate is determined endogenously and applies to all income up to 2.5 times the average wage income ($\overline{we}$) in the economy. In the U.S., contributions are calculated using the 35 highest earning years. Due to computational limitations on state space, I am unable to capture the full extent of social security's employment insurance role.[10] I simplify by first excluding earnings at ages below 25 (model age 5) in the retirement benefit determination, and then replacing current earnings with average eligible earnings to date in the calculation of wh', for agents in disabled states (*lfh* 3 and 4 for Π_1 and 4 for

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[10] Nichiyama and Smetters [2005] and Huggett and Parra [2006] also remark on this difficulty with computational models.

Table 3: Distribution of filers across tax brackets

Bracket as % of average income	Tax Rate as % of top rate	% filers: 1997 AIE	% filers: Model with Π_1	% filers: Model with Π_2
$[0, 19.5\%)$	0%	35%	14.8%	16.4%
Individuals paying positive tax:				
$[19.5\%, 90\%)$	40%	60%	60.3%	61.7%
$[90\%, 191\%)$	83%	32%	30.5%	29.8%
$[> 191\%)$	100%	8%	9.2%	8.5%

Π_2) and also in the "underemployed" state between real ages 25 and 34, and above 61 in the model using Π_1.

3.4 Estimation and Calibration Under Alternative Employment and Disability Transitions: Π

Under both calibration approaches, employment and disability shocks are captured through the use of 4x4 transition probability matrices Π, shown in Figure 3, and the model parameters p and q.

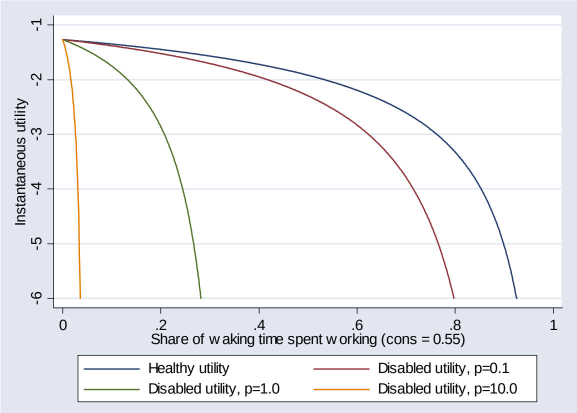
Figure 3: *lfh* transition matrix

$$(lfh', lfh) = \begin{bmatrix} \pi_{11} & \pi_{12} & \pi_{13} & \pi_{14} \\ \pi_{21} & \pi_{22} & \pi_{23} & \pi_{24} \\ \pi_{31} & \pi_{32} & \pi_{33} & \pi_{34} \\ \pi_{41} & \pi_{42} & \pi_{43} & \pi_{44} \end{bmatrix}.$$

In both the following descriptions of the employment-disability transition, I calculate Π separately for men and for women in four broad age classes: 21-29, 30-44, 45-54 and 55-64. All estimations are made using information from corresponding sets of variables in the PSID individual and family files spanning the period 1978 to 1993 (for Π_1) and 1986 to 1997 (for Π_2). The first captures the individual's subjective disability and/or labour force status; the second captures his or her labour hours supplied in the current period.

Figure 4 shows what happens to period utility, over the continuous part of the function, as labour supply increases for healthy individuals and for disabled individuals who face $p = 0.1$, $p = 1$ and $p = 10$, with consumption fixed at near the average rate generated by the models. For p large enough, basically any amount of work is infeasible – the condition assumed under the definition of disability in Π_1. Smaller levels of p correspond to states in which limited amounts of work may still be optimal for disabled individuals, as is the case for the "partial" disability state, *lfh* 2 and 3 in Π_2.

Figure 4: Healthy and disabled utility



3.4.1 Complete/Permanent Disability Transition: Π_1

The first *lfh* transition process, Π_1, assumes a narrow definition of disability, that is, one that effectively end the individual's ability to supply labour.. When "disabled", individuals face a single disutility-of-labour cost, p, which I set to 10. The disability state may be temporary - that is, the individual eventually returns to a healthy state (*lfh* 1 or 2) with $p = 0$ - or it may become permanent in which case it lasts until the agent's death (or, effectively, retirement).

Π_1 is calculated from information in the individual files of the PSID for the years 1978 to 1993. The two questions used to assess employment/disability status are $Q1$, which records the individual's current employment status with answers 1-3 representing labour force participation; 4 for retirement; 5 for disability; 6 for housewife; 7 for housewife; 8-9 for other.[11] (For 1978 I substitute information from a direct question on disability status.) $Q2$ records the indivdual's annual hours working for money in previous year, with the answer imputed from the average hours per week and number of weeks worked. I categorize individuals as being in *lfh* 2 - underemployment - if they work fewer than 1500 hours, but are still economic participants in that they average at least 600 hours a year (about twelve

---

[11] Between 1984 and 1985, the PSID work status question changed slightly to include "temporary" as well as "permanent" disability in category 5, resulting in a higher proportion of observations reporting being too disabled to work. Using the procedure outlined here and in Appendix 7.2 eliminates this descrepency; in the final estimations there is essentially no time-trend in the portion of the population categorized as temporarily or permanently disabled.

Table 4: Pooled-weighted distribution across *lfh* states

	All adult household members	Head and spouse only	Simulated
lfh 1	69.48%	71.65%	68.83%
lfh 2	26.22%	24.43%	26.44%
lfh 3	0.74%	0.72%	0.73%
lfh 4	3.56%	3.21%	4.00%

hours a week) in all the years they are healthy in the sample. I do not distinguish between market and non-market reasons for underemployment but assume that the differences do not arise from differences in preferences but from external constraints such as matching frictions in the labour market or family or religious obligations.

To differentiate *lfh* 3 and *lfh* 4, I assume individuals who do not work more than 1500 hours in any period after the initial report of a work-precluding disability and who do not average more than 600 hours a year while "disabled" are *lfh* 4 and have been so since their second year in disability. A more detailed description of the sample selection and estimation method, as well as estimates for the eight transition matrices, are provided in Appendix 7.2.

An advantage of the approach described above for my individual-based (as opposed to household-based) model is that it allows me to use the individual files of the PSID, which provide longitudinal information on adult household members other than the head and spouse. Table 4 shows the pooled distribution of observations across *lfh* states under the assumptions of Π_1 for all individuals and for heads and spouses only between 1978 and 1993, followed by the simulated distribution from using Π and the observed health-status shares among 21-year olds in the PSID. Using the head an spouse information in the family files underestimates the prevalence both of underemployment and of permanent work-ending disability among the participant population.

The final step in the calibration process for Π_1 is to calculate the distribution of *total* labour earnings from the same sample of workers from the CPS between 2001 and 2004, using γ_{type} as targets. To simplify the estimation, I assume that γ is identical across genders (that is, the lower labour supply of women stems entirely from external constraints on time and not from an inate relative taste for leisure), but varies with ability. The γ for the median-type agent is chosen so that he contributes 42.3% (42.3 hours) of his waking time to labour activities when fully employed, which is the average hours conditional on working at least 31 hours in the CPS sample.[12] The low-type and higher-type γs chosen to achieve a gini coefficient close to empeirical observation. The resulting distribution of γ and the average hours supplied by each type of agent when unconstrained in employment is given in Table

---

[12] This gender simplification is not fully consistent with observation: conditional on working more than 30 hours a week, the male sample members provide 43.4 hours at the mean and the female sample members 41.1 hours.

Table 5: Consumption preference and full-time labour supplied

	Gamma	Simulated hours supplied
Low type	0.387	44.4
Median type	0.386	42.3
High type	0.386	42.0
Highest type	0.385	45.0
Target	U.S. labour earnings distribution	Simulated distribution
90/10	5.03	6.57
50/10	2.22	2.71
90/50	2.27	2.42
St.dev (normalized)	0.704	0.718
Skewness	1.96	2.20
Gini	0.351	0.352

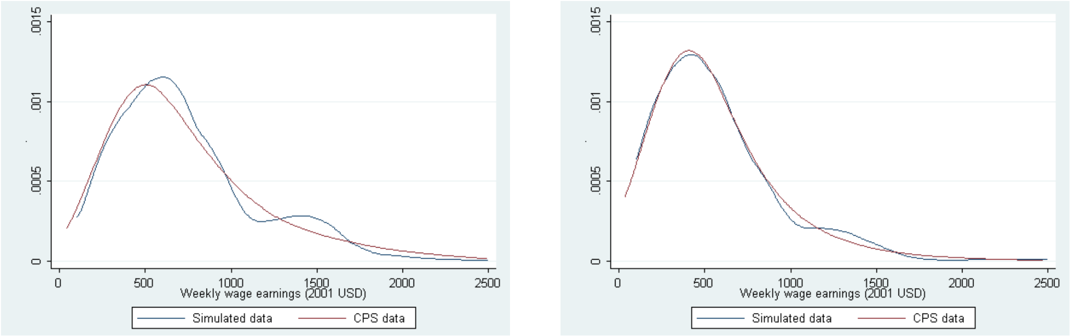
5. Labour supply is non-monotonic in productivity, even when γ is identical across ability types. Given constant-shares preferences, the difference comes from the tax treatment of earnings. Higher marginal income tax rates depress labour supply as ability increases, but the highest productivity agents face a zero marginal payroll tax. Though not shown here, these highest-ability type agents therefore concentrate their labour supply in their highest productivity years more than lower-productivity agents.

The lower panel of Table 5 and the three panels of Figure 3.4.1 show that the optimally cablibrated post-labour supply distribution does not perform quite as well as the hourly wage distribution shown in Part 3.4, at least for males. In particular, labour supply is too elastic with respect to changes in wage/productivity over the lifecycle, which leads to more mass in the tails than observed in the data (this is not obvious from Figure 3.4.1, but shows up in the 90/10, 50/10 and 90/50 ratios). This is likely because of the convention that lifecycle productivity variations are known to agents with certainty, with all uncertainty coming from restrictions on employment, which are generally more variable and binding for women (i.e. women are therefore more likely to work during low-productivity periods, to insure against future labour risk.) Nevertheless, the simulations give a reasonable appoximation to the labour earnings distributions in the U.S.

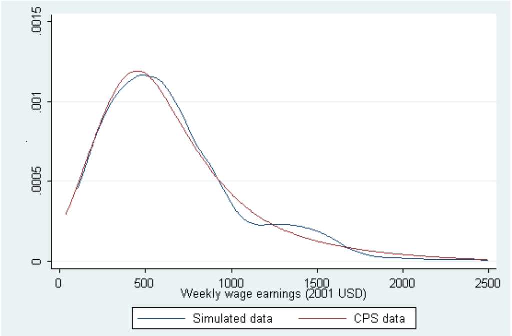
3.4.2 Partial/ Chronic Disability: Π_2

The second process for *lfh* status, Π_2 uses a different set of variables and assumes a broader, more continuous conception of disability. The primarily classification variable, $Q3$, is a combination of three PSID famil file variables that gage whether the individual in question (head or spouse) has a “physical or nervous condition”

Figure 5: Labour earnings distributions



(a) Male (b) Female



(c) Both genders

that limits the amount and type of work they can perform, and how much it limits them. For simplicity, I now ignore the healthy state underemployment stemming fom market frictions or lifecycle obligations. While healthy, males are unconstrained in their labour choice, and women have a time endowment 77% of the size of males'. Once an individual registers a disability, he or she leaves the healthy state and enters one of three disabled states. State *lfh* 2 corresponds to 'marginal" disability: subjective reporting of either no current disability or a disability that affects current labour activity "not at all" or "a little bit". *lfh* 3 corresponds to "partial" disability - subjective reporting of a disability that impedes labour effort "somewhat". *lfh* 4 corresponds to "acute" disability - a state in which agents report that their disability impairs their work "a lot" or that they "can do nothing". In order to exit the healthy state individuals must report a disability that limits their work at least "a little bit". Individuals can return to the healthy state *lfh* 1 if they report no current disability or a disability that does not limit their work at all for five consecutive periods after

Table 6: Population shares and $p_{lfh,gender}$ under Π_2

	Real (simulated) population shares (men)	Calbrated $p_{lfh,male}$		Real (simulated) population shares (women)	Calbrated $p_{lfh,female}$	
		(a)	(b)		(a)	(b)
lfh 1	77.9 (74.7)	0	0	74.4 (69.6)	0	0
lfh 2	14.5 (16.1)	0.050	0.070	17.1 (20.2)	0.095	0.115
lfh 3	3.4 (5.5)	0.100	0.145	4.5 (5.5)	0.115	0.150
lfh 4	4.2 (4.7)	0.330	0.445	4.0 (5.0)	0.380	0.600

their initial positive disability report.[13]

Information for computing Π_2 is available on an annual basis from the PSID individual and family files for the years 1986 to 1997, after which it is available on on bi-annual basis. Current calculations are made using only the 12 years of data for 1986 to 1997. Once Π_2 is determined, I calibrate p by *lfh* and gender so that the median type individual in each state supplies the same amount of labour as their *lfh* counterparts in the PSID. (As before, the median-type γ, is chosen to match the labour supply of the healthy-state median-type individual.)

In calibrating p I consider two further cases. For the process $\Pi_2(a)$, observations who receive SSI or SSD benefits in the year following their current disability report are excluded from the labour supply estimations. For the process $\Pi_2(b)$, these individuals, who are constrained under federal rules to supply no or very little labour, are included. The two calibrations can be thought of as rough bounds on the labour-inhibiting role of disability. Under $\Pi_2(a)$, the implicit assumption is that the population receiving SSD/SSI is no different in their work potential than individuals in the same *lfh* state who are not receiving benefits. Subject to some qualifying level of impairment, SSD/SSI receipt is essentially a lottery. Under $\Pi_2(a)$, the implicit assumption is the reverse: SSD/SSI recipients would provide no (or little) labour in the absence of benefits, as is the case under Π_1. SSD/SSI never accepts applicants who are capable of providing signficant amounts of labour.

Tables 3.4.2 and 7 summarize the information in the calibration process: the distribution of individuals across states (using the data from 1990 on); the calibrated disability costs; and the hours supplied by state. Additionally, 1% of the population is assumed to be born already disabled and to be SSI recipients from birth.

Given Π_2 and associated p, the final steps in calibrating the model economy are again to vary γ_{type} in order to target the earned income distribution from the 2001-2004 CPS. As before, the median-type γ, as well as the female labour supply constraint, is chosen to target the values given in the first row of the first panel of Table 7, and the remaining values of γ are used to match the tails of the labour-earnings distribution as closely as possible, assuming that they are identical across

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[13] A test of total persistence - that is, of never returning to the healthy state, is rejected at 1%.

Table 7: Π_2: Real (simulated) labour supply under Π_2:

	Male hours worked (a)	Male hours worked (b)	Female hours worked (a)	Female hours worked (b)
lfh 1	43.5 (43.6)	43.5 (43.5)	34.3 (34.2)	34.2 (33.8)
lfh 2	40.1 (39.9)	38.6 (38.5)	28.6 (28.5)	27.2 (27.1)
lfh 3	33.4 (33.5)	29.7 (29.6)	25.4 (25.4)	22.8 (22.7)
lfh 4	15.8 (15.9)	10.4 (10.4)	12.5 (12.1)	9.2 (9.7)

gender. (The labour supply targets are taken from the PSID since the comparable information on disability status can not be infered from the CPS. The process is otherwise similar.) Because disability is chronic, many individuals enter *lfh* 4 at some point. Individuals must cease all labour activity in order to apply. For the benchmark model, I therefore set q in order to target the US populations actually receiving SSD benefits. Setting q less than 1 filters the SSD population both because some applicants must wait multiple periods to receive benefits and because higher-ability agents will prefer not to stop working in order to gamble on qualifying for benefits.

4 Results for "Complete"/Persistent Disability

In the following results, I set A=2.65, which gives a per-capita gross output of 1 in the benchmark model (Table 8, row 1, panel 1) but otherwise has no effect on the results given the preference functions adopted. The parameter M reported in the first column of all the following tables is the multiplicative factor on the replacement rate, keeping all (relavent) bend points and ratios for income replacement across the labour income distribution equal, although the ratios are not fully maintained since the average yearly wage is a function of endogenously determined hours worked as well as exogenous ability shocks. Two standard utility measures as well as various macroeconomic and policy outcomes are presented. I present two measures of utility: discounted using β and non-discounted utility (which is the additively separable, equal weighted welfare function across steady states). Because social security shifts consumption from the young to the old, agents who discount the future at the negative rate commonly used in the computational literature always favour higher rates than the non-discounting planner, and are partial to any program that facilitates the enjoyment of consumption and leisure in later periods. Including non-discounted utility can be thought of as a check that imprecise and arguably irrational time preferences are not driving the welfare results.

4.1 Representation of the U.S. Economy

Table 8 presents the basic results for the economy calibrated using Π_1. I begin with brief comment on the benchmark results presented in Panel 1 of Table 8 replicate some long-run macroeconomic features of the U.S. economy. The interest rate comes out to 4.38%, roughly in line with the value of 4.2% that Huggett and Parra [2006] set to match the historical U.S. return on stocks and long term bonds, and not indicative of the over-saving we might expect given an individual-based rather than a household-based model. Performing less well, at 3.97, the capital-output ratio falls at the high end of the range of ratios targetted or estimated in similar computational models. The endogenous social security payroll tax comes out to 11.9%, only slightly below the actual U.S. social security payroll tax of 12.4% but appropriately higher than (non-SSD) payroll taxes generated endogenously in recent models by Storesletten et al. [1999] and Huggett and Ventura [1999].[14] The income tax top rate comes out to 34.8%, very close to what we expect the combined federal and state income tax rate to be (see Kotlikoff et al. [1998].

4.2 Social Security, SSD and Disability Risk

From Panel 1 of Table 8, in the benchmark model a social security replacement rate about 40% (70%) of the United States top rate turns out to be optimal from the non-discounting planner's (discounting individual's) perspective. Perhaps the central result of this section is that, in contrast to most previous studies, the steady state of the economy with social security generates higher welfare than the economy with no social security, even without accounting for the transition costs of moving between steady states. The individual utility gains from the insurance provided by social security in a world with work-ending disability risk dominate general equilibrium losses up to current replacement rate levels.

Panel 2 shows what happens to these benchmark results when the SSD component of social security is removed (agents who enter the economy disabled still receive SSI at a non-declining rate). Because the simulated economy is otherwise identical, utility comparisons can be made directly across Panels 1 and 2. Unsurprisingly, social security without its disability component turns out to be less efficient as social policy, generating lower ex-ante welfare at every positive rate of replacement, despite the fact that output and consumption are higher at larger replacement rates than in the benchmark model (consumption is 0.9% higher at the existing U.S. replacement rate.) The optimal replacement rate with (without) discounting remains at 40% (70%) of the existing U.S. rate.

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[14] Steady-state models of this type tend to produce payroll taxes that are too low, perhaps because they ignore the trust fund contributions being made under current demographic conditions as well as SSD. One common way of avoiding this problem is to set payroll taxes and benefits exogenously and simply discard whatever remainder the taxes produce. Letting payroll taxes be determined endogenously has two advantages: it provides an extra check on the model's performance and it avoids confounding the utility losses from general equilibrium effects with the utility losses from inefficient taxation (i.e. taxation that includes a deadweight loss).

4.3 Social Security vs. SSI

Panel 1 represents the "benchmark" specification (the one assumed in the decomposition analysis below, and in Part 5), in which disability benefits for all workers are assumed to be provided by a single program (SSD), bundled with social security retirement and survivor benefits (SSR). Means-tested SSI is limited to only the fraction of new adults who reach maturity already disabled (both permanent and temporarily disabled agents are given the option to take SSI benefits at model age 1.) These individuals receive the same SSI benefit – 22% of earnings in the full-replacement rate economy – as the SSR/SSD benefit falls with M, but the minimum benefit available to those who do accumulate work histories (and are therefore able to save) declines proportionately with M. Disability and retirement/survivor benefits share the same relationship - are computed using the same benefit formula - at all replacement rates.

Panels 3 and 4 capture two alternative assumptions about the linkage between SSD and SSI. In Panel 3, SSI and SSDI are assumed to be politically linked in that the total revenue spent on SSI benefits in the full-replacement rate economy equals the amount spent as the size of social security shrinks. Agents receive SSI benefits if their SSD benefit falls below the SSI "floor" and their asset holdings fall below the meanstested level. As can be seen from Table 8, panel 3, marginal earners in this economy default onto SSI as their social security benefits decline, but the SSI benefit also falls to accomodate the larger pool of recipients (from 0.183 to 0.093 as M goes from 1.00 to 0.00). Panel 4 assumes the same policy relationship between SSD and SSI, but no political or budget constraint on SSI. As social security shrinks, the SSI benefit available to *any* individual who passes the means test remains the same.

Table 8 confirms that the total welfare value of social security is linked to the relationship assumed between SSD/R and SSI. In all three regimes, a positive replacement rate turns out to be optimal, but only in the first, benchmark, case is the current steady-state regime significantly preferable to one with a zero replacement rate from both the discounting and non-discounting perspective. (With discounting, the current rate is actually preferable in all three regimes.) Clearly, this is because social security has greater value to poorer individuals in the economy, both because of its progressive structure and the greater marginal value of additional consumption for these workers. When a separate program protects them, SSD loses its value. Figure 6 shows how utility changes proportionally as M falls for male workers of each ability type in the benchmark regime.

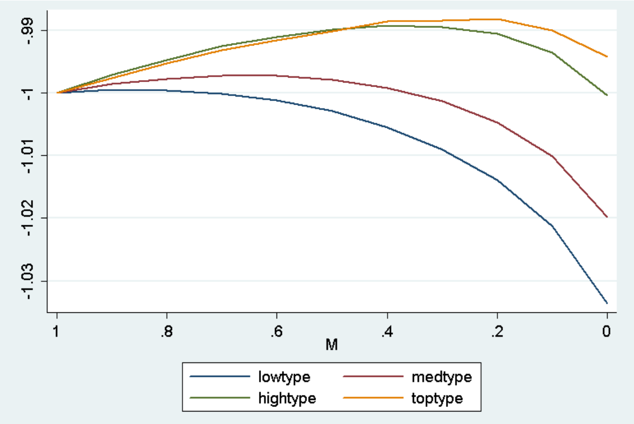
4.4 General Equilibrium and Dynamic Inefficiency

Earlier studies of social security with exogenous labour supply (and positive discount rates) have found its main welfare benefit to be the elimination of dynamic ineffi-

Table 8: Social security policy regimes

Replacement Rate	Discounted utility	Non-discounted utility (no discounting)	Output	Capital	Consumption	Interest Rate	Aggregate Labour supply	Income tax top rate	Payroll tax rate	Base period SSD p	Base period SSI recpients
Panel 1: Benchmark: SSI services only never-participants											
M=1.00	-120.2	-89.4	1.000	3.965	0.537	4.38%	0.174	34.8%	11.9%	2.6%	0.5%
M=0.80	-120.0	-89.0	1.035	4.143	0.545	4.00%	0.176	34.5%	9.51%	2.6%	0.5%
M=0.60	-120.1	-88.9	1.076	4.672	0.553	3.58%	0.178	34.1%	7.15%	2.5%	0.6%
M=0.40	-120.5	-88.9	1.121	5.146	0.560	3.14%	0.180	33.7%	4.77%	2.5%	0.6%
M=0.20	-121.3	-89.2	1.170	5.711	0.564	2.67%	0.181	33.1%	2.39%	2.6%	0.6%
M=0.00	-123.9	-90.8	1.241	6.597	0.566	2.08%	0.183	32.8%	0.00%	0.0%	0.6%
Panel 2: Benchmark with no SSD											
M=1.00	-121.2	-90.2	1.022	4.214	0.542	4.03%	0.174	35.0%	10.4%	0.0%	0.8%
M=0.80	-121.2	-89.8	1.056	4.534	0.548	3.68%	0.176	34.7%	8.42%	0.0%	0.8%
M=0.60	-121.3	-89.7	1.095	4.920	0.554	3.31%	0.178	34.4%	6.34%	0.0%	0.8%
M=0.40	-121.6	-89.7	1.137	5.360	0.559	2.94%	0.179	33.9%	4.24%	0.0%	0.8%
M=0.20	-122.3	-89.8	1.186	5.908	0.564	2.52%	0.181	33.3%	2.13%	0.0%	0.8%
M=0.00	-123.9	-90.8	1.242	6.601	0.566	2.08%	0.183	32.9%	0.00%	0.0%	0.6%
Panel 3: Total SSI payouts constant											
M=1.00	-120.2	-89.2	1.000	3.969	0.537	4.40%	0.174	35.2%	11.8%	2.4%	1.1%
M=0.80	-120.1	-88.8	1.035	4.280	0.545	4.13%	0.176	34.9%	9.43%	2.3%	1.2%
M=0.60	-120.1	-88.5	1.075	4.670	0.553	3.61%	0.179	34.7%	6.95%	2.3%	1.3%
M=0.40	-119.9	-88.7	1.120	5.105	0.563	3.23%	0.180	33.3%	4.25%	2.2%	1.8%
M=0.20	-120.9	-89.1	1.165	5.585	0.560	2.76%	0.180	33.7%	2.04%	2.0%	1.9%
M=0.00	-121.9	-89.3	1.205	6.057	0.564	2.42%	0.181	32.7%	0.00%	0.0%	2.1%
Panel 4: SSI benefit constant as SSDI benefit declines											
M=1.00	-120.2	-89.2	1.000	3.946	0.535	4.38%	0.174	35.3%	11.8%	2.3%	1.1%
M=0.80	-119.8	-88.8	1.034	4.307	0.564	4.03%	0.176	34.6%	9.0%	2.2%	1.5%
M=0.60	-119.7	-88.6	1.066	4.587	0.548	3.68%	0.176	34.8%	6.4%	2.1%	2.3%
M=0.40	-119.8	-88.4	1.089	4.862	0.550	3.37%	0.177	35.0%	3.8%	1.9%	3.5%
M=0.20	-120.2	-88.1	1.105	5.053	0.550	3.16%	0.178	36.3%	1.5%	1.7%	5.0%
M=0.00	-120.9	-88.3	1.102	5.036	0.540	3.09%	0.175	37.5%	0.0%	0.0%	6.7%

Figure 6: Utility by type for male workers



ciency at low replacement rates (Imrohoroglu et al. [1995]; Storesletten et al. [1999]). For instance, using the same positive discount rate, (Imrohoroglu et al. [1995] find that social security replacement of 30% of earnings is optimal in a representative-agent model with uncertain life span partly because of the overaccumulation of capital otherwise. In my model, because of assumptions about government consumption as output grows, the interest rate below which the economy would become dynamically inefficient with a fixed labour supply is 2.73%. [15] From both the discounting and non-discounting perspective, the optimal replacement rate is higher than the level that would eliminate government-expenditure-adjusted dynamic inefficiency. Nevertheless, overaccumlation of capital does appear to be a problem in low-replacement rate economies, even though increasing labour supply at lower rates keeps consumption from falling.

Table 9 compares the general equilibrium effects generated by my model (Table

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[15] As discussed in Part 3, I assume that government consumes a fixed share of net rather than gross output. As social security replacement declines and its obligations are replaced by private saving, the portion of the additional capital stock that depreciates each period is not taxed, causing the government share of gross output to fall. In the model without government, the golden rule interest rate with fixed labour is:

$$r^{*gr} = (1+n)(1+g) - 1 = 2.21\% \tag{35}$$

Leaving out the effects of government and the additional requirement that the marginal rate of transformation between leisure and consumption equal to wage rate, the model economy is dynamically inefficient at very low social security replacement rates (that is, without labour distortions, it would produce a suboptimal mix of leisure and consumption). SSD helps eliminate the dynamic inefficiency more quickly, though the difference is fairly negligible.

In an economy in which government consumes a fixed share of gross output, and this share is taken as given, the golden rule interest rate is much higher:

$$r^{*gross} = \frac{\delta G + (1+n)(1+g) - 1}{1-G} = 4.14\% \tag{36}$$

This effect tends to bias the model in favour of social security as it essentially eliminates the main general equilibrium cost of the program. In the model, with a fixed government share of *net* output the golden rule interest rate is:

$$r^{*net} = \frac{(1+n)(1+g) - 1}{1-G} = 2.73\% \tag{37}$$

This is only slightly above the optimal interest rate in the model without government and therefore reduces the bias in favour of social security.

Table 9: General equilibrium effects: S.S. elimination

Effect from eliminating S.S.	Kotlikoff et al 1998	Storesletten et al 1999 (Table 1)	Table 8, Panel 1
% increase in K	39.1%	90.7%	66.4%
% increase in Y	13.5%	29.5%	24.8%
% increase in C	4.4%	1.0%	5.4%
% increase in L	5.0%	n/a	5.2%

8, panel 1) against results from two of my reference papers that provide comparable simulations of the complete elimination of social security from the U.S. economy across steady states. The general equilibrium effects for capital and output fall roughly midway between the effects found by Kotlikoff et al. [1998] and those found by Storesletten et al. [1999].[16] The change in labour supply from social security elimination is nearly identical to that simulated by Kotlikoff et al. [1998].

4.5 Benefit Decomposition

Besides correcting government-enhanced dynamic inefficiency at low replacement rates, social security provides insurance against four types of risk:

1. Uncertainty lifespan / Missing annuities
2. Variable employment opportunities (from labour market risk and temporary disability)
3. Permanent disability risk
4. Initial ability shocks

Table 10 provides a decomposition of the four insurance roles of social security by removing one source of risk at a time, in the order listed above, until the model concerns no uncertainty at all (other than the risk of being born already disabled, which I assume to be beyond the ability of social policy to fix). At each stage, I adjust constraints to ensure that the relevant aggregate values (mainly labour supply) remain constant so as to eliminate the general equilibrium effects that are not direct results from changes in individual decision-making. In each case, I calculate

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[16] Storesletten et al's small consumption cost may be a misprint in their table, given the relatively large utility gain they report. I report results from their main simulation in which all income risk is due to persistent, idiosyncratic wage shocks. This is likely closer to replicating disability risk than a fixed-effects model. I would like to report results from Huggett and Ventura [1999] whose "fixed effects" wage distribution is similar to mine. However, their experiments, and those of Nichiyama and Smetters [2005], are not quite comparable. Huggett and Parra [2006] do not yet report general equilibrium effects in their working paper.

the (additive) CV required to eliminate the risk in the economies with and without social security (these will be negative values) and the CV required to eliminate social security at each stage. When all four measures of risk are removed, social security is almost purely distortionary as in the Diamond OG analysis without dynamic inefficiency.[17] Table 10, panels 1-6, summarizes the results from this exercise.

Table 10: Risk insurance decomposition

S.S. replacement	Capital	Interest rate	Labour	Consumption	Ex-ante utility	Planner's utility	Income tax top rate	CV (risk source)	CV (S.S.)
Panel 1: Full Risk Economy									
M=1.00	3.97	4.37%	0.174	0.537	-120.2	-89.2	34.8%	n/a	n/a
M=0.00	6.76	2.09%	0.186	0.588	-123.6	-90.8	32.7%	n/a	0.032
Panel 2: Mortality Risk Removed									
M=1.00	3.71	4.47%	0.165	0.508	-120.5	-90.3	46.3%	0.003	n/a
M=0.00	5.90	2.32%	0.173	0.540	-121.8	-90.2	47.4%	-0.017	0.011
Panel 3: Market Underemployment Risk Removed									
M=1.00	3.63	4.61%	0.165	0.507	-119.6	-89.3	47.5%	-0.011	n/a
M=0.00	5.61	2.53%	0.172	0.537	-120.3	-88.9	48.2%	-0.015	0.006
Panel 4: Health Underemployment Risk Removed									
M=1.00	3.60	4.66%	0.165	0.506	-119.6	-89.3	47.7%	0.000	n/a
M=0.00	5.39	2.69%	0.172	0.535	-119.9	-88.7	48.3%	-0.004	0.003
Panel 5: Disability Risk Removed									
M=1.00	3.61	4.64%	0.165	0.508	-119.5	-89.1	47.6%	-0.001	n/a
M=0.00	4.96	3.06%	0.170	0.534	-118.5	-87.7	48.2%	-0.016	-0.012
Panel 6: Ability Risk Removed									
M=1.00	3.38	4.87%	0.161	0.491	-115.1	-85.8	55.1%	-0.049	n/a
M=0.00	4.74	3.19%	0.167	0.514	-113.6	-83.2	57.7%	-0.069	-0.022

In Panel 2, I suppose the existence of a competitive short-term insurance market that offers actuarially fair one-period bonds that pay out one real unit conditional on survival and zero conditional on death. The actuarially fair price of these bonds is ψ_{j+1} and, on receiving the bonds, survivors invest the proceeds in the next period's production, as in Rull [1996]. Introducing annuity markets removes the role of estate taxes in the model and, as a result, drives up the income tax top rate.

Removing underemployment insurance from the model requires 2 steps: removing "market-based" underemployment and removing "health-based" underemployment - i.e. temporary disability. In the first step, I allow workers to choose up to

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[17] "Almost" because, as Storesletten et al. [1999] point out, the presence of social security lowers the capital share of the tax base, and so shifts part of the tax burden from capital to labour, which tends to be efficiency-enhancing. The technique described here is a variation on the approach of Storesletten et al. [1999], but allowing the the indirect effects of social security interacted with the incidence of taxes.

37.4 hours of work every period they are healthy, which generates the same aggregate labour supply as in the economy of panel 2 (annuity markets remain, so all new risk reduction is from elimination of employment risk). In panel 4, I remove both the government's temporary disability benefit and the disability cost p in *lfh* 3. In this case, agents in *lfh* 3 will almost always choose to work and labour supply increases. I reduce the total possible work time in all three (now) healthy states to 36.8 hours, again approximating the labour supply of panel 3.

The remaining two steps involve removing the two major sources of income risk - permanent disability risk and fixed gender/ability shocks. In the economy of panel 5, individuals born healthy never enter *lfh* 4 and maximum work hours in any state is set to 35.55 hours, again replicating the aggregate labour supply from the panel above. In panel 6, to remove the effect of the Weibull-distributed variable ability shocks from the model I set $k = 0$ and e_1 equal to its weighted mean value.

Table 10 suggests that the SSD/SSR bundled social security provides very good insurance against every type of risk in the model with the exception of permanent ability shocks. Utility values in the non-social security economies increase steadily as each source of risk is removed. The CV required to compensate an individual living in the social security economy of panel 5 vs. the social security economy of panel 1 is only 17% of the increase for agents in the laissez-faire economy. Of particular note, the elimination of disability risk in the model *with* social security produces essentially no increase in welfare.

Table 11 summarizes the findings with respect to social security and risk. The economy reported in panel 1 of Table 10 produces the most risk and the most positive role for social security relative to the no-policy alternative. The economy in panel 6 features no risk so that social security is almost entirely distortionary. Using the total difference in CV (S.S.) across the panels, I can show roughly how much of the gross benefit of social security is generated by each type of risk. [18]

Social security's role as an annuity provider generates the greatest benefit, accounting for 38.8% of the gross benefit, though the results suggest that, as in Imrohoroglu et al. [1999], the annuity benefit alone would not make the current social security regime superior to the no-social security regime in the absence of other types of risk. In the presence of social security, however, annuity markets are not welfare-improving because they reduce capital holdings and, more important in my capital-intensive model, cause individuals to substitute toward leisure. These results are consistent with findings by Storesletten et al. [1999] and Nichiyama and Smetters [2005].

Protection against disability risk generates the secondlargest benefit of social security in the model, at 27.8% of the total gross benefit – a benefit that is out of proportion to the 14% of social security revenues paid out as SSD. Social security's unemployment insurance role - decreasing the permanent income effect of spells of

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[18] Because I do not control for all general equilibrium and tax effects, the risk elimination is not strictly additive. However, experiments with eliminating the risk sources in the reverse order did not signficantly effect the results.

Table 11: Summary: social security as insurance

Risk Removed	$-\Delta CV$ (S.S.)	As % of Row 7
Mortality risk	0.021	38.8%
Underemployment risk	0.005	9.3%
Temporary disability risk	0.003	5.6%
Permanent disability risk	0.015	27.8%
Ability shock Risk	0.010	18.5%
Total ($-\Delta CV$) from risk elimination	0.054	100%

low labour market earnings due to health or market risk through the benefit formula - account for 14.9% of the gross welfare benefit of social security. Redistribution across ability types generates only 18.5% of the gross benefit, which is surprising given the "fixed effect" estimation procedure that puts a strong emphasis on early permanent shocks in determining outcomes. The results suggest that social security, given its current level of intrageneration redistribution, is a poor instrument for reversing the effects of structural inequality.

5 Results for an Economy with Chronic / "Partial" Disability

This section provides results from the alternative calibration of the model, using the assumptions underlying transition process Π_2. I consider four subcases, the results of which are presented in Tables 12 through 15. In each table, Panel 1 shows the benchmark model, in which q is chosen to match the U.S. working-age population receiving SSD. Panels 2 and 3 show specifications of the same economy with $q = 0.6$ (agents who apply continuously have an 84% chance of being covered within two years) and $q = 0$. The latter is equivalent to social security with no SSD component.

Table 12 and 13 give basic results for the two subcases discussed in Part 3.4.2, with p calibrated using program non-participants and all agents respectively. The tables confirm the central result of this section: social security with SSD performs relatively poorly as social policy when disability is chronic, partial and widespread compared to the economy in which it is permanent, total and rare; but it is still highly preferable to laissez-faire from the discounting perspective. From the non-discounting or cross-sectional perspective, the laissez-faire economy, or ideally one with a positive but low rate of replacement, is preferable.

In the absense of social security, the economies of Tables 12 and 13 (top panels) generate much higher interest rates and lower capital-output ratios than the economies of Part 4, despite having a larger labour force. In part, this is because disability risk is much lower, given that disable individuals are likely to go through periods in which work is relatively easy.

A comparison of the two tables also shows that the welfare results are fairly insensitive to the level of p within my estimates. An average increase of p across states of just under 50% does little to alter the welfare effects of policy. In the laissez-faire economy, an individual would pay 0.011 or roughly 2 percent of average consumption to live with the lower calibrated disutility costs. This CV declines to 0.003 in the presence of social security without SSD and to 0.001 in the full-replacement economy with $q = 0.6$.

The weaker utility results from the non-discounting perspective come from the higher negative general equilibrium costs, especially labour. SSD induces individuals who may return to healtier states to permanently exit the labour market. In the economy of Π_1, these individuals would not be participants in the absence of SSD/SSI. However, it is possible that the economies of Tables 12 and 13 overstate general equilibrium costs, either because disability is experienced primarily by lower-income, lower-productivity workers or that disabled individuals are less producitive workers. The latter possibility is plausible both because the weaker labour market attachment of disabled inviduals lowers their human capital accumulation and because disability itself adversely affects labour supply. In order to facilitate welfare comparisons, both subcases adopt the p and γ values calibrated in subcase 2.

I examine these possibilities separately. Table 14 considers the case in which only individuals (men and women) with the two lower ability shocks - comprising 80% of the population - are susceptible to disability and may qualify for SSD. The effects are significant. The reduced general equilibrium cost is enough to make the non-discounting agent indifferent between being born into the economy with $q = 0.60$ and full social security and the laissez-faire economy.

For the results presented in Table **??**, I ran a pooled OLS regression of ln(hourly earnings) on a cubic in age, years of education, a gender dummy, a time trend and dummies for the four *lfh* states for all employed individuals in all years and both genders in the PSID sample. The estimations give that in *lfh* 2 earn 16.2%, *lfh* 2 earn 24.5%, *lfh* 2 earn 29.1% less than their healthy-state counterparts. The estimated coefficients are likely to be biased away from zero due to unobserved characteristics that make agents both more likely to be or perceive themselves disabled and to be less productive workers, independent of education. The estimated values can be taken as probable upper bounds on the degree of lost labour productivity due to disability.

Again, the reduced productivity from disabled agents reduces the welfare costs associated with social security, but is not sufficient to make the U.S. rate preferable

Table 12: Π_2 Subcase 1

Replacement Rate	Discounted utility	Non-discounted utility	Output	Capital	Consumption	Interest Rate	Aggregate Labour supply	Income tax top rate	Payroll tax rate	Base period SSD p	Base period SSI recpients
Panel 1: Benchmark results: $q = 0.125$											
M=1.00	-132.6	-99.5	1.000	3.920	0.544	4.51%	0.171	34.8%	11.8%	4.1%	1.0%
M=0.80	-132.5	-99.1	1.041	4.165	0.554	4.27%	0.175	34.7%	8.85%	3.4%	1.0%
M=0.60	-132.4	-98.8	1.088	4.237	0.568	3.81%	0.178	34.3%	6.68%	2.8%	1.0%
M=0.40	-132.6	-98.5	1.133	4.507	0.580	3.47%	0.181	34.1%	4.17%	0.8%	1.0%
M=0.20	-133.0	-98.6	1.154	5.209	0.583	3.27%	0.188	33.5%	2.05%	0.3%	1.0%
M=0.00	-133.6	-98.6	1.217	5.800	0.599	2.86%	0.186	33.4%	0.00%	0.0%	1.0%
Panel 2: $q = 0.00$											
M=1.00	-132.9	-99.6	1.029	4.004	0.559	4.51%	0.176	35.5%	9.7%	0.0%	1.0%
M=0.80	-132.7	-99.1	1.064	4.313	0.568	4.19%	0.178	35.0%	7.82%	0.0%	1.0%
M=0.60	-132.7	-98.8	1.097	4.610	0.574	3.88%	0.180	35.1%	5.87%	0.0%	1.0%
M=0.40	-132.8	-98.5	1.137	4.975	0.583	3.54%	0.182	34.3%	3.97%	0.0%	1.0%
M=0.20	-133.1	-98.4	1.179	5.391	0.592	3.18%	0.184	33.3%	2.13%	0.0%	1.0%
M=0.00	-133.6	-98.6	1.217	5.799	0.599	2.87%	0.186	33.4%	0.00%	0.0%	1.0%
Panel 3: $q = 0.60$											
M=1.00	-132.6	-99.9	0.938	3.636	0.512	4.57%	0.161	33.6%	16.9%	12.2%	1.0%
M=0.80	n/a	n/a	n/a	4.180	0.550	4.23%	0.178	34.5%	9.22%	2.9%	1.0%
M=0.60	-132.0	-98.9	1.057	4.498	0.552	3.77%	0.172	33.7%	8.64%	8.6%	1.0%
M=0.40	-132.3	-98.5	1.124	4.994	0.572	3.42%	0.179	33.9%	4.99%	5.2%	1.0%
M=0.20	-132.8	-98.4	1.173	5.406	0.587	3.11%	0.183	33.6%	2.24%	2.6%	1.0%
M=0.00	-133.6	-98.6	1.218	5.800	0.599	2.82%	0.186	33.2%	0.00%	0.0%	1.0%

Table 13: Π_2 Subcase 2

Replacement Rate	Discounted utility	Non-discounted utility	Output	Capital	Consumption	Interest Rate	Aggregate Labour supply	Income tax top rate	Payroll tax rate	Base period SSD p	Base period SSI recpients
Panel 1: Benchmark results: $q = 0.125$											
M=1.00	-132.9	-99.7	1.000	3.925	0.538	4.43%	0.168	34.7%	11.9%	4.2%	1.0%
M=0.80	-132.8	-99.4	1.036	4.248	0.548	4.07%	0.171	34.6%	9.30%	3.8%	1.0%
M=0.60	-132.8	-98.9	1.083	4.277	0.562	3.74%	0.175	34.4%	6.78%	2.9%	1.0%
M=0.40	-133.1	-98.9	1.125	5.000	0.573	3.41%	0.177	34.1%	4.31%	1.9%	1.0%
M=0.20	-133.6	-98.9	1.169	5.400	0.583	3.09%	0.180	33.7%	2.08%	1.0%	1.0%
M=0.00	-134.3	-99.0	1.209	5.833	0.589	2.77%	0.182	33.4%	0.00%	0.0%	1.0%
Panel 2: $q = 0.00$											
M=1.00	-133.2	-99.7	1.023	4.039	0.554	4.41%	0.172	35.3%	9.7%	0.0%	1.0%
M=0.80	-133.1	-99.4	1.056	4.320	0.560	4.12%	0.174	34.9%	7.78%	0.0%	1.0%
M=0.60	-133.2	-99.2	1.090	4.613	0.568	3.80%	0.177	34.6%	5.97%	0.0%	1.0%
M=0.40	-133.3	-90.0	1.129	4.987	0.577	3.46%	0.179	34.3%	3.94%	0.0%	1.0%
M=0.20	-133.6	-99.0	1.171	5.392	0.567	3.12%	0.181	33.6%	1.99%	0.0%	1.0%
M=0.00	-134.3	-99.0	1.211	5.834	0.589	2.78%	0.182	33.4%	0.00%	0.0%	1.0%
Panel 3: $q = 0.60$											
M=1.00	-132.7	-99.8	0.932	3.631	0.508	4.52%	0.158	33.4%	17.0%	12.5%	1.0%
M=0.80	-132.3	-99.4	0.993	4.078	0.527	4.07%	0.164	34.0%	12.5%	10.7%	1.0%
M=0.60	-132.4	-98.8	1.050	4.506	0.545	3.71%	0.169	33.7%	8.75%	8.8%	1.0%
M=0.40	-132.7	-98.8	1.117	4.995	0.567	3.35%	0.176	33.6%	5.08%	5.5%	1.0%
M=0.20	-133.3	-98.7	1.166	5.422	0.581	2.27%	0.179	33.3%	2.92%	2.9%	1.0%
M=0.00	-134.2	-99.0	1.211	5.839	0.591	2.76%	0.182	33.2%	0.00%	0.0%	1.0%

to the laissez-faire alternative steady state. (From additional experiments, I find that disabled agents in *(*lfh) 3 and 4 would need to be about 50% as productive as healthy agents, with *(*lfh) 2 fixed at 84% of healthy productivity, in order for the non-discounting planner to actually favour by 1% of per-period consumption, the steady state with social security.) Social security remains highly preferable from the discounting newborn's perspective, and the net benefit of SSD continues to increase. In Table **??**, the a newborn would give up more than twice as much lifetime consumption to move from the laissez-faire steady state to one with $q = 0.6$ than to one with $q = 0$.

6 Conclusions and future research

The compuational literature has not explicitly examined the welfare value of social security in general equilibrium when social security offers insurance against disability onset as well as a public pension and survivors' insurance. This paper does so by postulating two potential models of work and disability transitions and examining how social security fares as an insurer in each one. I find that SSD fairly unambiguously improves the welfare value of social security when disability risk is rare and acute enough to make the provision of labour difficult to impossible, and when disabled individuals are not likely to be able to return to the labour force at a future date. The results are, however, sensitive to political-policy relationships assumed between SSD and SSI (work-accumulated and means-tested) disability benefits. The benefits of social security are more ambiguous when disability is modelled as chronic and variable, as in the second part of the paper. Individuals who discount the future at the positive rate commonly assumed in the compuational literature still strongly favour social security, though at a rate between 60% and 80% of the current U.S. rate. But from a non-discounting or cross-sectional (though still risk-averse) point of view, individuals are generally better off in the laissez-faire steady state.

Some caveats are in order. I have only considered cash benefits; disability may be accompanied by higher medical costs against which SSD insures. Relatedly, disabled agents may require greater consumption (of hospital or physicians' services or of special conveniences) that make it less possible for them to substitute leisure for consumption in the utility function. I have also used an individual-based model calibrated to approximate the entire participant U.S. population, as opposed to the more prevalent household-based model used in the literature. I am therefore likely omitting important effects of private or family insurance against labour market and mortality risk.[19] Finally, I assume that individuals cannot borrow. If there is a softer borrowing constraint, social security becomes less hard on the young, though it may also weaken the need for transfers in the chronic / partial disability economy.

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[19] See, for instance, Kotlikoff and Spivak [1981] for a quantification of the latter.

Table 14: Π_2 Subcase 3

Replacement Rate	Discounted utility	Non-discounted utility	Output	Capital	Con-sumption	Interest Rate	Aggregate Labour supply	Income tax top rate	Payroll tax rate	Base period SSD p	Base period SSI recpients
Panel 1: Benchmark results: $q = 0.15$											
M=1.00	-131.9	-99.0	1.022	3.920	0.553	4.51%	0.173	34.4%	11.6%	4.0%	1.0%
M=0.80	-131.9	-98.8	1.068	4.303	0.562	4.16%	0.175	34.4%	9.10%	3.6%	1.0%
M=0.60	-132.1	-98.7	1.095	4.618	0.572	3.84%	0.179	34.2%	6.68%	3.0%	1.0%
M=0.40	-132.4	-98.5	1.133	4.973	0.581	3.49%	0.180	34.0%	4.29%	0.0%	1.0%
M=0.20	-132.9	-98.5	1.179	5.404	0.591	3.16%	0.183	33.4%	2.08%	1.0%	1.0%
M=0.00	-133.6	-98.6	1.220	5.838	0.598	2.82%	0.185	33.1%	0.00%	0.0%	1.0%
Panel 2: $q = 0.00$											
M=1.00	-132.6	-99.2	1.039	4.085	0.563	4.47%	0.176	35.0%	9.6%	0.0%	1.0%
M=0.80	-132.5	-99.0	1.070	4.345	0.569	4.17%	0.178	34.7%	7.84%	0.0%	1.0%
M=0.60	-132.6.	-98.7	1.104	4.653	0.577	3.86%	0.180	34.4%	5.91%	0.0%	1.0%
M=0.40	-132.7	-98.5	1.139	4.989	0.585	3.53%	0.181	34.0%	3.95%	0.0%	1.0%
M=0.20	-133.0	-98.6	1.180	5.393	0.592	3.19%	0.183	33.5%	1.98%	0.0%	1.0%
M=0.00	-133.5	-98.6	1.221	5.835	0.598	2.83%	0.185	33.0%	0.00%	0.0%	1.0%
Panel 3: $q = 0.60$											
M=1.00	-131.1	-98.6	0.978	3.785	0.533	4.61%	0.167	33.9%	14.6%	10.1%	1.0%
M=0.80	-131.1	-98.6	1.022	4.137	0.543	4.26%	0.170	34.4%	11.6%	9.1%	1.0%
M=0.60	-131.5	-98.6	1.075	4.235	0.561	3.81%	0.174	33.7%	8.05%	7.7%	1.0%
M=0.40	-132.0	-98.3	1.128	5.976	0.578	3.45%	0.179	33.6%	4.83%	4.8%	1.0%
M=0.20	-132.6	-98.4	1.176	5.404	0.588	3.14%	0.182	33.3%	2.21%	2.6%	1.0%
M=0.00	-133.5	-98.5	1.221	5.839	0.598	2.81%	0.184	32.9%	0.00%	0.0%	1.0%

Table 15: Π_2 Subcase 4

Replacement Rate	Discounted utility	Non-discounted utility	Output	Capital	Consumption	Interest Rate	Aggregate Labour supply	Income tax top rate	Payroll tax rate	Base period SSD p	Base period SSI recpients
Panel 2: $q = 0.00$											
M=1.00	-135.6	-100.9	1.004	4.076	0.536	4.20%	0.167	34.8%	9.80%	0.0%	1.0%
M=0.80	-135.6	-101.1	1.026	4.296	0.539	3.88%	0.167	34.8%	7.84%	0.0%	1.0%
M=0.60	-135.7	-101.1	1.062	4.620	0.547	3.58%	0.170	34.2%	5.93%	0.0%	1.0%
M=0.40	-136.0	-101.0	1.103	5.019	0.554	3.25%	0.172	34.0%	3.93%	0.0%	1.0%
M=0.20	-136.4	-101.0	1.145	5.452	0.563	2.87%	0.174	33.4%	2.00%	0.0%	1.0%
M=0.00	-137.3	-101.0	1.186	5.898	0.570	0.00%	0.176	32.8%	0.00%	0.0%	1.0%
Panel 3: $q = 0.60$											
M=1.00	-134.5	-101.2	0.912	3.963	0.492	4.37%	0.153	33.2%	17.1%	12.4%	1.0%
M=0.80	-134.3	-100.8	0.965	3.963	0.510	3.96%	0.158	33.3%	12.8%	11.3%	1.0%
M=0.60	-134.5.	-100.7	1.019	4.463	0.525	3.53%	0.162	33.4%	8.78%	9.3%	1.0%
M=0.40	-135.2	-100.6	1.086	4.985	0.545	3.16%	0.168	33.4%	5.28%	6.4%	1.0%
M=0.20	-136.0	-100.6	1.144	5.550	0.561	2.80%	0.173	33.1%	2.33%	3.5%	1.0%
M=0.00	-137.3	-101.0	1.186	5.898	0.570	0.00%	0.176	32.8%	0.00%	0.0%	1.0%

7 Appendix

7.1 Computational Algorithm

The recursive algorithm for computing the steady states of the economy is written in FORTRAN and adapted from a program used in Imrohoroglu et al. [1999] (publicly available on Selahattin Imrohoroglu's website), and modified following a heuristic description provided by Huggett and Ventura [1999]. The procedure is as follows:

1. Parameter values for $\Pi_j, j = 1, 2$; for the population distribution across gender and ability; for lifetime productivity profiles $\{\epsilon_{j,type}\}$; for preferences $\{\omega$, γ_{type}, $\beta\ p\}$; for technology and population conditions $\{A,\ g,\ \lambda,\ \alpha,\ n\ \ \psi\}$; for policy and program eligibility rules $\{\overline{mt},\ G,\ \overline{W},\ q,\ SSI\}$, plus bend points and rates for social security replacement and income taxes; and for consumption taxes $\{\tau_c\}$ are set following the descriptions and calibrations in Part 3. Initial values for labour (L), capital (K), estate taxes and the benefit-weighted populations receiving SSR, SSD and SSI benefits are also chosen, which together produce an initial set of prices and income/payroll taxes: $\{w, r\}$ and $\{\tau_s(.), \tau_g(.)\}$.

2. Given these prices and taxes, FORTRAN recursively computes optimal decision rules $\{a^{'}$,c,l,$d_.\}$ for agents across every possible age-state-type combination (where "state" $x_.$ is defined as in Part 2 to include wealth holding a, employment/health (*lfh*) status or retirement date (R) and SSD/R-eligible earning accumulation (wh)). Calculations are made at a series of grid points for capital (41) and previous social security earnings (11), with optimal choices for each point interpolated to lie off the grid. (The results are essentially identical to an earlier algorithm on which optimal choices are constrained to lie on an asset-accumulation grid of 121*61). The calculations are peformed first for retired agents ($R > 0$), from model age J to model age 1 and then for working agents from model age $j^* - 1$ to model age 1. The domains ($\overline{A}_{type}$, $\overline{W}_{type}$) are chosen separately for different agent types, such that $\overline{A}_{type}$ never binds and $\overline{W}_{type}$ binds only if $\overline{W}_{type} = \overline{W}$. Earning accumulations are updated automatically from labour choices, which are made over discreet blocs of 5 hours for healthy and 1 hours for disabled individuals in the benchmark model. To compute the optimal work-saving choice for a given asset and earning-accumulation grid point, the program first brackets the best saving grid point in the neighboorhood of the initial point, with binding neighborhoods automatically enlarged, using a step function similar to Imrohoroglu et al. [1999]. A golden section search is then used to find the optimum level of assets within the space spanned by the three grid points containing the maximum. The procedure is repeated for every feasible labour choice given *lfh* status ($l = 0$ for retired individuals). The convexity of the nearly all choice sets (see step 5) guarantees that the lo-

cal maximum labour and asset choice selected from this exercise is the global maximum in the feasible set.

3. The disability retirement choice is calculated as follows: for agents in *lfh* 4, the optimal non-retirement $\{a^{'},\ l\}$ choice is first calculated in the same manner as for healthy agents (but using the appropriate preferences). The maximized value function is then compared to the maximized value function for retired agents with the same initial $\{a,\ wh\}$ and the appropriate R (given the age of the individual, which determines his retirement date relative to the base period) and, consequently, receiving the size and type of benefit for which the non-retired individual is currently eligible. If the latter value is greater than the former, the individual retires (computationally, $d_{.}$ is set to 1), provides no labour, receives the appropriate transfer benefit, and makes the asset choice previously computed for his retired counterpart. (A similar process is used for individuals in *lfh* 3, who choose either to supply positive labour or to receive the temporary ui benefit.)

4. Once the decision rules for all individuals have been computed, the program compiles a panel based on survival probabilities, initial distributions, *lfh* transitions and optimal decision rules. The initial distribution of agents is entered exactly and the RANDOM@ function in FORTRAN 95 generates the subsequent *lfh* transistions. A panel of 50000 individuals is sufficient to insure that all model populations to converge to $< 0.1\%$ (the large "sample size" is needed because the probabilities associated with some states are quite small). For every age-individual in the panel, the labour choice is computed by using the optimal labour choice associated with the nearest neighbouring grid point in $a - wh$ space. For assets, saving is computed to replicate the MPS out of total income from the nearest neighbouring grid point in $a - wh$ space. The panel produces a new set of savings and labour supplies, and a new set of populations receiving SSI, SSD and SSR (and associated taxes and prices). These values are compared with the initial values and, if the difference is smaller than a pre-set tolerance threshold (typically 0.005), the program stops. Otherwise, new starting values for labour, capital and program populations are chosen as a weighted average of the old starting and the computed values (the weight depending on whether the difference between the values has narrowed over previous iteration) and the program calculates new prices and repeats steps 2-4. Depending on the initial choices for labour, capital and social program populations, the program typically takes between 11 and 20 iterations to converge.

5. Given slight non-convexities in the tax structure (due to capped payroll taxes – see Kotlikoff et al. [1998]), successful tests of the model were performed to insure that it converges to a single equilibrium in L-K space, with associated

prices, and in the relevant program populations starting from different initial values and for different values of labour-agumenting producitivity A.

7.2 *lfh* Transition Matices

7.2.1 Π_1

The data selection procedure, written in STATA, for estimating Π_1 from the individual files for the PSID is as follows:

1. The potential sample population is all individuals in the PSID individual files, with their associated weights, for the years between 1978 and 1993, after which the relevant information on labour hours supplied is not available other than for heads and spouses. Individuals with missing years are divided into separate panels by blocks of consecutive years for the initial *lfh* assignments. For the final sample used in the estimation of Π and other summary statistics, individuals are dropped starting at the first missing year. An exception is if the missing year occurs before 1982 and the individual shows up for ten or more consecutive years after 1979, in which case the latter years are included and the waves between 1978 and the missing year are dropped instead. All analysis is restricted to individuals who show up in at least six consecutive periods at some period in the sample.

2. Annual hours are reassigned as the average of reported hours worked in the previous year and hours reported over the next year (reported in the next wave). This ensures that the survey date, at which current labour force status is obtained, falls in the middle of the corresponding annual hours worked. If the observation corresponds to the final wave in which the individual appears, hours are replaced with hours reported for the previous year (the response in the current wave).

3. I assign *lfh* status based on hours worked and disability reports. Observations are *lfh* 1 if they work 1500 or more hours in a year, regardless of disability report. Individuals are *lfh* 2 if they work under 1500 hours, with no corresponding disability report. Sequentially, individuals are assigned to *lfh* 3 if they report their labour force status as "disabled" and work fewer than 1500 hours, or if they work fewer than 600 hours on average in the years following or in the year immediately preceding a qualifying disability report – otherwise they are reassigned *lfh* 2. Once basic disabled status is finalized, individuals are reassigned to *lfh* 4 from *lfh* 3 in their second year of disability if they are permanently disabled and never re-enter a lower *lfh* state before exiting the sample.

4. Based on these criteria, I next recategorize individuals who are deemed healthy as non-participants if they do not average at least 600 hours in all years they are "healthy" in the sample. These non-participants are not part of the model population and are dropped. I do, however, include observations who identify as housewives, students or "other" in the years *following* a disability report on the grounds that individuals who are too disabled to work may find non-work alternatives or eventually redefine themselves as non-participants rather than as permanently disabled.

5. In order to exclude healthy non-participant adults in the model population (for instance, a housewife who develops back trouble), individuals who are already permanently disabled in 1978 are traced back through time to make sure they either entered adulthood disabled or were participants at some point before becoming disabled. Individuals who entered the sample in 1971 or 1972, years in which a variant on $Q3$ was asked at the individual level (and for which the average age of entry is 38 as opposed to 24 for later entrants), are excluded if they do not report a disability in either of those years but still work less than 600 hours in their year of entry and average less than 600 hours a year during the "pre-sample" years, 1971 to 1977.

Using the sample obtained from the previous procedure, I estimate $\Pi_{sex,agecat}$ by running an SOLS regression of current *lfh* states on their lags, for each gender and age category, over the years 1979-1993. The estimated transition matrices are as follows:

$$\Pi_{(male,21-29)} = \begin{bmatrix} 0.9426 & 0.3235 & 0.0635^{\iota} & 0.0000 \\ 0.0569 & 0.6717 & 0.2022 & 0.0000 \\ 0.0005^{\iota} & 0.0048^{\iota} & 0.6098 & 0.0000 \\ 0.0000 & 0.0000 & 0.1245 & 1.0000 \end{bmatrix}$$

$$\Pi_{(female,21-29)} = \begin{bmatrix} 0.8739 & 0.2259 & 0.0863^{\iota} & 0.0000 \\ 0.1257 & 0.7716 & 0.2773 & 0.0000 \\ 0.0004^{\iota} & 0.0025^{\iota} & 0.2654 & 0.0000 \\ 0.0000 & 0.0000 & 0.3710 & 1.0000 \end{bmatrix}$$

$$\Pi_{(male,30-44)} = \begin{bmatrix} 0.9656 & 0.3111 & 0.0798 & 0.0000 \\ 0.0331 & 0.6618 & 0.1720 & 0.0000 \\ 0.0013^{\iota} & 0.0271 & 0.5590 & 0.0000 \\ 0.0000 & 0.0000 & 0.1892 & 1.0000 \end{bmatrix}$$

$$\Pi_{(female,30-44)} = \begin{bmatrix} 0.9072 & 0.1750 & 0.0549^{\iota} & 0.0000 \\ 0.0921 & 0.8203 & 0.2122 & 0.0000 \\ 0.0007^{\iota} & 0.0047^{\iota} & 0.4688 & 0.0000 \\ 0.0000 & 0.0000 & 0.2641 & 1.0000 \end{bmatrix}$$

$$\Pi_{(male,45-54)} = \begin{bmatrix} 0.9568 & 0.2526 & 0.0693 & 0.0000 \\ 0.0393 & 0.6805 & 0.0832 & 0.0000 \\ 0.0039^{\iota} & 0.0669 & 0.4183 & 0.0000 \\ 0.0000 & 0.0000 & 0.4292 & 1.0000 \end{bmatrix}$$

$$\Pi_{(female,45-54)} = \begin{bmatrix} 0.9171 & 0.1731 & 0.0108^{\iota} & 0.0000 \\ 0.0810 & 0.8118 & 0.1690 & 0.0000 \\ 0.0019^{\iota} & 0.0151 & 0.3405 & 0.0000 \\ 0.0000 & 0.0000 & 0.4797 & 1.0000 \end{bmatrix}$$

$$\Pi_{(male,55-64)} = \begin{bmatrix} 0.8932 & 0.0935 & 0.0411^{\iota} & 0.0000 \\ 0.1023 & 0.8786 & 0.1277 & 0.0000 \\ 0.0045^{\iota} & 0.0279 & 0.2578 & 0.0000 \\ 0.0000 & 0.0000 & 0.5734 & 1.0000 \end{bmatrix}$$

$$\Pi_{(female,55-64)} = \begin{bmatrix} 0.8685 & 0.0951 & 0.0264^{\iota} & 0.0000 \\ 0.1290 & 0.8915 & 0.0506^{\iota} & 0.0000 \\ 0.0025^{\iota} & 0.0134 & 0.4332 & 0.0000 \\ 0.0000 & 0.0000 & 0.4898 & 1.0000 \end{bmatrix}$$

The superscript ι indicates where the estimated coefficient is insignificant at 5% (due mainly to the small number of observations who move back into a healthy state having once entered a disabled state). As well, using pooled observations on entrants into the sample under age 25, I estimate the following initial distribution across *lfh* states for $j = 1$:

	Males	Females
lfh 1=	0.4414	0.4165
lfh 2=	0.5475	0.5791
lfh 3=	0.0018	0.0002
lfh 4=	0.0093	0.0042

7.2.2 Π_2

The data selection procedure for estimating Π_2 from the individual and family files of the PSID is as follows:

1. The potential sample population is all individuals in the PSID individual files, with their associated weights, for the years between 1986 and 1997, before which the subjective disability question for heads and wives in the PSID family file is not comparable and after which the necessary information is only available on a biannual basis. The first two steps of the process are identical to the description for Π_1.
2. I assign *lfh* status based strictly on subjective disability reports. Observations are *lfh* 1 if the individual has never reported having a disability or experienced five consecutive disability-free periods after a spell of disability. Individuals are *lfh* 2 if they reported a disability within five years but either do not report a disability currently or report a disability that affects their work "not at all" or "just a little".Individuals are assigned to *lfh* 3 if their current disability affects their work "sometimes" or "a lot". Individuals are assigned to *lfh* 4 if their curren disability status is such that they "can do nothing".
3. Given this process for Π, I take the average work hours provided by men and women in each *lfh* state provided that they are not receiving positive amounts of SSI or SSD/R. For years in which only household amounts of SSR/SSD are reported, I assign positive SSR/SSD to the individual in question if they report an *lfh* state greater than 1 and worked less than 600 hours in the previous year.
4. In order to exclude healthy non-participant adults in the model population, individuals are excluded if they work less than 600 hours during the periods they are in *lfh* 1, using the expanded sample period 1981-1997 to check for participation.

Again, using the sample obtained from the previous procedure, I estimate $\Pi_{sex,agecat}$ by running an SOLS regression of current *lfh* states on their lags, for each gender and age category, over the years 1986-1997. The estimated transition matrices are as follows:

$$\Pi_{(male,21-29)} = \begin{bmatrix} 0.9802 & 0.0544 & 0.0000 & 0.0000 \\ 0.0103 & 0.8318^{\iota} & 0.8162 & 0.5088 \\ 0.0066 & 0.0572 & 0.1350 & 0.1686 \\ 0.0029 & 0.0566 & 0.0488 & 0.3226 \end{bmatrix}$$

$$\Pi_{(female,21-29)} = \begin{bmatrix} 0.9670 & 0.0592 & 0.0000 & 0.0000 \\ 0.0155 & 0.8588 & 0.6908 & 0.6070 \\ 0.0106 & 0.0515 & 0.2049 & 0.0840 \\ 0.0069 & 0.0304 & 0.1043 & 0.3090 \end{bmatrix}$$

$$\Pi_{(male,30-44)} = \begin{bmatrix} 0.9764 & 0.0525 & 0.0000 & 0.0000 \\ 0.0123 & 0.8281 & 0.5101 & 0.3066 \\ 0.0063 & 0.0747 & 0.3438 & 0.1697 \\ 0.0050 & 0.0447 & 0.1461 & 0.5237 \end{bmatrix}$$

$$\Pi_{(female,30-44)} = \begin{bmatrix} 0.9696 & 0.0629 & 0.0000 & 0.0000 \\ 0.0129 & 0.8020 & 0.5537 & 0.3427 \\ 0.0100 & 0.0906 & 0.3378 & 0.2326 \\ 0.0075 & 0.0445 & 0.1085 & 0.4247 \end{bmatrix}$$

$$\Pi_{(male,45-54)} = \begin{bmatrix} 0.9673 & 0.0643 & 0.0000 & 0.0000 \\ 0.0183 & 0.7479 & 0.4204 & 0.2565 \\ 0.0066 & 0.1285 & 0.4439 & 0.0932 \\ 0.0078 & 0.0593 & 0.1357 & 0.6503 \end{bmatrix}$$

$$\Pi_{(female,45-54)} = \begin{bmatrix} 0.9654 & 0.0742 & 0.0000 & 0.0000 \\ 0.0170 & 0.7383 & 0.4387 & 0.2531 \\ 0.0101 & 0.1278 & 0.4010 & 0.1230 \\ 0.0075 & 0.0597 & 0.1603 & 0.6239 \end{bmatrix}$$

$$\Pi_{(male,55-64)} = \begin{bmatrix} 0.9614 & 0.0402 & 0.0000 & 0.0000 \\ 0.0185 & 0.6882 & 0.4481 & 0.2273 \\ 0.0129 & 0.1252 & 0.3730 & 0.0855 \\ 0.0072 & 0.1464 & 0.1789 & 0.6872 \end{bmatrix}$$

$$\Pi_{(female,55-64)} = \begin{bmatrix} 0.9498 & 0.0186^{\iota} & 0.0000 & 0.0000 \\ 0.0263 & 0.7027 & 0.4663^{\iota} & 0.2367 \\ 0.0136 & 0.1873 & 0.3065 & 0.1664 \\ 0.0103 & 0.0914 & 0.2272 & 0.5968 \end{bmatrix}$$

The superscript ι indicates where the estimated coefficient is insignificant at 5%. Using pooled observations in the sample at age 21, I estimate the following initial distribution across *lfh* states for $j = 1$:

	Males	Females
lfh 1=	0.9498	0.9122
lfh 2=	0.0203	0.0603
lfh 3=	0.0098	0.0139
lfh 4=	0.0101	0.0036
R 45 =	0.0100	0.0100

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